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from

National Seminar
on
Advances in Coastal Agriculture and Value Addition from National Perspectives

Kasaragod, Kerala, 21-24 January, 2004

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and

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Inaugural
Session

Acknowledgement

The Indian Society of Coastal Agricultural Research (ISCAR) is grateful to the Indian Council of Agricultural Research (ICAR), New Delhi for recognising the contribution of ISCAR for disseminating the research findings on the various aspects of Coastal Agriculture through the Journal (Journal of The Indian Society of Coastal Agricultural Research) published by the Society. The Society is highly indebted to ICAR for providing necessary financial assistances for publication of the Journal.

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Information to Authors

It is requested that in future all articles submitted for publication in **'Journal of the Indian Society of Coastal Agricultural Research'** or for presentation in its **Seminars** must be typed in **MS-Word 97** or later versions with Times New Roman Script in 12 pt. Font size, in double space on A-4 size paper, with at least 1.5 inch margin on the left side and one inch margin on all other sides.

Two hard copies of the manuscript along with a CD or 1.44 MB (3.5") floppy disk must be sent for consideration. Further the same may also be sent by e-mail as an attachment (Word document) to iscar@rediffmail.com, cssri@wb.nic.in, arijit_sen@vsnl.net.

The author(s) are also requested to sent their e-mail address if any, for quick correspondence.

Appeal

Fresh drive has been initiated for membership for which a copy of membership form has been attached at the back of this issue. The person(s) interested may please multiply the copies for use of others.

Coastal Agricultural Research – Present Status and Future Perspective With Special Reference to Value Addition

J. S. P. YADAV

President, Indian Society of Coastal Agricultural Research

It is my great pleasure to be amongst you and share my views about the development of coastal agriculture on the eve of 7th National Seminar on "Advances in coastal agriculture and value addition from national perspectives" being held at CPCRI, Kasargod, Kerala during January 21-24, 2004. When we look back to review the progress of our agriculture during the last fifty-six years after independence, we find several success stories which have transformed India from the image of "begging bowl" to not only self-sufficiency in food grains but also to be a leading exporter of some agricultural produces in the international market. In this long journey, the country has the distinction of making a few impressive revolutions in the agricultural sector – *Green* (from 51 to 211 Mt food grains), *White* (from 17 to 81 Mt milk), *Blue* (from 0.7 to 5.7 Mt fish), and Yellow (from 5.2 to 22 Mt oilseeds), of which the "*Green Revolution*" is considered as the most amazing one even at the global level surpassing the population growth rate. The country has emerged as the largest producer of milk, pulses, jute & allied fibres, and tea; the second largest producer of rice, wheat, groundnut, sugarcane, fruits and vegetables, and ranks seventh in fish production in the world. India has exported agricultural products, fresh as well as processed, worth Rs. 25313.6 crores during 1999-2000, which is 15.9 % of the total national export. Significant breakthrough has been made in exporting fine quality basmati rice, meat, spices and cashew. During 2000-01, the country exported fruits and vegetable worth $283.5 million, animal products worth $353.2 million, and marine products (mainly frozen items) worth $1416.33 million. The principal exports include rice, cotton, cashew nuts, pepper, turmeric, chillies, cloves, ginger, coriander, cumin seeds, fenugreek, etc.

Despite this magnificent progress during the last few decades, we cannot ignore the grim side of the story as well. The annual compound yield growth rate from 1980's to 1990's decreased from 2.74 to 1.52% in case of food grains, from 2.31 to 1.04 % in case of non-food grains, and from 2.56 to 1.31% in case of all principal crops. India occupies dismally a low position in respect of yield levels in comparison to many countries. In case of rice and wheat which together accent for 78% of food grain production, the situation is equally disappointing. This dismal situation is attributed to low input use efficiency, degradation of resources like soil and water, and deceleration of total factor productivity. There is, therefore, an urgent need for massive well-planned action programmes for enhancing input use efficiency and crop productivity to sustain the tempo of agricultural growth in both irrigated and rainfed areas, particularly the fragile and disadvantaged ecosystems such as, 'coastal, hill, mountain, etc. When China with much less cultivated land can achieve much higher production of rice, wheat, total cereals, cotton vegetables and fruits, why it should not be possible for India having better natural resources to attain that distinction. Today, 26.1% of our population (260 million) lives below poverty line and though we have significant food reserve, it is irony that a vast section of our society (majority of them being women and children), goes hungry to the bed everyday. The fast swelling population growth along with over- exploitation and inefficient management of our natural resources has reduced the per capita availability of food grains (458.0 g per day), arable land (0.15 ha) as well as water (2464 cubic metre), and has also led to massive degradation and pollution of the land and water resources at unacceptable levels. Currently about 57% of our land area is degraded due to various reasons.

Another aspect of serious concern in Indian agriculture sector is the deplorable plight of the small and marginal farmers (>2ha), who constitute 80% of our farming community but are largely deprived of the benefits of Green Revolution due to very little access to the modern technologies. With

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fast rice in population, the average size of operational holdings in India has decreased from 2.3 ha in 1970-71 to 1.41 ha in 1995-96. Kerala state has the smallest average size of the holding (0.27 ha), followed by Tripura (0.6 ha), Bihar (0.75 ha), J&K (0.76 ha), Goa (0.84 ha), W.B. (0.85 ha), U.P. (0.86 ha) and Tamil Nadu (0.91 ha). An analysis shows that the small and marginal farmers make major contribution to the production of total foodgrains, fruits, vegetables, milk, etc. Therefore, if Indian agriculture has to attain and sustain high growth rate as envisaged in X Five Year Plan and also to become poverty-free nation by 2020, the complex issues with regard to technological advancement including judicious soil and water conservation and management, precision farming, diversification, integrated farming, value addition, processing, marketing and other related infrastructure development have to be addressed adequately to suit the socioeconomic conditions of these resource poor farmers. Such technological change needs priority attention particularly for the farmers of the coastal ecosystem.

The coastal ecosystem has a wide variability in climatic, topographical and edaphic conditions and supports diverse cultivated crops as well as natural vegetation ranging from tropical rain forests to coastal mangroves. The vast deltaic region of east coast forms the rice bowl of the country. The ecosystem provides livelihood to several million people and thus, contributes to the national economy to a significant extent. However, the entire ecosystem is extremely fragile in nature and prone to the ill effects of human activities as well as weather adversities. The agriculture faces a host of difficult problems related to seawater, saline air due to close proximity to sea, poor water quality as well as its inadequate supply, and severe competition for land. The cyclones, gales and heavy rains followed by floods, that cause colossal loss to the crops and property, are an annual feature in the east coast. The supercyclone in the Bay of Bengal in 1999 took a heavy toll of 1500 lives of human population and half a million of bovine population apart from total loss of agricultural crops and other properties in ten districts of Orissa. The agriculture sector is influenced by other sectors and their relationship with the coastal ecosystem is often more antagonistic.

The lowlying agricultural lands frequently suffer from severe drainage congestion and soil salinity problems due to rising water table, stagnation of rainwater, flooding from rivers, and periodic storm surges. The high tides usually cause intrusion of saline seawater far inside the inland tracts, thus salinizing the soil, ground water as well as river water, and making the latter unfit for irrigation. Deforestation, overgrazing and improper agricultural activities at the upstream side often lead to increased runoff and erosion, nutrient less and higher sediment load in rivers, which often induce severe floods in the coastal areas.

Diversification of the traditional rice farming in the coastal areas has become essential owing to its suboptimal resource utilization as well as poor return. Inclusion of high value crops like pulses, oilseeds, seasonal vegetables, spices and fruits in the cropping systems is needed. Moreover, integration of livestock, poultry, fishery, etc. with arable cropping is equally important to raise the income of the farmers. Apart from consumption, numerous value added products can be prepared from these plant and animal commodities which will not only fetch additional return to the farmers but will also generate significant employment opportunity, as this will require post harvest as well as processing units both at homestead and industrial scale. Inspite of the vast resource potential, the coastal regions are lagging behind many inland areas in terms of productivity due to a number of constraints and are environmentally disadvantaged because upstream discharge of industrial and urban effluents charged heavily with toxic chemicals that degrade the quality of water and marine life. The expected climatic change will submerge extensive lands near the coast and will further worsen the situation. It is, therefore, essential to address these complex issues in relation to the holistic development of coastal ecosystem and to formulate relevant strategies with a long term perspective to improve the quality of life of the coastal people.

Soil problems

The coastal soils show tremendous variability. Broadly, the soils in the east coast are fertile, predominantly in the deltaic alluvium. The other soils belong to red loam, red sandy loam, sandy clay, coastal sand, and black group. The soils of the west coast, on the other hand, consist mainly of laterites, lateritic, clay loam, gravelly clay, sandy loam, and coastal sand. The salt affected soils occupy extensive area spread over both east and west coast regions, and include saline, sodic, acid sulphate, marshy and waterlogged subgroups situated in the lowlying areas. Soil salinity hampers crop production in the coastal ecosystem to such an extent that the term 'coastal saline soil' has become almost synonymous, though not correctly, with the entire ecosystem. Impeded drainage, inundation, and ingress of seawater have led to the development of salinity and alkali conditions, rendering vast tracts of *Khar, Pokhali* and *Kole* lands unsuitable for cultivation.

Certain location specific problems are also encountered in the coastal soils viz., Fe toxicity in the soils of Orissa, highly permeable sandy soils in parts of Gujarat, and highly leached low fertility lateritic soils in Maharashtra, Karnataka and Kerala. Crop failures due to acidification and salinization are common in the acid sulphate and tidal marshy areas of Kerala and West Bengal. Phosphorus and zinc deficiencies are common and widespread, while Fe and Al toxicities are confined to the acid laterite and lateritic soils. Inadequate amount of K and Ca occurs in acid soils and coarse textured soils.

The acid sulphate soils with distinct characteristics occur in the lowlying areas of Kerala, Sundarbans of West Bengal, and Andaman & Nicobar Islands, and are highly acidic having toxic content of soluble Fe and Al. These soils mostly develop as a result of drainage of those soils that are rich in pyrites (FeS_2), which on oxidation produce sulphuric acid in the presences of excess SO_4 ions, and are very poor in available P but rich in organic matter. Application of lime, rock phosphate and single superphosphate has been beneficial in improving soil properties and rice growth in the acid sulphate soils of Sundarbans. Addition of Ca rich oystershell in powdered from has proved as an effective ameliorative agent. In the acid sulphate soils of Andaman & Nicobar Islands, lime application depressed the concentrations of Fe, Al and Mn, thereby creating favourable environment for rice. Thus, a large number of soil problems associated with deficiency as well as toxicity of several nutrients beside the problem of water logging are met with in different coastal areas and accordingly, the management technologies have to be location specific.

Water management

The agriculture in the coastal ecosystem is predominantly rainfed in nature and is characterized by excess water during the rainy season followed by acute water scarcity in the post-monsoon period and this poses a severe threat to improved agricultural production as well as productivity of the region. Management of rainwater is, therefore, crucial particularly with regard to the small holdings in the coastal ecosystem. Apart from erratic rainfall pattern, the poor and inefficient water management practices result in about 70% loss of the rainwater, mostly as surface runoff to the seas, thereby reducing the per capita availability of fresh water to the coastal people. Kerala state presents a typical example where despite more than 3000 mm annual rainfall, the per capita effective rainwater availability is less than even some dry parts of Rajasthan mainly due to heavy surface runoff loss because of steeply sloping topography, excessive deforestation and road construction. Moreover, the growing competitive demand for good quality water from industry, power and household sectors is further compounding the water crisis. The excess runoff results in eroding the top fertile soil of the region and also leads to poor ground water recharge due to lesser ponding time. The indiscriminate and excessive withdrawal of ground water causes lowering of water table and also ingress of seawater which in turn, leads to acute salinization of land and water. The poor drainage is another key factor limiting the agricultural production in the coastal region. The excess rainwater available during the monsoon period needs to be conserved through reduced runoff and storage in natural/artificial tanks so that the same may be recycled as life saving irrigations to the crops during the lean periods.

A careful water balance analysis of annual precipitation and PET is essential to determine the water surplus/deficit periods beforehand, so that all the agricultural operations can be adjusted accordingly. This will help to save the crops from water stress (excess/deficit) during its critical growth stages and will also help the farmers in the decision making regarding crop choice as well as its acreage depending upon the water availability. The CSSRI Research Station Canning designed an "On Farm Reservoir" technology to harvest the excess rainwater, and recommended conversion of 20% of the farm area into OFR. This harvested rainwater can be effectively utilized for growing pulses, oilseeds, tuber crops, vegetables, spices, etc. after *kharif* rice. Drip irrigation system can prove beneficial for the coastal region particularly to irrigate the high value crops such as plantation crops of coconut, arecanut, oilpalm, cashew and cocoa, spices viz., black pepper, cardamom, ginger, turmeric, coriander, cumin, etc. . The controlled use of water and fertilizer directly in the root zone through drip irrigation not only increases the input use efficiencies but also reduces possible negative interactions in the soil profile. Besides, this system provides scope of using poor quality water in conjunction with fresh water for irrigation.

Impeded drainage is also a key factor restricting crop productivity in the coastal region. The flat topography, siltation of the drains, high downstream water level and seawater backflow, alone or in combination, cause severe drainage problems in the coastal region. Conversion of the flat lands to raised bed-pond system can offer greater opportunity for cultivation of vegetables, tuber crops, spices, etc. on the raised beds in the *kharif* season or with supplemental irrigation from the stored water in the ponds during post-rainy season, and can, thus, improve the productivity as well as the cropping intensity. However, this system is not suitable for rice. Adoption of subsurface drainage can also effectively control water table and leach out the salts from the soil profile. This will definitely improve the physicochemical as well as biological properties of the soil apart from increasing the crop yield. While designing an efficient drainage system over a large area, a careful study to ensure the economic feasibility of the system on a long term basis. The experiments conducted under AICRP on Drainage showed the pay back period of the investments of different drainage systems as: ring bunding – 1 year, for subsurface drainage - 4 years, and for raised bed-pond system – 2 years. In this regard it is worth mentioning that the improved drainage systems combined with modern irrigation techniques can bring more land under cultivation of high valued crops like seasonal vegetables, tuber crops and spices. This will obviously reduce the pay back period and make the systems economically viable.

Rice based production system

Rice, the major crop of the coastal area, is commonly grown in the uplands, shallow lowlands, deepwater submerged areas as well as in the flood plains, mostly under the rainfed conditions, and usually has low productivity. The upland and shallow lowland rice ecosystems comprise about 5.2 and 5.8 million ha area located in eastern India alone
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region with productivity less than 0.5 t ha^{-1}. Thus, the major part of the coastal tracts of West Bengal, Orissa, and southern parts of Andhra Pradesh, where rice is grown under the rainfed condition, constitutes the low productivity rice belt of the country. Impeded drainage, deep waterlogging and flash floods, high saline ground water, inundation and ingress of seawater leading to acute salinization of land and water, and vast area under acid sulphate soil are some of the key factors limiting the productivity of rice crop. The imbalanced use of fertilizers, delayed planting, suboptimal plant population, and higher incidence of pest and diseases also contribute significantly to marked decline in the crop yield.

The estimated production target for coastal regions for 2010 AD is 45 million tons which can be achieved only if the current productivity level (2.13 t ha^{-1}) is raised to 3.6 t ha^{-1} within this short span of time. Despite all the constraints of this fragile ecosystem, I believe, that this is not a mission impossible if we can understand the problem and tackle it in a holistic manner. According to one estimate of CRRI, Cuttak, there is a wide scope for increasing rice production from the different coastal ecosystems through the use of improved varieties and efficient management practices. As per the farmers' experience, efficient drainage alone can increase the rice yield by 20-30 percent. Conjunctive use of organic and inorganic fertilizers not only increases the yield by 15-18 percent but also improves the soil health on long term basis. Application of biofertilizers - nitrogen fixers like Azolla and BGA, phosphate solubilisers like *Bacillus subtilis*, *B. circulans* and *Aspergillus niger*, inclusion of green manuring crops like *Sesbania*, green leaf manuring with *Glyricidia* or *Leucaena sp.* can definitely improve the grim soil fertility of the coastal region. Extensive promotion of IPM technology involving resistant /moderately resistant varieties, need based application of chemical pesticides and use of biocontrol agents including host-specific

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Rice being the most inefficient user of water and nutrients even under irrigated ecosystem needs extensive diversification instead of monocropping in vogue in many areas, particularly those having limited water resources. Inclusion of low water requiring crops like millets, pulses and oilseeds into the cropping systems will not only increase the cropping intensity, but also promote optimal utilization of land, water and nutrient resources. Rice based diversified integrated farming shows a great promising alternative to the current poor and diminishing return condition under the traditional rice cultivation. Sequential rice-fish farming i.e., alternating rice and fish culture on the same piece of land in alternate years can fetch good return to the farmers in addition to enriched soil fertility and improved pest management. Rice-cum-fish culture is another promising technology developed by CSSRI, Canning and CRRI, Cuttak for semideep lowlands involving high value components like fish/ prawn, vegetable and fruit crops. The system has been found to yield 0.6 t of fish/prawn, and vegetables worth Rs. 13,000-15000/- in addition to rice yield of 2.5 t ha^{-1}, and hence needs to be propagated to other amenable parts of the coastal regions.

Diversification and value addition

During the year 2000-01, India earned 8.44 billion rupees by exporting fresh fruits and vegetables, while another 13.46 billion rupees came from the export of processed fruits, vegetables and their products. There is obviously a wide scope of growing vegetables, fruits and tuber crops with adoption of suitable soil and water conservation techniques, and ample opportunities exist for value addition in the coastal agriculture. Adoption of simple technique like raised bed-pond system enabled the farmers of Dankuni basin, West Bengal to get good yields of vegetables like pumpkin, bottle gourd, bitter gourd, lady's finger, sponge gourd, etc. during *kharif* season where no crop could normally be grown due to prolonged water stagnation. Besides, in *rabi* season vegetables like brinjal, chilli, tomato, cabbage and cauliflower could also be grown successfully with the help of life saving irrigations from the water stored in the pond as observed under AICRP on Drainage. Development of improved varieties and agro-techniques suited to the varied agroclimatic conditions and efficient post-harvest techniques are needed to boost up the vegetable and fruit production further. Tuber crops owing to their high dry matter production rate and capacity to withstand several biotic and abiotic stresses can find a remunerative position in the coastal agricultural production system. Apart from their conventional use as staple food, various low cost and value added products like instant foods - cassava rava and porridge, sweet potato jam, pickles, sauce, etc. can be prepared at home front. The tubers can also be utilized for producing alcohol, gums, cold water soluble starches, feeds for poultry, fish and cattle at a commercial scale. These provide a marvellous avenue for setting up rural industries to improve the economy of the region.

The coastal ecosystem provides an excellent niche for various plantation crops like coconut, cahew, arecanut, cocoa and oil palm, spices like black pepper, cardamom (small and large), ginger, turmeric and seed spices like cumin, coriander and fennel and also for medicinal plants. Coconut alone contributes around Rs. 7000 crores annually to the GDP, supports nearly 10 million farm families (of which Kerala alone accounts for about 5 million), and earns foreign exchange to the tune of Rs. 238 crores through export of coconut products, primarily coconut coirs and coir-based products. Apart from the traditional use of the nut and oil for beverage and edible purposes, several value added products like coconut cream, coconut honey, coconut skimmed milk, nata-de-coco, etc. have tremendous commercial scope both in domestic as well as in international markets. Therefore, concerted and well planned efforts are needed for developing integrated and ecofriendly management of nutrient, water and other inputs for these commercial crops to ensure sustainability of the production systems with minimal pesticide load in the finished products as well. In the wake of liberalization of global marketing it has become imperative to ensure competitive quality and cost of the produce in order to capture the opportunity of export potential.

Agroforestry for income and environment

Agroforestry systems integrating woody perennials with agricultural crops, have a significant role to play in improving the agricultural and environmental scenario of the coastal region through enhanced availability of food, fodder, wood and fuel and also through effective conservation and amelioration of the natural resource bases. The trees maintain the soil productivity by improving the soil structure, enhancing the nutrient availability and maintaining a favourable hydrological balance in the ecosystem. Different need based and location specific agroforestry models like Agri-Silviculture, Silvi-Pusture or Silvi-Horti-Pastoral systems can be developed. Some important tree species adapted to the coastal regions are - *Casuarina equisetifolia, Terminalia arjuna, Acacia nilotica, A. auriculiformis, Eucalyptus robusta, Samania saman, Azadirecta indica, Albizzia lebbeck, Albizzia procera, Salvadora persica, Pongamia pinnata, Populus nigra, Zizyphus sp., Gmelina arborea, Tamarindus indica, Lagerstroemia flos-reginae* and *Prosopis juliflora.*

Farming system research

Integrating arable cropping with livestock, poultry, and fishery through farming system approach is gaining tremendous importance for improving the productivity of resource poor areas such as the coastal regions on a sustainable basis for optimization of use of resources, for maintaining good soil health, and for ensuring environmental safety. Several farming system models developed at TNAU, Coimbatore have shown increased net return as well as employment generation compared to the traditional arable farming. For instance, dairy + poultry + crop system increased the net income and employment opportunity to the tune of Rs. 9460 ha^{-1} yr^{-1} and 640 manday $ha^{-1}year^{-1}$, respectively at Salem; rice + poultry + fish culture system produced additional net income of Rs.8500/- and employment of 150 man day $ha^{-1}year^{-1}$. The main task lying ahead is the extensive validation of these technologies on the farmers' fields in order to facilitate speedy adoption on a large scale.

CONCLUSIONS

From the above it is evident that we cannot afford to be complacent with the past success of green revolution. Certain disadvantaged and hitherto neglected areas such as coastal regions offer vast opportunities for enhancing the productivity and improving the national economy. Keeping in mind the ever increasing multiple demand of the soaring population, we need to develop rational production systems that will not only improve the input use efficiency and augment food basket, but will also conserve the natural resource bases. We need to modernize our agriculture to meet the challenge of hunger and poverty without posing further threat to the our ecosystems. Increased food availability, higher income of rural people, and improved health and nutrition, particularly for the poor and marginal farm families are the key issues for the development of coastal areas. The holistic development of the coastal region can be achieved only through farming system approach which can upgrade the productivity of the ecosystem on a sustainable basis through detailed characterization and optimal utilization of the natural resources rather than aiming at the improvement of only a particular commodity. As all our research endeavors are primarily focused towards the economic upliftment of the farm families, we can no longer ignore their views as well as their participation in the planning and implementation of such production systems. It is essential that we explore the immense wealth of traditional knowledge that our farmers have acquired from their experience while designing the farming system models for different locations.

In the end, I would like to emphasize that we have the responsibility to ensure a healthy environment for the future generations and in this context, it is imperative that our technology must work in harmony with our mother 'Nature' rather than damage it. I thank you all for your patient hearing and I am confident that the deliberations of this seminar will surely chalk out technically sound strategies for all round development particularly from the point of view of value addition, for the coastal ecosystem. I also wish to express my sincere gratitude to Dr. V. Rajagopal, Director and his team of dedicated scientists and other staff members of CPCRI for their excellent cooperation, generous help and untiring efforts in organizing this Seminar. I wish you a very comfortable stay and meaningful interaction on all issues relating to the upliftment of the coastal economy with environment safety.

Coastal Agro-ecosystem Research Perspectives : NATP Strategies

S. EDISON

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The Green Revolution was one of the great success stories of the second half of the 20th century. Food production in the developing countries kept pace with population growth. Both more than doubled. And the benefits reached many of the world's poorest people. Forty years ago half of the world's population did not get enough to eat, compared with one-fifth of today. If the population had remained unchanged, the hungry would be in excess of two billion more than double the current level. Since the 1970s, world food prices have declined in real terms by over 70%. Those who have benefited most are the poor, who must spend the highest proportion of their family income on food.

Hunger and poverty

Viewed globally, food is plentiful. If we were to add up all the world's production of food and then divide it equally among the world's population, each man, woman and child would receive a daily average of over 2700 calories of energy. This is just about enough to prevent hunger and probably sufficient for everyone to lead an active healthy life.

Most of the hungry are women and young children of extremely poor families. More than 180 million children under five years of age are severely underweighed-that is, they are well below the standard weight for their age. This represents a third of the under-fives in developing countries. Young children crucially need food because they are growing fast and, once weakened, are likely to succumb to infections. Seventeen million children under five die each year, and malnourishment contributes to at least a third of these deaths. (Conway, 1999).

Globalisation

While conflict between East and West has declined, there is a fast growing divide between the world of the peoples, countries and regions who 'belong' in global power terms, and those who are excluded. At the same time, the growing interconnectedness of the world – the process commonly referred to as globilisation – holds the promise of alleviating, if not eliminating poverty and hunger. Globalisation, while threatening on the one hand to concentrate power and increase division, on the other contains the economic and technological potential to transform the lives of rich and poor alike. Much depends on where our priorities lie and, in particular, whether the poor will have sufficient access to the economic opportunities that the products of the new technologies create.

Our common future

Changes everywhere, in the pattern of natural resources use and management, the impacts of which respect no political or geographic boundaries, and the preoccupation with sustainable development have unshered in a new era of globalism captured in the three words "OUR COMMON FUTURE". In the 1990 Bergen Conference on *Sustainable Development : Science and Policy,* the synthesis of deliberations included the following reflections.

"The message conveyed by OUR COMMON FUTURE is a very powerful one. It is more than interdependence, more than international cooperation; more than technology and resource transfers; more than intergenerational equity; more than science and policy dialogues. OUR COMMON FUTURE provides the soul, the ethic, and the methods for our actions. Without this, no sustainable development is possible. Most of the environmental issues are confrontational and divisive whether between North-South, rich-poor or between disciplines. The SCIENCE COMMUNITY has the obligation to provide the empirical and knowledge base for the faith we have in OUR COMMON FUTURE. (Castillo, 1994).

Global science and local knowledge

Scientific breakthrough in identifying high yielding varieties by CGIAR system and thereafter transferring to and recast by NARS have paved way for green revolution and its impact was immense in regions endowed with resources. Adoption of high yielding fertilizer responsive varieties, which has epitomized the revolution, has been largely limited to the more intensively farmed, "core" agricultural areas of Asia, especially the rich, alluvial soils of the Indo-Gangetic plain, the coastal plains of Asia in general and the deltas in particular. The failure of the Green Revolution to have much impact in more extensively farmed, "peripheral" environments suggests a failure to comprehend the needs of those environments, which are often highly heterogeneous (hilly areas for example) fragile in many cases, enjoy less government infrastructure, and are associated with risk prone, low input agricultural and complex, diverse farming systems. (Farmer, 1978). The local architects of these systems have tended to operate with survival focused farming strategies rather than strategies for simple productivity or profit maximization, although increasing need for cash and a growing population are leading to unsustainable intensification in many areas. Rural communities have reservoir of expertise in management of complex agroecologies and their associated agricultural, livestock and aquatic systems. (Prain, 1994) Yet remarkably, this widely available knowledge resource is rarely tapped by resource-starved national agricultural research and development systems. Indigenous people and other communities have a vital role in environmental management and development because of their knowledge and traditional practices. States should recognize and duly support their identity, culture and interests and enable their effective participation in the achievement of sustainable development.

System perspective

In most countries of Asia, agricultural researchers and mid-level extension staff have little direct experience of these systems, since education patterns have tended to favor either urban-based recruitment or recruitment from wealthier rural families. Among internationally recruited scientists, needless to say, direct experience of this type of agriculture is even rarer. Given that such agricultural systems are likely to have particular technology needs that will be different from the core farming areas, a "knowledge gap" between researchers, extension workers and farmers probable partly explains the failure so far to introduce appropriate development options. (Prain, 1994).

A system is an assemblage of elements in a boundary. Within the boundary elements are strongly linked to each other. Across the boundary links with elements in other systems are few, weak or non-existent ; The strong links with the boundary produce a distinctive behaviour ; The system respond to many stimuli as a whole, even if a stimulus is only applied to one part of the system. (Conway *et al.*, 1987)

National agricultural technology project

Despite the liberalization of the Indian economy, continued growth in the agricultural sector remains crucial for broader national development. Increased agricultural productivity and profitably, especially in resource poor areas, are also crucial to achieving the national objectives for rural poverty alleviation and the welfare of those living in rural areas, particularly women and other disadvantaged group. All these needs will have to be met through intensified demands on the natural resource base.

But while the Green Revolution technology was the cornerstone of past success, demands for agricultural technology are now changing and diversifying. Factor productivity growth in India's Green Revolution areas does not match that of some East Asian Countries and may be declining ; new approaches, for instance involving frontier sciences such as biotechnology as well as production systems approaches to breaking through yield plateau, are needed for these well-endowed areas. At the same time, India must – both for economic and social reasons – invest more in technology for less well-endowed areas, particularly the rainfed lands which comprise 63 percent of its cultivated area. And in all areas, as agriculture intensifies, greater attention is needed to ensure sustainability and the containment of potential adverse impacts on the natural resource base and environments. (Kaul and Mittal, 1998).

These trends have set a new agenda for the generation, assessment and dissemination of agricultural technology. Copying with the great diversity of agroecological settings and producers across the subcontinent calls for a decentralized approach. It should focus on individual production systems and integrate the contributions of frontier sciences as well as conventional disciplines and indigenous knowledge in augmenting productivity, stability and sustainability. In contrast to the blanket Green Revolution recommendations appropriate to the needs of the past, the new technologies will increasingly have to be participate more in setting the technical agenda, contributing their own ideas as well as assessing and disseminating results. Because much of the new technology will not be commercially marketable – for instance because it deals with broader management of natural resources of is aimed at the rural poor- it will still have to be publicly funded. But pressures on government expenditure mean that public funds will have to be more carefully targeted and utilized more efficiently. Considering all these factors, it was felt to give new design to Agricultural research in India under National Agricultural Research Project which would facilitate evolution of the new NARS aiming at 1. Improved management and organizational changes 2. Decentralization and devolution 3. Competitiveness 4. Refocusing public sector role 5. Linkages.

Agro-ecosystem

An agro-ecosystem (or agricultural ecological system) is an ecological system partly modified by man to produce food, fibre or other agricultural product. Features of an agro-ecosystem are 1. Boundaries become sharper and stronger 2. Reduction in natural and biological components 3. Ecological processes remain 4. Ecological processes modified by socioeconomic process. Thus the combined ecological and socioeconomic processes create and determine the agro ecosystem.

For realization of agricultural research and developmental goals on a long term basis, it is essential to use the natural resources more judiciously. Keeping this in view, the Indian Council of Agricultural Research has divided the country into 20 agro-eco regions (AERs) and 60 agro-eco-sub regions (AESR) using the criteria of soils, physiography, bioclimate (climate, crops and vegetation) and the duration of the growing period. While categorization indicates homogeneity of the regions for their growth potential, it fails to reflect the socioeconomic endowment, market support and service sector in agricultural development. In reality, spatial distribution of production possibility sets determines spatial diversity of farming systems even within the same AER/AESR. Moreover, introduction of irrigation alleviates a major constraint for crop production and in fact provides opportunities for diversification of agriculture. Therefore, the ICAR has focused research Programmes under NATP on the production system research (PSR) which is not only analogous to AER and geographical approach but goes beyond both of them and integrates all the system components for determining the productivity and profitability of the system.

Although the country could be broadly delineated into irrigated and rainfed ecologies for providing the required focus of the area specific developmental needs of regions, bypassed by Green Revolution technologies, research and technology dissemination would be supported in the following five agro-ecosystems : Irrigated, Coastal, Arid, Rainfed, and Hill & mountainous. Within each of the agro-ecosystems, there are two to four different production systems (totaling 15 production systems in the 5 agro-ecosystems) which, because of their importance to national policy objectives, require super specific needs. This would represent a significant shift from the commodity and the discipline specific approach that has characterized Indian Agricultural Research and extension, and would require important changes in the way research and technology transfers are carried out and funded.

Common features of agro-ecosystem research

- Identification and characterization of the main features of the production systems in priority locations.
- Identification of the main constraints to intensification and diversification for sustainability under farm conditions
- Supporting strategic research through teams of excellence and supporting cross cutting research in mission mode approach feeding into the production system research and
- Collaborative research and extension in on-farm adaptive research and demonstrations.

Coastal agro-ecosystem

India has a 8,129 km long coastline. Its peninsular region is bounded by the Arabian Sea on the west, the Bay of Bengal on the east and Indian Ocean to its south. It has two distinct major island ecosystems, the Andaman and Nicobar Islands in the Bay of Bengal and the Lakshadweep Islands in the Arabian Sea. India's continental shelf of 500,000 km^2 and its economic jurisdiction in the seas for exploitation and management of the marine resources spreads over 2.02 million $sq.km^2$ of an Exclusive Econimic zone (EEZ). The tropical seas around India abound in rich natural fishery resources that account for an annual haul of 2.8 million tones against a potential of about 3.9 million tones. The base of this marine fishing industry has been assiduously built up over a period of half a century and consists of 2 million fishermen living in 2,400 fishing villages, catching fish with about 180,000 artisan crafts and some 30,000 mechanized boats and landing the catch in about 1,500 landing centres and about 40 major/minor fishery harbours.

With an estimated 1.2 million ha of brackish water area available for the purpose, coastal aquaculture is emerging as a major production activity. Utilizing about 1000,000 ha, the annual production stands at about 75,000 tonnes of shrimp which has assumed the status of an export oriented cash crop. Attention is also being paid to cultures of fishes, other species of shrimps, crabs, lobster and seaweeds apart from several non-conventional species. Clearly, the coastal ecosystem of India forms a very valuable resource community, supporting the livelihood security of several million rural poor and also contributing to the national economy in a large measure. The hinterland of the coastline has varied geomorphic and topographical features of mountains, valleys, coastal plains, riverine systems, climatic conditions, soil conditions and water budgets and a wide range of cultivated crops. It also supports diverse vegetation ranging from rich tropical rain forests to coastal mangroves. The vast deltaic region the east coast forms the rice bowl of the country. Agriculture, agroforestry and silviculture are the agro-based activities here.

However, over 3 million ha of India's coastal area is plagued by salinity (1-45 dSm^{-1}). What gives cause for concern that the salinity is on the increase. Sea level rice due to global warming has been predicted time and again. The implications of this phenomenon to coastal zone and island ecosystem can be imagined. Over and above this, natural causes like cyclones, currents and tides are a common feature of these areas. Anthropogenic pressure, unfavourable environmental changes are also taking place. All this calls for an integrated coastal system management strategy based on ecological sustainability, economic efficiency and social security of sustainable use and management of the ecosystem. In this direction, NATP will concentrate on research and technology development of two production systems viz., the fish and livestock production system and the agri - horti - production system.

Production Systems Research (PSR)

Sustainability of the production systems is addressed in a holistic manner involving cross-cutting issue e.g., natural resource conservation, land and water management, Integrated Pest Management, Integrated Nutrient Management, livestock, fisheries, etc. through development of institutional partnerships.

The main objective is to raise the efficiency, responsiveness the relevance of agro-ecosystems research. The PSR, therefore, focuses on sustainability issues while responding to farmer's needs, improved research, planning & management and capacity building at the local level to monitor and addresses research priority setting, production and sustainability issues. The main departure is the involvement of farmers and including PRA and other rural diagnostic techniques and on-farm and farmer-participatory evaluation of research outputs. Additionally, Technology Assessment & Refinement have also been included with Institute Village Linkage Programme (IVLP) so as to not only reduce the time gap in technology dissemination but also involve beneficiaries in identifying constraints and evaluation.

The other modes of Research in NATP are: Mission Mode, Team of Excellence (ToE) Mode, Competitive Grants Program (CGP).

Organization & management system

Under this category support has been built for O&M Reforms, Information system development and support for Headquarters for project implementation activities. The major objective are:- to introduce reforms in ICAR Organization and Management processes including support for enhancing the management capabilities of institutions including Priority Setting & Monitoring, extension of ARIS connectivity, Library and Information System Strengthening and Strengthening of socioeconomic research including upgrading production capacity of publications.

NATP was implemented during 1999 has passed through four years and significant contribution is already felt in the NARS in terms of infrastructure, technologies generated and human resources development.

The Indian Society of Coastal Agricultural Research established in 1982 at CSSRI, Canning Town is very active in promoting Coastal Agricultural research and issue related to problem diagnosis and solutions. It has successfully organized six National Seminars and the seventh one now is being organized at Kasaragod. I wish fruitful deliberations during the seminar and the seminar and grand success.

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Coastal Ecosystem in India — An Overview[1]

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Respected Dr. J. S. P. Yadav, Dr. S. B. Kadrekar, Dr. S. Datta, Dr. Rajagopal, Dr. Sen, Dr. Modagil, fellow scientists, distinguished delegates, ladies & gentlemen, members of the press and media.

India has a 8,129 km long coastline. Its peninsular region is bounded by the Arabian Sea on the west, the Bay of Bengal on the east and Indian Ocean to its south. It has two major island ecosystems, the Andaman and Nicobar Islands in the Bay of Bengal and the Lakshadweep Islands in the Arabian Sea.

Coastal areas, mostly saline in nature, are different from inland areas in that the latter are formed due to secondary salinization through high water table conditions caused by the introduction of irrigation in arid and semiarid areas, whereas salinity problems in coastal soils is caused during the process of their formation under marine influence and subsequently due to periodical inundation with tidal water, and, in case of lowlands having proximity to the sea, due to the high water table with high concentration of salts in it.

Although there is no sharp demarcation for the coastal land it used to be generally believed until recently, based on a thumb rule approximation, that the marine influence with typical coastal flora and fauna exists approximately upto 50 km inshore. A recent approximation by NBSS&LUP have shown for the first time, on the basis of agro-subecoregion estimate, that the total coastal area in the country is spread over an area of 11.8 million ha area.

Salt injury to plants may be due to osmotic stress, specific ion effects, ion antagonisms, toxicities caused by ions released through cation exchange, and effects of ionic activities. In flooded soils, salt displaces K^+, Ca^{++}, Mg^{++} from the exchange sites into the soil solution. In wet acid sulphate soils excess water soluble iron, aluminium, hydrogen sulphide and organic substances, especially fatty acids, are common examples to affect the rice crop.

Besides a number of soil- and water-related factors limiting productivity of food grain crops, the entire shoreline is extremely fragile in nature. As a result, there is always an element of uncertainty to the lives and properties all along the shoreline, especially those in the lowlands, in India and similar other countries. The areas are environmentally disadvantaged and are at a great risk to the ill-effects of human activities and weather adversities. Frequent occurrence of strong cyclones causes colossal damage to the agricultural crops, human and animal lives, and other properties.

The climate of coastal saline areas of India is not much varied. Except the North Gujarat coast, the area falls under hot and humid or subhumid climatic zones. The general cyclic features of the climate are:

1. Mild and short winters during December to February
2. Hot and humid summers during March to May
3. Rainy period during June to September with extended rainy period of October-November in the southern-most peninsula.

Crops and cropping systems

Out of 42.1 million hectare of total rice in India, rice being the predominantly grown crop in coastal areas consists of (i) shallow lowland ecosystem occupying 8.0 million hectare in the country of which 5.8 million hectare are located in the Eastern India, majority of which are in the coastal belt, (ii) intermediate and semideep ecosystem occupying nearly 4 million hectare of rice land with a standing water of 30-50 cm depth in the field during the crop growth stage, of which 3.5 million hectare are in Eastern India, almost entirely in the coastal belt, (iii) semideep lowlands occupying 3.0 million hectare, of which 2.5 million hectare are located in the coastal part of Eastern India alone, and (iv) deepwater and floating rice ecosystem occupying 2.1 million hectare in Eastern India, almost entirely in the coastal belt out of 2.4 million hectare in the whole country. India, as a whole, has about 55 percent of the total rice area under lowlands, but the proportion is much higher in coastal tracts. West Bengal, having the largest share of coastal area, has about 90 percent of the total area under 30-90 cm depth of water.

[1]Presented in absentia by Dr. S. Ayyappan, DDG (Fishery and Engg.), ICAR

As per the present production growth rate of rice, the estimated production targets for the coastal regions have been projected at 34 million tonne for 2010 AD compared with the present level of 20 million tonne i.e., an increase in the productivity level from 2.13 tonne ha^{-1} at present to 3.62 tonne ha^{-1} in the next 7 years.

Breeding strategy : The future crop management lies in the evolution of better varieties through appropriate breeding strategies coupled with improved agro-input management practices for rainfed and harsh agro-ecological environments viz., salinity, acidity and floodprone for development/ identification of genotypes with higher genetic yield ceiling under irrigated and rainfed shallow lowland conditions, and consolidation of the already achieved yield gains in rainfed and irrigated ecosystems.

Biotechnology : Innovative biotechnological tools should be used, where conventional breeding does not produce the desired result, in overcoming specific disorder in metabolism or in developing isogenic lines better suited to coastal environment. Recent success achieved in the transformation of rice with novel toxin genes (Bt genes) from the bacterium *Bacillus thurengenesis* for resistance to yellow stem borer, virus coat protein gene to resist RTV, and chitinase gene against sheath blight will ensure the desired stability to rice production growth in the coming decades. Adequate attention is warranted to understand the mechanism for salt tolerance in rice, which should help in developing salt tolerant rice genotypes.

Hybrid technology : It is heartening that India is the second country after China in the development and commercial exploitation of hybrid rice technology, which is readily recognised as the exploitable technological option to raise further the genetic yield ceiling. Concerted research efforts since 1990 have led to the development and release of as many as 11 rice hybrids for general cultivation in the states of Andhra Pradesh, Karnataka, West Bengal and Maharashtra. Significantly, Tamil Nadu Agricultural University has successfully evolved and released TNRH 16 exclusively for salt-affected soils of Tamil Nadu.

Flash flood, tidal swamp and deepwater areas : In areas experiencing short duration flash floods and tidal swamps intermediate plants with elongation ability may not be preferred. For areas having water depth more than 100 cm semidwarf character may not be desirable. The traditional floating varieties tend to elongate above the water level more than 1 m, which may result in lodging-kneeing-elongation sequence. If the semidwarf character is associated with shorter plant height above the water level it should be better suited under 2-3 m water depth situation. Isogenic lines with different degrees of plant parts above the water level need to be developed and tested, since rapid elongation ability should be considered as a distinct advantage for this system.

For long duration deepwater rice Rapid Generation Advance (RGA) technique, where at least three generations can be grown in a year, may be a more suitable breeding technique. Mutation may also be a potential technique to develop deepwater/ flood-tolerant varieties as compared to the conventional technique. Wild rice, say, *Oryza rufipogon* with a long elongation ability and drought tolerance may be a good source to employ advanced biotechnological tools to develop improved varieties.

A number of elite rice germplasms suitable for different coastal ecosystems have been identified/ developed.

Cropping systems

In the predominantly monocropped coastal tracts, the net sown area in the East coast plains is 8.58 million hactare with a cropping intensity of 134 percent, and that in the West coast is 2.77 million hactare with a cropping intensity of 125 percent. Mono or multiple rice cultivation, in vogue in several areas, impairs soil fertility greatly, declining the productivity. Small size of average operational holdings, as found in Kerala (0.36 ha) and West Bengal (0.92 ha), suggests change in the cropping system. Research focus thus needs to be reoriented towards an integrated planning for rice-based multiple crop planning which should be compatible with the available land and water resources for sustainable productivity.

Horticultural and plantation crops

The coastal ecosystem offers vast scope for commercial use not only for a wide variety of fruit and vegetable crops, but also plantation crops, spices and medicinal plants. Plantation crops, like coconut, arecanut, oilpalm, cashew, cocoa, spices like black pepper, cardamon (small and large), ginger, turmeric, and seed spices like cumin, coriander, fennel, fenugreek are high value commercial crops. Both cashew and black pepper are good foreign exchange earners, totaling approximately US$ 600 million annually. India has emerged as the largest producer of coconut in the world, and coconut coir industry is a well established business. Cashew is cultivated mostly in the coastal areas. Release of improved varieties in all these crops and improved production technology has brought significant improvements in the production of these crops.

Medicinal and aromatic plants play important role in Indian traditional medicines. It is reported that over 2,000 native plant species have curative properties, and another 1,300 species are known for their aroma and flavour. Medicinal and aromatic plants, like isaphgol *(Plantago ovata* Forsk) and opium poppy are produced on commercial scale. Plant-based drugs worth US$ 19 million are produced annually.

Intensive research and entry of many corporate firms in vegetable seed business has contributed to the growth of vegetable industry. Vegetable seed business is another area where India may do well. In vegetables demand for processing and export is approximately 4 million tonne. Without discounting post-harvest loss total demand of about 130 million tonne of vegetables has been projected for the country for 2002 AD, showing ample scope of vegetable farming hi the country.

There are a large number of plantation crops and spices holding good prospects under coastal ecosystem. Oil palm *(Elaeis guineensis* Jacq.) is recognised as the highest edible oil yielding crop producing 4-6 tonne of oil per tree in 25 years. Total potential area spread over 11 states in 0.796 million ha mainly along the coastal belt has been identified for growing oil palm. It may be grown in different size farm holdings. The major constraints to oil palm cultivation in large scale are non-availability of quality seeds and improved production technologies.

Forestry

The role of forestry in maintaining the level of CO_2 and other toxic gases in the atmosphere is well established and caught the attention of all concerned worldwide. The present status of forest areas in the East and West coastal belts constitutes only about 18.7 and 29.0 percent, respectively of the total geographical area of the country. The forest coverage in the A&N Islands, however, is as high as nearly 88 percent of its total land area. Mangroves growing under natural conditions along the coastal shoreline occupy nearly 0.4 million hectare in the country. According to Government of India estimate mangroves are estimated to cover about 0.6 million hectare located in the alluvial deltas of rivers, such as the Ganga, Mahanadi, Godavari, Krishna and Cauveri, in the Andaman and Nicobar Group of Islands, and in minor patches in Maharashtra and Gujarat, comprising about 7 percent of the world's mangroves.

Threat to mangrove ecosystems : Although key pressures on mangrove ecosystems vary from country to country, by far the greatest threats are clear-cutting, diversion of fresh water from upland watersheds, and reclamation for agriculture and aquaculture. One major consequence of such mangrove degradation is reduced fish yields. Brackish water aquaculture has a particularly pronounced environmental impact because of the fundamental changes it creates in the mangrove environment.

There are no systematic quantitative estimates of mangroves, seagrass beds, and coral reefs destroyed or degraded over the last 10-20 years.

Agroforestry

Agroforestry systems are more common in India and other developing countries than in the developed countries. It has good prospect for the coastal ecosystem. Based on the nature of the components the common agroforestry systems in India are broadly classified as agri-silviculture (crops + trees), agri-horticulture (crops + fruit trees), agri-horti-silviculture (crops + fruit trees + multipurpose trees), silvipasture (trees + pasture + animals), hortipasture (fruit trees + pasture + animals), homestead agroforestry (multiple combinations of various components) and others.

Aquatic systems

Inshore fishery : Aquaculture technology has been classified into three broad categories viz., intensive, semi-intensive and extensive. Taiwan adopted intensive technologies since land costs are high. Indonesia and the Philippines adopted the semi-intensive and extensive technologies because they could find land for the purpose more easily.

In West Bengal and Kerala, traditional aquaculture has been practiced for many generations. However, not much effort has been made to upgrade these culture systems to enhance productivity. India's entry into full scale scientific aquaculture was made in 1986-87 when some of the State Governments, such as those of Andhra Pradesh, Tamil Nadu, Maharashtra and Gujarat made land allotments to private entrepreneurs.

India has a great advantage of favourable climate for 2 or 3 crops in a year coupled with availability of trained and skilled manpower. Development of aquaculture can take place in India only if there is simultaneous development in the fields of hatchery, feed mill, processing plant and farms.

Future strategies : The corporate sector may play a vital role in the international export especially in the areas of market and investment which have been barriers to the entry (for example, the feed mill and the processing plants which can produce value added products).

The Giant Fresh water Prawn, *Macrobrachium rosenbergii* is an important candidate species for introduction in fresh and low saline brackish water systems of the coastal zones as a diversified eco-friendly activity. Out of 30,000 tonne production in Asia and Latin America, India's contribution is around 10 percent only. India is endowed with 2.15 million hectare of fresh water bodies in the form of ponds and tanks, out of which 0.826 million hectare is being utilised for carp production, and out of 1 million hectare of brackish water about 0.1 million hectare is under shrimp culture. It is proposed to achieve a targeted production of 20,000 tonne of *M. rosenbergii*, a seven-fold increase in the coming years. Giant fresh water prawn culture could be taken up as an ecofriendly activity in 20,000 hectare pond area during the next decade, with an average production of 1 tonne ha^{-1} (average initial harvest size 50 g). To achieve the proposed prawn production of 20,000 tonne per year, it is estimated that about 800 million seed and 40,000 tonne of feed are required. Prawn seed production in synthetic seawater and salt solution, and seed production throughout the year under controlled conditions have been achieved in case of riverine prawn.

The technologies of induced carp breeding and composite carp culture gave a fillip to fresh water aquaculture in the country in the Sixties and Seventies. Several new components are being added to optimise productivity. Advancement of carp maturity to March over the prevailing period of June-July, and breeding of the same individual four times a year with gaps of 45 days between two successive breedings have made it possible to provide fish seed almost throughout the year.

Successes achieved in cryopreservation of spermatozoa have eliminated the need for maintenance of male broodstock, while attempts at cryopreserving the ova and the embryos are presently underway. With alternatives to crude pitutary gland extract available for induced breeding, sequencing and synthesis of GnRH are being carried out in order to evolve indigenous replacement for the imported products. Having produced intergeneric hybrids of carps as also gynogens and androgens, the application aspect pertains to sterile triploid grass carp that can be stocked in irrigation canals for control of aquatic vegetation. Genetic assessment of riverine stocks of rohu for selection is an ambitious programme that will provide superior stocks with sustained vigour, and an improved rohu is about to be released. The techniques of breeding and seed rearing in cases of catfish species, Magur *(Clarius batrachus)*, singhi *(Heteropneustes fossilis)* have been standardised.

The large inshore water bodies in the form of ponds, tanks, *beels*, *jheels*, derelict waters, reservoirs, canals in the country can be put to different fish culture practices or even culture-based capture fishery. The sector with its present contribution of 1.38 million tonne of fish/shellfish worth over US$ 950 million has a potential of producing over 4.5 million tonne annually if the available techniques are fully adopted, and transfer of know-how and production of inputs properly organised.

Marine fishery : Of the total fish production, about 2.3 million tonne is from the marine sector and 1.6 million tonne from the inland sector. The annual marine fish production has gone up from around 1.5 million tonne during the early Eighties to the current level of 2.3 million tonne.

Almost 90 percent of the current marine fish production comes from the inshore waters, which accounts for only 15 percent of the total EEZ. Overall, the resources of the inshore waters have been exploited to levels closer to the sustainable levels. To increase marine fish production it is imperative that the resources of the deeper water, that is beyond 50 m depth, are tapped.

Future target : As a foreign exchange earner, marine fishery involving 9.5 million fishermen is classified as an "extreme thrust" area. While the marine exports accounted for US$ 215 million during 1990-91, the figure for the next year was US$ 327 million, recording a growth rate of 54 percent. It was expected to touch US$ 1190 million mark in the first decade of twenty-first century. With a coastline of over 8,000 km and an Exclusive Economic Zone (EEZ) of 2,02 million sq. km, in addition to a vast potential of marine resources, the achievement of such a target would not be difficult.

The Indian Ocean provides an excellent opportunity for fishing as it is least polluted, and at the same time, exploited particularly along the Indian coastline. The Indian EEZ is estimated to be able to sustain an annual fish production of 3.9 million tonne, out of which about 59 percent is currently exploited.

Livestock-based

Milk production in coastal states constitutes 38.99 percent of the total production in India. There is considerable scope to increase milk production in these areas, where it is constrained due mainly to poor health of the cattle breed under unfavourable climate, restricted fodder availability and lack of organised cooperative movements in most parts.

In coastal areas with water bodies duck should form a popular poultry constituent. In the coastal states of Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra and West Bengal commercial poultry farming has already made a dent, but not in Orissa. Poultry has not entered into the world market in a big way due to lack of competitiveness although it has the requisite infrastructure in India. There is need to reduce the cost of production and introduce proper quality control into the industry to make it competitive in the world market.

Alternate farming systems : This would provide steady income to the farmers, ensure buffer stock against risks due to crop loss or price fluctuations, and generate income during gestation period from horticulture and plantation crops. For coastal areas having rich and diverse stock of flora and fauna the integrated farming system may combine crop production with sericulture, apiculture, dairy, poultry, aquaculture, forestry, etc. Agroforestry, silvi-horticultural, silvi-pastoral system would come under this programme for which location-specific packages, which should be socially acceptable and economically viable, need to be developed. A suitable example on alternate farming package may be combining aquaculture with lowland rice.

Drainage & water management

Among the suggested methodologies are improved irrigation and drainage in soil suitable to the coastal ecosystem. Some works have been done on this aspect but a lot more is required to be done especially in the field of drainage for coastal lowlands which should be cost-effective. This is a challenging field and I call upon the hydrologists and drainage engineers to pay their attention in developing location specific technologies in integrated watershed management mode. Indigenous methods are available, an example of successful application is the Moti-Rayan Project in Gujarat, which has the distinction of successfully combating the ecological threat due to ingress of seawater through the aquifer.

Rainwater conservation & management

It forms the core of the improved watershed management approach suited particularly to the small land holdings in coastal ecosystem. It is an integrated approach on rainwater management, dealing with on-farm harvest and storage of excess rainwater during monsoon, and recycling the same for irrigation for dry season (deficit water period) crops, with the objective to introduce multicropping in the otherwise predominantly monocropped areas. Some good works have been done in this respect and we have seen successful implementation of a number of such technologies in the rainfed coastal areas. The important NGOs or developmental agencies are Sundarbans Development Board in West Bengal, Dr. M. S. Swaminathan Research Foundation for Ramanathapuram and Pudukottai in Tamil Nadu, Vivekananda Research Institute, Mandvi for Kachchh of Gujarat, Lupins Laboratories for Bharatpur, Rajasthan, Anna Saheb Hazare's Pani Panchayats for Maharashtra, and MYRADA for Karnataka.

Another improved technology to utilize the surface water is life-saving irrigation by digging *Doruvus*, which is a conical pit dug to collect seeped-in water, hi this method, suitable particularly for sandy loam soil, fresh water floating over saline groundwater may be skimmed horizontally through tile drains at the rate of 18 Ips, which would be sufficient for operating six sprinklers continuously. The economics of improved *Doruvu* technology developed in Andhra Pradesh is very favourable. The benefit-cost ratio is more than 2.5 and the internal rate of return is about 28 percent. High capital requirement is one of the major drawback as the entire system complete with pump, sprinkler/ deep system costs between Rs. 65,000 - 80,000) (US $ 1500 - 19000).

Nutrient management

Most of the coastal saline soils are deficient in nitrogen. Besides lesser utilization of nitrogenous fertilizer, especially in coastal areas, the mineralization of soil organic nitrogen, and thus the release of native soil nitrogen to the plant available form, is also slowed down in the salt affected soils due to decrease in the population as well as activity of microbes with increase in soil salinity. The level of phosphorus in the coastal saline soils is highly variable, and depend largely on the nature and degree of salinity. Very little work has been done on the transformation and availability of P to crops in coastal saline soils. The availability of potassium depends largely on the parent material, clay minerals and weathering conditions. It also depends on the nature and amount of salts in the soil. Work done so far on the role of micronutrients in coastal saline soils is meagre. The soils are generally rich in micronutrients, such as Fe, Mn, Zn, Cu, B and Mo. However, there are other location specific problems.

As Alternative sources use of green manure crops like Sesbania spp. *(S. aculeata)* has been proved very suitable for saline alkali soils. In favourable climate with proper management, these crops accumulate well over 100 kg N ha^{-1}, mostly through biological N fixation, in 50-55 days, thereby increasing the yield of the following rice crop significantly. Likewise *Glyricidia maculata* @ 10 tonne ha^{-1} was also found useful, hi view of rising energy cost and limited input availability, recycling of organic wastes and use of renewable sources of biofertilizers viz., rhizobium cultures for pulse or legume, and blue-green algae for waterlogged rice field may play a significant role in terms of integrated nutrient management for rice in coastal saline soils.

Acid sulphate soil management

Large area of acid sulphate soils have been reported in Kerala and A&N Islands which needs special attention. It has been reported from Andaman Islands that application of lime and phosphorus may be beneficial for lowland rice, but the soils should be leached of excess salts in case of high soil salinity before using these amendments. In another study on mangrove *(Avecenia marina)* muds in this island, it has been reported that liming significantly depressed the concentrations of Al, Mn and Fe. Exchangeable Al content also decreased with lime application. The depression of exchangeable Al may be due to precipitation of trivalent Al and $Al(OH)_3$ in the presence of high concentration of OH^- ions. Lime, application, in general, also reduced the exchangeable and extractable Fe contents of the soil.

Brackishwater farming vis-à-vis ecological security & social impact

A very important problem of brackish water aquaculture is the conversion of agricultural lands into shrimp farms. It has been estimated that gross value of productions in aquaculture per ha is 35 times that of paddy. Attracted by the high returns farmers allowed conversion of highly productive lands especially in the East and West Godawari and Nellore districts of Andhra Pradesh. A study conducted in West Godawari district found that 75 percent of the land converted to shrimp farms were paddy lands. Such diversion of productive agricultural land may affect the food grain sufficiency in the country.

Social environment is also affected in several ways due to highly capital intensive shrimp culture. Shrimp farming with modern technology and high profitability attracts rich entrepreneurs and introduces capital from urban areas to rural areas. Though flow of capital to rural areas is welcome it creates another kind of problem. The small fishermen are deprived of the benefits and so are the small farmers, who cannot adopt the costly technology.

Also, when the land is shifted from agriculture to fish farming some displacement of labour also takes place. For example, as against the average labour requirement of 183 mandays/ha for paddy shrimp farming requires only 90 mandays. Further, due to intensification of shrimp farming there is increasing incidence of landlessness in coastal villages. The entry of corporate sector has activated the land market by inducing the small and marginal farmers to sell their land at lucrative prices. The owner of resource becoming landless proletariat is not desirable in a populous country like India as it would lead to social tensions.

Future strategies for technology generation and transfer for poverty alleviation

Since majority of the farmers in the coastal ecosystem have poor resource base and operate in highly fragile ecosystem having diversified farming situations, economic conditions and sociocultural background, they have to make complex decisions about the allocation of scarce resources and factors of production for different enterprises. In the present technology generation system, there is often no role of farmers except a nominal or contractual participation by way of conducting adaptive trials on their fields. In this process the farmers' problems, goals and expectations may not be adequately addressed to. As a result, most of the technologies developed have not been acceptable to the farmers especially for such ecologically disadvantaged areas. I strongly suggest adoption of farmers' participatory mode of extension methodology for technology generation, and transfer through assessment and refinement, where the role of scientists should be only as a facilitator.

Finally, I wish you all a successful deliberation and I will look forward for a useful road map for augmenting productivity in coastal ecosystem in a time-targeted fashion.

Indian Fisheries and Aquaculture: Present Status and Future Prospects

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Indian fisheries sector has come a long way since independence and immensely contributed to the food basket of the country with annual production levels of over six million tonnes of fish and shellfish from capture fisheries and aquaculture. India being the fourth largest producer of fish, it is playing an important role in global fisheries. Further, with production of over 3.1 mmt from the inland fisheries sector the country occupies second position in the world. During the last five decades, Indian fisheries has made great strides, with the annual production increasing from 0.75 million tonnes of fish and shellfish in 1950 to about 6.1 million tonnes in the year 2002, indicating over eight-fold increase during the period. The share of inland fisheries sector, which was 29% in 1950-51, has gone up to over 50% at present. While production from marine sector has been solely contributed by capture fisheries, aquaculture contribution in inland fisheries sector has been significant in recent years. Further, while the production from capture fisheries during last two decades has grown by only 72% i.e. from 2.08 million tonnes in 1980 to 3.59 million tonnes in 2000, the aquaculture sector has shown a overwhelming growth of 468% during the same period i.e., 0.37 million tonnes in 1980 to 2.1 million tonnes in 2000. The country has also emerged as one of the giants in export front, recording a peak during the year 2000-2001, with earnings of Rs. 5957 crors (US $ 1.25 billion), which however showed a decline of 7.56% during 2001-2002 due to economic recession and drastic decline in price realization of black tiger prawn in international market.

Inland fisheries

India is blessed with huge inland water resources in terms of 29,000 km of rivers, 0.3 million ha of estuaries, 0.19 million ha of backwaters and lagoons, 3.15 million ha of reservoirs, 0.2 million ha of floodplain wetlands and 0.72 million ha of upland lakes. It has been estimated that about 0.8 million tonnes of inland fish is contributed by different types of inland open water systems. Though production breakup of these water bodies are not available, it is believed that capture fisheries production from rivers and estuaries contribute only a small share of total inland catch, and bulk of the production comes from reservoirs and floodplain wetlands which are managed on the basis of culture-based fisheries or various other forms of enhancement. The 14 major rivers, 44 medium rivers and innumerable small rivers of the country with combined length of 29,000 km provide for one of the richest fish faunistic resources of the world. While production figures from different riverine systems are not available, estimates made for major rivers showed yield varying from 0.64 to 1.64 tonnes per km with average of 1 tonne per km. Further, as per the available statistics the average estimated yield in different estuaries range from 45-75 $kgha^{-1}$.

Reservoirs form the largest inland fisheries resources in terms of resource size with 56 large reservoirs (>5000 ha), 180 medium reservoirs (1000-5000 ha) and 19,134 small reservoirs covering water area of 1.14 million ha, 0.527 million ha and 1.485 million ha, respectively, with substantial areas added year after year due to construction of new impoundments created through erection of dams over rivers, streams or any other water course. In India, management of medium and large reservoirs can be considered as more akin to enhanced capture fisheries and their fisheries largely depend on natural recruitment. On the other hand, the fish catch of the small reservoirs depends on stocking and management, is termed as culture-based fisheries. However, stocking in such small reservoirs is not merely a simple matter of releasing appropriate species into the ecosystem but an important management option which needs evaluation of an array of factors *viz.*, biogenic capacity of the environment, the growth rate of the desired species, fishing condition, shallowness of the reservoirs, natural recruitment, etc. In general, stocking of advanced fingerlings (10-15 cm) of Indian major carps at density of 400-500 numbers per ha are suggested for small reservoirs. However, the average national production levels obtained from the small reservoirs of the country are still low, about 50 $kgha^{-1}$, compared to other countries in Asia and Latin America.

Efforts on scientific management by CIFRI in several small reservoirs have shown to improve the yield to a great extent *viz.*, 102 $kgha^{-1}$ in Baghla, 140 $kgha^{-1}$ in Bachhra, 150 $kgha^{-1}$ in Markonahalli (all are in Uttar Pradesh), 194 $kgha^{-1}$ in Aliyar, 182 $kgha^{-1}$ in Tirurnoorthly (both are in Tamil Nadu), 108 kg in Meenkara and 316 $kgha^{-1}$ in Chulliar (both are in Kerala) are a few examples which has shown high yields. It has been estimated that the 1.5 million ha of small reservoirs can produce at least 0.15 million tonnes against the present levels of less than 0.07 million tonnes. Further, the medium and large reservoirs can yield another 0.15 tonnes though proper species and stock enhancement. Thus, greater thrust is warranted to exploit the fisheries potential of these water bodies through culture-based fisheries in coming years.

Floodplain wetlands or *beels* are other potential fisheries resources in the states of Assam, West Bengal and Bihar, which offer tremendous scope for both culture and capture fisheries. These water bodies play vital role for recruitment of fish stocks of the riverine system and provide nursery grounds for commercially important finfishes and shellfishes. It has been estimated that these *beels* possess potential to yield higher production levels of as much as 1000-1500 $kgha^{-1}$ $year^{-1}$, while the present level remains at only 100-150 $kgha^{-1}$. The rich nutrients load and availability of fish food organisms make this water bodies ideal for culture-based fisheries leading to higher growth of stocked fish species compared to the reservoirs. The marginal areas of the *beels* can be utilised for construction of ponds or pens of suitable sizes for raising the required fingerlings for stocking the beels.

Considering the present threat of increased pollution levels and siltation of open water resources like rivers, estuaries and lagoons and also the over-exploitation of these resources leading the stagnation of fisheries production, thrust on culture based fisheries in reservoirs and floodplain wetlands holds the key for future of the inland fisheries development in India.

Marine fisheries

Marine fisheries over the years have played a pivotal role in ensuring food and nutritional security of the growing population, employment generation, enhanced income and foreign exchange earnings through its vast resources in terms of 8,129 km long coast line, 0.5 million sq km of continental shelf and 2.02 million sq km of exclusive economic zone. It is only after the establishment of Central Marine Fisheries Research Institute in 1947, the marine fisheries development was put on a sound footing through its researches on biology of commercially important species and monitoring their stocks for proper management; judicious exploitation and conservation; conducting exploratory surveys and mapping of the productive fishing grounds and locating new areas and resources; and carrying out environmental studies relating to fisheries. During the first two Five Years Plans, emphasis on marine fishery sector was on the mechanizations of indigenous crafts, introduction of mechanized fishing boats, improvements in fishing gears, establishment of infrastructure facilities such as processing plants, ice plants, cold storages and landing and berthing facilities. This programmes, backed by the discovery of rich fishing grounds in inshore waters paved the way for establishment of Sea Food Exports Industries. Over the next three Five Year Plans, the above programmes were continued with greater emphasis on introduction of mechanized fishing boats and adoption of synthetic materials for fishing gears. Researches on various aspects of marine fisheries and exploration of their resources were intensified. With the declaration of Exclusive Economic Zone of 200 miles in 1976, the programmes relating to deep-sea fishing were intensified. While in fifties and sixties, mechanized boats with trawl nets and motorized indigenous crafts were introduced for efficient harvests from the inshore region, in seventies, purse-seines were introduced along the south-west coast. These developments resulted in expansion of fishing areas and increase in production. Improved harvesting technologies coupled with increasing demand of fish for domestic and also export market have resulted in significant increase of production over the last fifty years i.e., from 0.53 mmt in 1951 to 3.0 mmt in 2001-2002. However, the intense exploitation of resources in coastal areas up to 50 meters by artisanal and small mechanized fishing sector resulted in the annual catch showing a plateau, with decrease in catch per unit effort. While the contribution of the artisanal sector to the total production was significant up to sixties, their contribution at present is at a low, with contribution of only 13% and rest 87% by mechanized and motorized sector.

Fisheries technological research in India did not receive much attention until the establishment of Central Institute of Fisheries Technology, which gave a foundation for researches in the aspects of design of various fishing crafts, gears, fishing techniques, methods of handlings and post-harvest processing and utilization. Initially motorization of indigenous crafts was taken up as first step of mechanized fishing. Subsequently, several designs of small, medium and larger sized mechanized boats were introduced into the fishing industry. Fish detection facilities were introduced in large boats with facilities for proper gear handling for enhancing their efficiencies. Various designs and sizes of mechanized crafts were introduced besides specialized fishing vessels like trawling-cum-fish carrying, trawler-cum-purse-seiner, boats for long line fishing and trolling, etc.

Gear designing was given greater emphasis for enhancing the production output from the mechanized vessels as also diversify the fishing activities. This led to development of different gears, and methods introduced were stern trawling, out-rigger trawling, mid-water trawling, purse-seining and long-lining. Introduction of gears like four-seam trawl and bulged-belly trawl could increase the catching efficiency by about 30% and specialized gill nets were fabricated for lobster fishing. The use of synthetic fibre in fishing gears was another significant achievement for the development of fisheries due to its non-rotting character. Of late, the use of mechanical fishing accessories, ancillary fishing equipment and electronic testing devices of practical value in fishing operation have also added a new dimension for enhancing the catch per unit effort of specific gear and craft.

Increase in fishing intensity, declining stocks, conflict between the fishing sectors, decreasing catch rate, decreasing recruitment, inappropriate exploitation pattern, habitat degradation and resource degradation have been identified to be the major issues of coastal fisheries at present. Addressing these issues for sustaining the growth of the sector, several regulatory measures *viz.*, regulation of mesh size, regulation of fishing areas, seasonal closure of fishing, ban/limit the destructive gears, promotion of marine sanctuaries, promotion of artificial reefs and sea ranching, effecting code of conduct for responsible fishing etc. have been suggested.

Freshwater aquaculture

Indian aquaculture has shown significantly higher growth rates than those of capture fisheries during the last decade with the quantity increasing from 1.01 million tonnes in 1990 to 2.10 million tonnes in 2000. Further, the freshwater aquaculture has continued to form a major share of the aquaculture production, with a contribution of over 95% in terms of quantity. It is only the three Indian major carps which share as much as 1.6 million tonnes. On the other hand, shrimp forms the main component of brackishwater aquaculture sector with production crossing a lakh tonne mark recently.

Freshwater aquaculture in India has made notable strides in recent years with growth trend similar to that of the world. With an annual growth rate of over 6% during the last decade, the sector possesses higher growth rates than most of the food producing sectors. The sector has evolved from the stage of a domestic activity in Eastern Indian states of West Bengal and Orissa to that of an industry in recent years, with states like Andhra Pradesh, Punjab, Haryana, Maharashtra, etc. taking up fish culture as a trade. With technological inputs, entrepreneurial initiatives and financial investments, the pond productivity has gone up from 500-600 $kg ha^{-1} yr^{-1}$ to over 2000 $kg ha^{-1} yr^{-1}$ on a national basis, with several farmers and entrepreneurs achieving higher production levels of 6-8 $t ha^{-1} yr^{-1}$. Carps form the mainstay of culture practice in the country which is supported by strong traditional knowledge base and scientific inputs in various aspects of management and contribute as much as 87% of the total aquaculture production. Further, while the country possesses a large number of potential cultivable carp species, it is only the three Indian major carps *viz.*, catla (*Catla catla*), rohu (*Labeo rohita*) and mrigal (*Cirrhinus mrigala*), contribute a lion's share with production of 0.546, 0.567 and 0.517 million tonnes, respectively recorded during the year 2000. Scientific interventions over last five decades have led to development of a host of carp culture technologies with varied production potentials depending on the type and level of inputs. Further, other produce like catfishes, freshwater prawns and molluscs for pearl culture have also been brought into the culture systems. In addition, a range of other non-conventional culture systems *viz.*, sewage-fed fish culture, integrated farming systems, cage and pen culture, running water fish culture and so on has made freshwater aquaculture an increasingly growing activity across the country. Being mainly organic-based, the freshwater aquaculture practices are also able to utilise and treat a number of organic wastes including domestic sewage, enabling eco-restoration.

1. Carp breeding and seed production

Seed being the basic input in any culture systems, its production has been accorded highest priority in terms of broodstock management, establishment of hatcheries, refinement of induced breeding techniques, rearing and production of quality seed across the country. The technology of induced breeding of carps under control condition has become a common practice of the farmers today. The breakthrough of induced breeding through hypophysation is undoubtedly the most important aspect that led to the overwhelming growth of freshwater aquaculture sector. The technology has made mass production of quality seed under control condition possible, thereby reducing the dependence on natural seed collection. Development of several ready-to-use synthetic inducing agents, as alternative to pituitary hormone, made the technology of induced breeding easier and more farmers' friendly. Besides Indian major carps, the technology of breeding of Chinese grass carp and silver carp has also been domesticated all over the country. Various carp species are domesticated to breed much ahead of monsoon and months beyond monsoon. The technology of multiple breeding of carps has been able to demonstrate 2-3 fold higher spawn recovery from a single female during season through 3-4 times breeding within an interval of about 45 days. The technological evolution of hatchery design and operation from initial earthen pits to double-walled hapa and subsequently to glass-jar and circular eco-hatchery provided scope to produce and handle mass quantities of eggs during hatching. Carp hatcheries in the public sector have contributed for the increase in seed production from 6,321 million fry in 1985-86 to over 18,500 million fry at present. Even states like Assam and West Bengal are producing seed much beyond their requirement, showing the prospects of export trade and its economical viability. However, in the wake of increased emphasis on diversification of carp culture, greater research thrust is warranted for commercial production of important medium and minor carp species.

Despite domestication of induced breeding technology and production of carp seed to the tune of over 18,500 million fry in the country, the availability of stocking materials of desired species and size still remains a constraint. Raising of seed in the initial two stages is associated with high rates of mortality due to several management problems. Packages of practices have been developed and standardized for raising fry and fingerlings with higher growth and survival levels. Higher survival levels of fry of over 40-60% through intensive rearing during nursery stage have been demonstrated at stocking densities of 5-10 million ha^{-1} in earthen ponds and up to 30 million in ferro-cement tanks. A farmer is now able to harvest 3-4 crops of fry even in a season of 3-4 months i.e., during June-September. Further, at 2-3 lakh ha^{-1} stocking densities the technology of fingerlings rearing can result 60-80% survival, with mean fingerlings size of 100 mm in a rearing period of 3 months.

2. Grow-out culture of carps

Research and development efforts during last five decades have greatly enhanced average fish yields in the country making carp culture an important economic enterprise. The three Indian major carps were the principal species cultured by the farmers in ponds since ages and production from these systems remained significantly low till the introduction of carp polyculture technology. Introduction of exotic species *viz.*, silver carp, grass carp and common carp into carp polyculture system during early sixties also added new dimension to the aquaculture development of the country. It is the Pond Culture Division of the erstwhile CIFRI, Cuttack which was responsible for the development and refinement of scientific carp culture in India through its researches carried out at different centres all over the country under the All India Coordinated Research Project on Composite Fish Culture and Fish Seed Production. With the adoption of technology of carp polyculture or composite carp culture, production levels of 3-5 tonnesha^{-1} year^{-1} could be demonstrated in different regions of the country. It is the technology of carp polyculture that has revolutionized the freshwater aquaculture sector and brought the country from a level of backyard activity to that of a fast growing organized industry. Researches over the years have led to the development, refinement and standardization of a host of technologies with varied production levels depending on the input use. The technology of intensive carp culture has demonstrated higher production levels of 10-15 tonnesha^{-1} yr^{-1}.

The necessity of bringing more species of promise into the carp culture practice is being emphasized. It may be stated that species like *Labeo calbasu, L. gonius, L. bata, Puntius pulchellus, P. sarana, P. kolus, Cirrhinus cirrhosa* etc. are considered to be important candidate species due to their production potential, consumer preference and high market price, and calls for greater research thrust for diversification of carp culture sector.

3. Culture of catfishes

Though catfishes possess considerable commercial importance, their culture in the country is yet to make any mark. *Clarias batrachus* (magur) and *Heteropneustes fossilis* (singhi) are the two air-breathing catfishes which are well adapted to adverse ecological conditions. It may be stated that while the technology of induced breeding and seed production of these two important catfish species has been perfected, their large scale production is yet to be taken up. With more or less similar pond management measures as that of carp culture practices and stocking with 20,000-50,000 fingerlings ha^{-1}, production levels of 3-5 tonnes ha^{-1} are achieved in grow-out culture of magur, which attain 100-200 g in 6-8 months. These groups of fishes can suitably be cultured both in monoculture and polyculture systems. Further, considering the availability of huge potential resources in the form of swamps and derelict waters that could be effectively used for commercial farming and huge market demand of these species, large scale culture of these species is yet to receive due attention. In this regard, development of balanced supplementary feed owing to its carnivorous feeding habits and availability of desired quantity of seed of right size are the two critical aspects to be considered. Researches with regard to development and standardization of induced breeding and grow-out technologies of several other non-air breathing catfishes *viz., Mystus* seenghala, *M. aor, Pungasius pungasius, Wallago attu, Ompak pabda* etc. are also being envisaged in view of their high consumer preference in different parts of the country.

4. Culture of freshwater prawn

The giant freshwater prawn, *Macrobrachium rosenbergii* is the largest and fastest growing species among freshwater prawns. The technology of hatchery of the species has been developed and standardized for obtaining commercial production seed with an average survival level of 60% from zoea I to PL. The development of hatchery technology for *M. rosenbergii* and later the technology of seed production of Indian riverine prawn, *M. malcolmsonii* has opened up possibilities for diversification of freshwater aquaculture. There are about 35 freshwater prawn hatcheries established mainly in the states of Andhra Pradesh, Tamil Nadu and Kerala producing only about 200 million seeds per annum, as against the projected demand of 10,000 million seed for development of at least 0.2 million ha water area in coming years.

During the last five years, freshwater prawn farming sector has witnessed overwhelming growth with as much as 24,000 ha additional area, thus brining total area coverage of the country to about 37,000 ha achieving production over 30,000 tonnes. Monoculture of freshwater prawn at stocking densities of 30,000-50,000 ha^{-1} has shown production levels of 1.0-1.5 tonnes ha^{-1} in a culture period of 7-8 months. Further, polyculture of freshwater prawn along with carps has also demonstrated to be a technologically sound culture practice and economically viable option for enhancing the farm income of the farmers. With the increased thrust of the farming practice in last few years, inadequacy of seed has posed major constraint, calling for establishment of a chain of commercial hatcheries in the coastal states of the country.

5. Freshwater pearl culture

While marine pearl culture in India had its beginning in the early seventies, freshwater pearl culture remained an unexplored area till late eighties until the initiation of research programmes by the Central Institute of Freshwater Aquaculture, Bhubaneswar. The investigations by the Institute in last one and half decades not only have led to development of the base technology of surgical implantation by using three commonly available freshwater mussel species *viz., Lamellidens marginalis, L. corrianus* and *Parreysia corrugata*, but also standardized different steps involved for the production of cultured pearls. Three different surgical procedures *viz.*, mantle cavity insertion, mantle tissue implantation and gonadal implantation techniques have been standardized for obtaining different kinds of pearl products. In mantle cavity insertion method the products obtained are shell attached, half round or design pearls depending upon the shape of nuclei implanted. While in mantle tissue implantation procedure the products are unattached, irregular to oval graft pearls or small round nucleated pearls, in gonadal implantation the pearls produced are unattached and slightly larger round pearls.

Inspite of fact that freshwater pearl culture possesses several advantages in terms of commercial scale availability of natural stock of pearl mussels with over 50 species; wider area of farming, even in non-maritime regions; operational ease in management of freshwater culture environment; absence of natural boring and predatory organisms; traditional pearl marketing environment; availability of economically viable indigenous technology; overall cost effectiveness of operations; and most importantly the availability of cheap labour force who can be trained for taking up the pearl culture, commercial farming of the freshwater pearl mussel is yet to be established in the country. Emphasis on entrepreneurship development though institutional backup for technology transfer; assistance by financial institutions for credit; governmental interventions for greater technology dissemination and subsidies; and organized and coordinated effort for market promotion are the aspects need serious attention for the future development of the sector.

6. Integrated fish farming

Integrated fish farming is the combination of two or more normally separate farming systems where byproduct i.e., waste from one subsystem is utilized for sustenance of other e.g., fish-pig/ poultry/duck farming. Though organized integrated farming systems are not very common in the country, use of organic manures in the form of cattle wastes and poultry droppings is common in most of the farms of the country, especially in carp culture farms. Production levels of 3-5 tonnes$ha^{-1}year^{-1}$ have been demonstrated by the integration of fish with poultry/duck/pig, with waste derived from these farm animals as principal input and without provision of any supplementary feed. The system not only found to provide considerable potential and scope for augmenting production, but also offers enormous scope for employment generation, betterment of rural economy and improving the socio-economic status of rural community.

7. Cage and pen culture

Commercial fish farming in cages is almost non-existent in the country even when the practice is largely accepted all over the world. The information on cage culture in the country is limited to a few experimental trials with major carps and catfishes, with a maximum recorded production of 3.3 kgm^{-3} $month^{-1}$ during grow-out culture of grass carp. With over 3 million ha potential area under reservoirs, which otherwise are either unutilized or under-utilized, the emphasis on cage culture is inevitable in coming years to meet the ever-increasing demand of fish. Further, cages can also be used for nursing fry in reservoirs where transportation of desired quantity and size of seed from distant places are difficult.

Pens are usually constructed in shallow margins of reservoirs, tanks and ox-bow lakes. They can effectively be utilized for raising fry and fingerlings, which has been demonstrated in several trials carried out all over the country. The system possesses great potentials considering the availability of large extent of the water resources in terms of reservoirs, swamps and ox-bow lakes in the country.

8. Sewage-fed fish culture

The practice of recycling sewage through agriculture, horticulture and aquaculture is in vogue traditionally in several countries including India. Sewage-fed fish culture in *bheries* of West Bengal is an age-old practice. Though the area of coverage is gradually reducing, about 5700 ha are still utilized for growing fish by intake of raw sewage into the system and as much as 7000 tonnes of fish, mainly contributed by carps, are produced annually from these water bodies. Experimental result has shown high potential productivity of the system with record of over 9 tonnes of fish per ha within a culture period of one year. As sewage arising out of domestic wastes content high level of nutrients, emphasis on this practice has been on the recovery of nutrients and raising protein rich fish from the filth. To overcome from the concern of public health relating to consumption of fish cultured in sewage water, depuration measures by keeping the harvested fish in clear freshwater at least a fortnight before marketing has been suggested. Recently aquaculture has also been employed as a major option for treatment domestic sewage and in this regard the Central Institute of Freshwater Aquaculture has evolved an aquaculture-based sewage system incorporating duckweed and fish culture for treatment of domestic sewage.

9. Ornamental fish culture

Ornamental fish form an important commercial component of fisheries with world trade of over US$ 7 billion. The relatively minimum requirement of space or attention compared to other pet animals is the reason for growing interest in keeping aquaria in household levels. Inspite of India possessing a rich diversity of ornamental fishes with over one hundred varieties of indigenous species, in addition to similar number of exotic species that are bred in captivity, the export of ornamental fishes from the country is only about Rs. 10 million, while the potential of the country has been estimated to be as much as US$ 30 million. The export of the country at present is mainly confined to a few indigenous species from north-eastern states and few varieties of exotic species. Inspite of having vast potential domestic and international demand the sector has not received due attention either by the researches or by the industry and calls for systematic cataloguing of potentially important ornamental varieties, detailed study on their biology and behaviour, breeding and husbandry etc. The sector possesses great potential for growth even by the establishment of commercial breeding and culture farms as a cottage activity with minimum levels of investments in different locations of the country.

10. Coldwater fisheries development

The country possesses significant aquatic resources in terms of upland rivers/streams, high and low altitude natural lakes, manmade reservoirs, both in Himalayan region and western ghats, which hold large populations of both indigenous and exotic cultivable and non-cultivable fish species. Important food fishes in the region are mahseers and schizothoracids among the indigenous species and trouts among the exotic varieties. Research efforts over the years have led to development of technology of seed production of important cultivable species like trout, mahseers and snow trout. High survival rates of hatchery seed in case of trout along with successes in production of mahseer seed under control conditions have led to possibilities of farming. Breeding of different species of snow-trout *viz., Schizothoraichthys niger, S. esocinus, S. micropogon* and *S. planifrons* and *Schizothorax richardsonii* has also become possible and the technology has been perfected for mass production of the seed under controlled farm conditions.

Brackishwater aquaculture

Brackishwater aquaculture in India though is an age-old practice in *bheries* of West Bengal and *pokkali* fields of Kerala, the modern and scientific farming in the country is only about a decade old. The country possesses huge brackishwater resources of over 1.2 million hectares suitable for farming. However, the total area under cultivation is just over 13% of the potential water area available i.e. 157,400 ha in 2001-2002. Shrimp is the single commodity that contributes almost the total production of the sector. The production levels of shrimp recorded marked increase from 28,000 tonnes in 1988-89 to 127,170 tonnes in 2001-2002. Moreover, the black tiger prawn, *Penaeus monodon,* again contributes the lion's share. The other shrimp species being cultivated are *P. indicus, P. penicillatus, P. merguiensis, P. semisulcatus* and *Metapenaeus* sp. Culture of crab species like *Scylla serrata* and *S. tranquebarica* has also been taken up by few entrepreneurs. Besides, there are several other finfish species *viz., Mugil cephalus, Liza parsia, L. macrolepis, L. tade, Chanos chanos, Lates calcarifer, Etroplus suratensis* and *Epinephelus tauvina* which also possess great potential for farming, though commercial production of these species is yet to be taken up in the country.

The studies on induced breeding of shrimps were initiated by the Central Marine Fisheries Research Institute in the early 70s' and though an experimental hatchery was established by the Institute in 1975 at Narakkal, Kerala, it is the MPEDA which took the lead for establishment of two large scale hatcheries *viz.*, TASPARC and OSPARC in 80's that gave a boost for the establishment of a number of commercial hatcheries in the private sector. The technology of hatchery production of shrimp seed involving broodstock development, induced maturation and spawning, larval-rearing and post-larval (nursery) rearing has been standardized. At present about 226 shrimp hatcheries are operational with a total production capacity of 10.5 billion PL20 per year.

Though brackishwater farming in India is an age-old practice, the scientific and commercial aquaculture of the country at present is restricted to shrimp farming owing to the high export potential of the shrimps. The development of shrimp farming in the country took place only during early 90s with several industrial units joining the sector. Semi-intensive culture practices mainly with black tiger prawn have demonstrated production levels of 4-6 t ha^{-1} in a crop of 4-5 months. The high return coupled with credit facilities from commercial banks and subsidies from MPEDA have helped in the development of shrimp farming in the country to a multi-billion dollar industrial sector. Inspite of disease problem that has been plaguing the sector since 1994-1995 the industry has learnt to live with certain modifications in pond management, which has resulted in sustaining the shrimp production of the country during last two years. During the year

2000-2001 the shrimp production of the country from aquaculture has witnessed a record production of 97,100 tonnes valued as Rs. 3,620 crores. Further, mullets and milkfish are important cultivable brackishwater herbivorous fish with high growth potential. Seed production technology of seabass, *Lates calcarifer* is available for commercialization.

Mariculture

Intensive researches during last two decades by the Central Marine Fisheries Research Institute have led to the development of several viable technologies with regard to seed production and culture of important marine crustaceans, molluscs and seaweeds. Several programmes on sea ranching of exploited stocks such as pearl oyster, *Xancus pyrum*, *Trochus* sp., *Turbo* sp. and giant clam have also been taken up in the country.

1. Mussel culture

Green mussel, *Perna viridis* and brown mussel, *Perna indica* are the two important mussel species available in the country, the culture technology of which has already been standardized. Mussel farming is carried out either in rafts or by long line methods. While long line system is very flexible and can withstand turbulent sea, raft system is more rigid and suited for more calm seas. Mussels attain harvestable size of 70-80 mm in 6-7 months of culture period and production levels of 12-14 kg mussels per meter of rope are obtained. In a raft size of 8 m x 8 m as many as 100 ropes can be suspended and the culture is done at about 5-10 m depth. Economic analysis of the mussel farming made based on the several pilot scale studies on raft culture by CMFRI showed over 40% profit margins on investment of about Rs. 24,000 per raft of 8 m x 8 m during a culture period of 6-7 months.

2. Edible oyster culture

The culture of edible oyster in India was initiated as early as the beginning of this century. However, intensive researches on various aspects of the culture were taken up only during seventies. The technique of oyster farming consists of two items, collection of spat and growing the spat to adult stage. *Crassostrea madrasensis* is the only species that is found to be important for commercial farming. The species reach harvestable size (80 mm) in a culture period of 7-8 months and production levels of 8-10 tonnes of shell on oysters per ha are obtained. Estimated economics of the culture of edible oysters in an unit area of 300 sq. m with rack and ren method showed over 44% of profit over an initial investment of about Rs. 21,000 including Rs. 16,000 as fixed cost. Technology has been developed for hatchery production of seed, which has opened up scope for establishment of large-scale commercial farms.

3. Pearl culture

The success of marine pearl culture in India was achieved in 1973 by the Central Marine Fisheries Institute at its Tuticorin Regional Centre. Raft culture techniques are followed for culture of pearl oysters and the important species being *Pinctada fucata*. Oysters of over 20 g at its post-spawning recovery stage are used for nucleus implantations. The oysters after thorough cleaning in cleaned seawater are narcotized by using menthol, which helps in relaxation of adductor muscles within 45-60 minutes. The surgery involves grafting of a piece of mantle of the donor oyster in the gonad of the oyster, followed by implantation of a spherical shell-bead nucleus of about 3-7 mm diameter. Multiple implantations are also done depending on the size of nucleus. The post-operative culture period for the implanted oyster is usually 3 months to 18 months depending on the size of nucleus implanted.

4. Seaweed culture

Seaweed forms an important component of the marine living resources, available largely in shallow seas wherever suitable substratum is available. Agar agar and algin are two principal industrial products of seaweeds, besides their use as food, fodder, fertilizers and several other industrial and pharmaceutical products. The seaweed resources of the country are mainly confined to the coasts of Tamil Nadu and Gujarat. Since 1972, CMFRI is involved in experimental culture of different seaweed species and developed technologies for important agarophytes like *Gracilaria edulis*, *G. corticata* and *Gelidiella acerosa*. Both net and rope culture technologies have been standardized. Fragments of seaweeds are inserted in the twists of the coir rope nets of 4 m x 2 m in size for culture of *G. edulis* and the nets are fixed at about 1 m depth in near-shore water with the help of wooden poles. According to this method 1 kg of seed material on an average would yield 3 kg of *G. edulis* in a culture period of 60 days. One thousand such nets can be fixed in one-hectare area and production of 30 tonnes per ha can be obtained. With a minimum of four crops a total of 120 tonnes of fresh *G. edulis* can be produced in one year. In case of *G. acerosa* both coral stone method and net culture method have been standardized. Culture practices of several other species, however, are on experimental scale.

Governmental support and assistance from public financing institutions with an element of risk coverage in the initial stages are necessary for establishment of commercial mariculture farms. Further, ownership or leasing right with protection against navigation, traditional fishing and encroachment are other pre-requisites for development of the farming, which must be addressed by the governmental interventions.

Action plan for enhancing production

In view of the potentials of production of fish and shellfish from different areas of the fisheries sector, strategies for enhancing production have been evolved.

Coastal aquaculture

Brackishwater area available	1.2 million ha
Presently under utilization	0.1 million ha
Present Production	0.9 lakh tonnes
Projected potential production	0.5 million tonnes

Strategies

- Increasing water area under aquaculture practices
- Increasing productivity of existing water bodies
- Diversification of candidate species
- Research support for sustainable, ecofriendly and techno-economically viable hatchery & culture systems
- Fish health management and disease diagnostics
- Fish nutrition and feed formulation
- Fish genetics and selective breeding
- Utilization of inland saline soils for aquaculture

Capture fisheries

Present annual production	0.5 million tonnes
Estimated production potential	0.8 million tonnes

Strategies

- Management of stocks in reservoirs
- Stocking and selection of right species
- Maintaining proper harvesting schedules
- Fishery regulations, closed seasons, mesh regulation, fishing efforts, etc.
- Culture based fisheries
- Pen & Cage culture technologies
- Resources specific harvesting techniques
- Management models for culture based fisheries
- Hill fishery resources assessment and management
- Development of sport fisheries in hill areas

Culture Fisheries

Present annual production	2.3 million tones
Estimated production potential	4.5 million tonnes

Strategies

- Increase in the coverage of areas of ponds and tanks for aquaculture practices
- Increasing productivity of existing water bodies
- Diversification and Intensification of culture practices
- Research support for sustainable, ecofriendly and techno-economically viable hatchery & culture systems
- Fish health management and disease diagnostics
- Fish nutrition and feed formulation
- Fish genetics and selective breeding
- Aquaculture technologies for hill fisheries

Harvest and post-harvest sector

Strategies

- Fuel-efficient and resources specific craft and gear
- Ecofriendly and responsible fishing techniques for EEZ
- Post-harvest, value addition, waste utilization and by products from un-conventional fish species
- Biomedical, pharmaceutical & industrial products from aquatic organisms
- Expansion of domestic and international marketing network

CONCLUSIONS

Possessing 2.4% of the global land area India sustains 16% of the world population. Increasing per capita fish availability from the present level of only 8 kg to 11 kg as recommended by World Health Organization is the primary challenge before the country. Considering the limited scope of the capture fisheries from coastal waters and natural inland waters like rivers and estuaries, emphasis on aquaculture and culture-based fisheries from reservoirs and floodplain wetlands to meet the targeted fish requirement of 8.3 million tonnes by 2020 sounds appropriate considering the availability of vast water resources, rich cultivable species diversity and sound technological base.

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Agricultural Management in Coastal Agro-ecosystem Problems and Prospects

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Coastal areas are commonly defined as the interface or transition areas between land and sea, including large inland lakes. Coastal areas are diverse in function and form, dynamic and do not lend themselves well to definition by strict spatial boundaries. Unlike watersheds, there are no exact natural boundaries that unambiguously delineate coastal areas (Anon., 1998).

The coastal agro-ecosystem, more than any ecosystem, plays a significant role in controlling the overall ecological balance on earth. It is also critical in terms of food, nutrition, and sustainability of the entire coastal region. This is a unique ecosystem blessed with the potential to meet many of the demands in agriculture, horticulture, fisheries and livestock. It is also biologically highly productive and physically variable in space and time. However, the coastal ecosystem, wherein there is a tremendous scope for the production of many high value and export oriented commodities, is facing many location specific problems.

The coastal agro-ecosystem of our country is recognized as one of the five important ecosystems. It comprises hinterland, which has varied geometric and topographical features of mountains, valleys, coastal plains, riverine systems, climatic conditions, different soils and water bodies, vegetations ranging from rich tropical rain forests to coastal mangroves and a wide range of crops that are cultivated in this region. India has got a large coastal region stretching over a length of 8129 km from East coast to West coast, covering the states of West Bengal, Orissa, Andhra Pradesh, Karnataka, Tamil Nadu, Gujarat, Kerala and the Andaman & Nicobar group of Islands (Anon., 2003).

Coastal ecosystem in India-classification

The National Bureau of Soil Survey & Land Use Planning (NBSS & LUP) of India (Sehgal *et al.*,1992) has brought out a 21-zone agro-ecological regional map of the country, essentially based on physiography, soils, bioclimatic types, and growing period which influences the supply of water for plant growth. The zones coming under coastal ecosystems are:

a. Eastern Coastal Plain, Hot Sub-humid Ecoregion with Alluvium - derived Soils: It covers the Eastern coastal plain extending from Cauvery Delta to Gangetic Delta and occupies 2.5% of the land area. It has hot summers and mild winters, with an annual rainfall of 1200 to 1600 mm. The growing period ranges from 150 to 210 days. The soils are mainly clayey with slight acidity. Rainfed and irrigated rice farming are practised. Imperfect drainage and salinity are the major constraints.

b. Western Ghats and Coastal Plains, Hot Humid - Perhumid Ecoregion with Red, Lateritic and Alluvium - derived Soils: It constitutes Western coastal plains of Maharashtra, Karnataka, and Kerala States covering 3% of the land area. It has hot summers, with rainfall exceeding 2000 mm. The growing period is more than 270 days. It has red, lateritic and alluvial soils. Water logging and severe erosion are the major problems. It has high potential for export-oriented plantation crops.

The economic and environmental importance of coastal areas

Many of the world's major cities are located in coastal areas, and large portions of economic activities are concentrated in these areas. The coastal zone is an area of convergence of activities in urban centres, such as shipping in major ports, etc. Thus, traditional resource-based activities, such as coastal fisheries, aquaculture, forestry and agriculture, are found side by side with activities such as industry, shipping and tourism.

Among the various ecosystems, the coastal ecosystem is the most diverse and most productive zone. Agriculture in coastal areas often plays an important role and, as elsewhere, it occupies the major share of available land. Coastal areas often provide excellent soil and climatic conditions for agriculture. Apart from its evident function in providing food to coastal populations, agriculture also often provides raw materials to industry, which may be established in the area to make the most of port facilities. Agricultural products may find markets in the tourism sector, although this is not always as strong a link as is sometimes assumed.

Agriculture, horticulture, agroforestry and silviculture are the various activities practised in this ecosystem. The agroclimatic conditions of the coastal zones are congenial for growing horticultural crops like mango, cashew, pine apple, banana, plantation crops like rubber, coconut, pepper, arecanut, tea, cocoa, oil palm, etc. This is the only system where agriculture and aquaculture co-exist. Marine, estuary and coastal wetland areas often benefit from flows of nutrients from the land and also from ocean upwelling, which brings nutrient-rich water to the surface. They thus tend to have particularly high biological productivity. It is estimated that 90 percent of the world's fish production is dependent on coastal areas at some time in their life cycle. In addition, these areas support large numbers of migratory and non-migratory birds and other organisms.

India has a vast potential for marine fisheries development with 2.02 km^2 area of exclusive economic zone along the coastline. Besides, about 1 million hectare of brackish water area in the form of estuaries for brackish water fish and prawn farming is available. The region occupies commendable position in the export of horticultural produce, spices and marine products to the international market. It supports the livelihood of several million people whose socio economic conditions are very much dependent on the system (Anon., 2003).

Agriculture in coastal areas

Coastal agriculture in lowlying areas consists primarily of rice, pulses as rice fallows and sugar cane as rotational crops. The horticulture consists of plantation crops like coconut, arecanut, cocoa, spices like pepper, clove, nutmeg, ginger, turmeric and fruit crops like mango, banana, pine apple, guava etc. Tuber crops mainly, tapioca, sweet potato and elephant foot yam are also grown to a great extent. The agroclimatic zones of coastal regions are rich in natural resources and occupy a commendable position in the export of horticultural and marine produces to the international market. Hence it is quite evident that the agricultural production in the region should attract the highest priority as foreign exchange earner of improving the national economy. Appropriate crop management practices and cropping systems aiming at optimum use of land and water resources will go a long way in increasing production and rural economy.

Planning for coastal agricultural activities must consider the wide range of farmers' interests and activities, including non-farm activities, the limited flexibility that farmers have in production decisions, their high vulnerability to adverse environmental change etc. The complexity of these factors makes farmers' participation or consultation with them particularly important in coastal area planning.

Potential harmful effects of agricultural activities on coastal ecosystems

Agriculture is the main use of land, and as a result, agricultural activities can have a significant impact on natural resources in coastal area. Many of the external effects of agriculture on coastal ecosystem and other sectors are associated with the intensification, expansion or marginilization of agricultural activities. The potential harmful effects of agriculture on the coastal environment are given in Table 1 (Anon.,1998).

The table shows the main ways in which coastal agriculture can adversely affect the ecosystem. The impacts may result from resource depletion, from loss of habitat, from hazards to human health or from loss of protection against coastal erosion or sand dume migration.

Potential benefits of agricultural development for the coastal environment

There are a number of ways in which appropriate agricultural development can have positive impacts on coastal ecosystems. The details are furnished in Table 2 (Anon.,1998).

An appreciable contribution can come from reducing the competitive and antagonistic effects of existing agricultural activities, for instance by the adoption of irrigation systems or crops that use less water, or crop protection methods that do not rely on insecticides. Higher and more sustainable productivity on existing agricultural land may reduce pressures to bring new land under cultivation.

Appropriate agricultural development can also have positive secondary effects, for instance, providing improved livelihoods for rural people can reduce pressure on coastal fisheries and wetlands. Agricultural development may increase the general

Table 1. *Potential harmful effects of agricultural activities on coastal ecosystems*

Activity	Environmental change	Impact of social concern
Estuary flood control, impoundment or diversion of coastal rivers	Increased estuarine salinity, reduced circulation, sediment trapping, decreased supply of beach material to shoreline, shoreline erosion	Reduced crop yields, reduced fish yields, increased water-borne diseases
Agricultural pesticides	Toxic pollution of estuaries and inshore waters	Killing of fish, reduced fish yields, potential human consumption of toxic fish, coral pollution and loss
Fertilizer use	Increased amount of nutrients, eutrophication and pollution of estuaries	Killing of fish, reduced fish yield, coral pollution and loss
Over cropping or grazing in coastal watershed	Watershed erosion, estuary sedimentation and increased turbidity, increased deposition in flood plains	Corals and beaches covered with sediment, coral death, decline in fish yields, decreased recreation and tourism attraction, obstruction of navigation channels with sediments
Irrigation from coastal aquifers	Depletion of coastal aquifers	Saltwater intrusion, contamination of groundwater
Coastal wetlands reclamation	Draining or dyking, physical destruction of habitat, toxic (acid) drainage, change in sedimentation patterns, change in water circulation/drainage, loss of coastal protection (mangroves), increased water-borne diseases	Loss of wetland and forest/wildlife production, loss of biodiversity, biological diversity, loss or rarefaction of endangered species, killing of fish, reduced fish yields, increased storm damage and coastal erosion
Intensive livestock activities	Organic effluent, eutrophication and pollution	Killing of fish, reduced fish yields, coral pollution and loss, reduction in recreation and tourism attraction
Agro-industries	Organic and toxic effluents, eutrophication and pollution	Killing of fish, reduced fish yields, coral pollution and loss, reduction in recreation and tourism attraction
Overgrazing	Destabilization of grazing areas	Initiation or increased migration on to agricultural or urban areas

Table 2. *Potential benefits of agricultural development for coastal ecosystems*

Action	Benefit
More efficient irrigation systems	Increased water availability for other sectors
Cropping varieties and practices giving higher and/or sustainable yields on suitable land	Increased land availability for other sectors: less cultivation of steep erodable slopes and less clearing and drainage of wetlands
Less cultivation on steep slopes, controlled grazing, conservation practices, appropriate manuring methods, integrated pest management methods	Improved water quality: reduced erosion and nutrient leaching, reduced organic and chemical pollution
New enterprises or higher productivity leading to improved livelihoods from agriculture	Reduced exploitation and more sustainable use of fisheries and wetlands
Increased food supplies, demand for agricultural inputs and services, supplies of raw materials for processing, export	Increased incomes, nutrition, employment and wealth in other sectors reducing pressure on fisheries and wetlands

level of economic activity in a coastal area. Increased demand for agricultural inputs and services and consumption goods and services, and increased supply of food, export of crops or industrial raw materials will all contribute to the local economy and stimulate growth and employment in other sectors, with positive secondary effects.

While increasing levels of economic activity in rural coastal areas lead to increasing pollution problems without any reduction in the pressure on coastal fisheries and wetlands, higher levels of economic activity in coastal areas can lead to improved livelihoods and reduced pressure on coastal fisheries and wetlands. This can also generate wealth for investment in the protection of coastal ecosystems. Similarly, higher sustainable crop yields can reduce the demand for new land for cultivation, but they can also make crop production more attractive and in turn increase the demand for agricultural land. The effects of agricultural development are thus very sensitive to the nature of development and to economic, social and political structures and circumstances.

Problems and prospects of coastal agro-ecosystem

The coastal agro-ecosystem is an important production system in terms of diversity of crops, vegetation, soil and topographic features, supporting several million people whose socio-economic conditions are very much dependent on this system. It faces problems of multidimension in nature, which calls for strategic integrated technology development with a view to augment the overall productivity of varied types of enterprises.

Coastal regions suffer from problems of water scarcity, soil erosion and depletion of biological diversity and possible threat of rise in sea level due to global warming. The coastal areas suffer both in monsoon and post-monsoon seasons. In monsoon season, excess rainwater, prolonged water stagnation, high water table, high humidity, impeded drainage and loss of nutrients are some of the problems. In the post monsoon season, high salinity of soil and ground water and also scarcity of fresh water limiting crop productivity are the common unfavourable factors. The production is further constrained by extensive occurrence of problem such as saline soils, clayey soils, eroded soils, pest and disease problems etc. Over and above this, natural calamities like cyclones, floods, currents and tides are common features of these areas.

Issues of concern

Some of the major issues of concern regarding agriculture in coastal agro ecosystem are as follows.

1. *Soil degradation*

Soil degradation is the decline in soil productive capacity of land due to processes induced by human intervention. The human-induced processes like deforestation and encroachment of forest land for cultivation etc. have resulted in over-exploitation of natural resources, leading to degradation of soils. Degradation can occur through displacement of soil material by wind and water erosion, or soil deterioration resulting from soil accumulation and loss of nutrients thorough physical processes including water logging. In India, it is estimated that out of total geographical area of 329 million ha, 187 million ha representing 57 % presently suffers from various kinds of degradation problems (Paroda, 2003).

2. *Physical deterioration*

Waterlogging is another major physical deterioration process, which alone accounts for degradation of 11.6 million ha land (Paroda, 2003). Vast areas of physically degraded common grazing lands, uncultivable waste lands and degraded forests pose a serious threat to adjoining productive crop land. The degradation takes place mainly due to over grazing and foraging far in excess of the carrying capacity of the land.

3. *Chemical deterioration*

Soil deterioration due to chemical process includes accumulation of excess salts and loss of organic matter and plant nutrients. The estuaries and back waters of the coastal region permit the flow of tidal water into the low lying areas causing salinity that increases in summer. Problems of salinization and alkalization are most serious in the canal-irrigated areas where indiscriminate use of water results in rising of ground water table. The gravity of chemical degradation through loss of nutrients has become quite visible in recent years with the incidence of multi-nutrient deficiencies, particularly in intensively cultivated areas without addition of proper amounts of organic manures. Deficiency of boron noticed in many parts of coconut growing areas is a classic example for this.

4. *Water crisis*

The challenge of growing water scarcity is becoming increasingly serious due to over exploitation of already depleting ground water sources and wasteful use of already developed water resources. Water gets misused by farmers for various reasons including lack of realization of cost of water, lack of concern for damage and deprivation to the down stream farmers from the overuse of water in upstream, lack of awareness about scientific water management programmes etc. Hence all efforts should be made for the effective rainwater harvesting and judicious use of such conserved water for sustainable agriculture.

Future strategies

1. *Ecoregional approach*

More than 50% of the growth rate in yield of any crop has to come from research efforts by developing location specific low input use and eco-friendly technologies. In this context, emphasis is to be given for eco-regional planning. Research activities have to be formulated and implemented within the eco-regions and by interlinking R&D priorities between and within eco-regions. Farmer participatory research planning and implementation will be very useful in this regard. Farmer-Extension personnel-Scientist interfaces and discussions will be also very helpful in this regard (Rajagopal *et al.*, 2004 a).

2. *Farming system approach*

Farming system approach assumes greater importance from the point of view of both ecological and balanced nutrition aspects as well as maximum utilization of resources such as sunlight, land and water. Changing consumption and demand patterns and new trade opportunities provide impetus to the trends towards diversification of farming system through more emphasis on other enterprises such as horticulture, animal husbandry, pisciculture, bee keeping, etc. Crop diversification is of utmost importance in mitigating the problems arising on account of crop failures and price fall of crops due to monoculture. Emphasis is to be given for identifying suitable crop combinations for different situations and development of cropping system models with higher and stable yield and/or profit in different agro-ecological regions and popularization of appropriate model is necessary. Central Plantation Crops Research Institute has developed high-density multispecies cropping system models for plantation crops such as coconut and arecanut (Bavappa, 1995). Introduction of suitable medicinal and aromatic plants with high market potential and high value low volume spices like vanilla as inter/mixed crop not only enhances the employment potential but also increases the net return from unit area (Krishnakumar, 2003). Studies on complimentary and competitive interaction effects between crop/livestock/aquaculture components are also required.

3. *Integrated Nutrient Management (INM)*

It is the supplementary as well as complementary use of organic manures, crop residues, green manures, bio fertilizers and rural and industrial wastes (preferably after composting) along with chemical fertilizers to meet the nutrient demand of crop plants. It is important to work out models for conjunctive use of organic manures and fertilizers for sustaining the biological productivity of soil. The reduction of soil fertility due to over mining of nutrients and inadequate replenishment through fertilizers can only be controlled by adoption of INM. Application of *Glyricidia* leaves as green leaf manure @ 30-40 kg per coconut palm in littoral sandy soil of the coastal area is found to reduce the inorganic nitrogen requirement by around 25% (Subramanian *et al.*, 2004). Technologies have also been developed and transferred to farmers for recycling of biomass from coconut and arecanut plantations through vermicomposting (Thomas *et al.*, 2003).

4. *Integrated Pest Management (IPM)*

Indiscriminate use of pesticides often adversely affects ecological balance resulting in complex problems such as pest resurgence, pesticide resistance, pollution of soil and water and accumulation of pesticide residues at toxic levels in the food chain. Integrated Pest Management (IPM) technologies that area environmentally friendly involving all available pest control measures such as host plant resistance, pest specific bio control agents, botanical pesticides, cultural and mechanical control methods are to be integrated and adopted for cost-effectiveness and ecological security.

5. *Precision farming*

Precision farming or site-specific farming is an emerging technology that allows farmers to have most efficient use of inputs and agronomic practices. It has the potential not only to reduce cost of cultivation through more efficient and effective application of crop inputs but also protects the fragile environment. Precision farming is very essential because inputs in agriculture such as fertilizers and pesticides are based on non-renewable source of energy.

6. *Value addition through post harvest management*

The increased agricultural production warrants better post harvest management programmes to reduce losses and value addition to increase the income to farmers. To generate employment opportunities and to enhance profitability of the farmers, on-farm agro-processing activities and product diversification are to be encouraged.

7. *Watershed approach*

Integrated watershed approach for management of resources is considered as the most appropriate approach in preventing degradation of ecosystem, restoration of degraded lands, efficient water harvesting and utilization as well as improving the overall productivity of cultivated land. On-farm water harvesting and its efficient use through appropriate irrigation systems and crop diversification programmes as well as efficient and timely adoption of crop management operations will definitely help in realization of higher economic returns. Central Plantation Crops Research Institute in association with the District Panchayath of Kasaragod has successfully organized a series of training programmes for watershed based integrated development of wastelands of the district and necessary action plans were also prepared (Rajagopal *et al.*, 2004b).

CONCLUSIONS

About 25 % of the world's population lives in coastal areas and most of the largest urban concentrations are on the coast. The current urban population of 220 million is projected to almost double in the next 20-30 years. Unless appropriate actions are taken by government and users of coastal resources, population pressure and associated levels of economic activity will further increase the already evident overexploitation of coastal resources and environment degradation of many coastal habitats. An integrated coastal area management with respect to agriculture and other related enterprises offers a means for balancing the demand for limited resources and optimizing the benefits to be derived in a sustainable manner.

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The increased agricultural production warrants better post harvest management programmes to reduce losses and value addition to increase the income to farmers. To generate employment opportunities and to enhance profitability of the farmers, on-farm agro-processing activities and product diversification are to be encouraged.

7. *Watershed approach*

Integrated watershed approach for management of resources is considered as the most appropriate approach in preventing degradation of ecosystem, restoration of degraded lands, efficient water harvesting and utilization as well as improving the overall productivity of cultivated land. On-farm water harvesting and its efficient use through appropriate irrigation systems and crop diversification programmes as well as efficient and timely adoption of crop management operations will definitely help in realization of higher economic returns. Central Plantation Crops Research Institute in association with the District Panchayath of Kasaragod has successfully organized a series of training programmes for watershed based integrated development of wastelands of the district and necessary action plans were also prepared (Rajagopal *et al.*, 2004b).

CONCLUSIONS

About 25 % of the world's population lives in coastal areas and most of the largest urban concentrations are on the coast. The current urban population of 220 million is projected to almost double in the next 20-30 years. Unless appropriate actions are taken by government and users of coastal resources, population pressure and associated levels of economic activity will further increase the already evident overexploitation of coastal resources and environment degradation of many coastal habitats. An integrated coastal area management with respect to agriculture and other related enterprises offers a means for balancing the demand for limited resources and optimizing the benefits to be derived in a sustainable manner.

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Session
On
Genesis, characterization and inventory of coastal soils including acid sulphate soils and its management

J. Indian Soc. Coastal agric. Res., 22(1&2), 35-42, 2004 **Invited paper**

Ecology and Soil Health of Coastal Ecosystem

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Around the world, nearly 1 billion people live along the 3,12,000 km long coastline. The Indian coastline runs around 8,129 km distributed along nine coastal states, two groups of islands and two union territories. The narrow coastal stretches are under immense pressure today. The coastal belt comprises of a wide range of ecosystems extending from sandy beaches and mangroves to coral reefs and rocky shores. Coastal ecosystem in India has rich and diverse stock of natural resources especially soil, water and biodiversity. Coastal ecology consists of various components i.e., estuaries, coral reef, salt marsh, dunes, forests including mangroves, marine organisms/animals, livestock, various crops, and fruits, etc. Deforestation of mangroves may impair the food chain threatening the existence of several aquatic species. Industrial runoff, sewage and domestic effluents, mining, smelting, and indiscriminate fossil fuel combustion discharged heavy metals into aquatic ecosystem. Some of these pollutants in the aquatic environment can become toxic to aquatic organisms and plants and can also reach to human beings *via* food chain as bioaccumulation. The production systems in the coastal areas are constrained with several soil health related problems (soil salinity, soil acidity, low organic matter, high concentration of heavy metals, high oxidation rate, brackish water, waterlogging, etc.). The problems and constraints in the coastal agro-ecosystem are manifold and they are intricately woven with each other, so no one-tunnel approach can solve these problems. It should be of vital importance to work out and suggest optimal and integrated management of resources for sustainable productivity without affecting the ecological balance of the coastal ecosystem.

*(**Keywords:** Coastal ecosystem, Ecology, Soil health, Saline soil, Coastal pollution)*

Coastal ecosystem includes estuaries, coastal waters and lands located at the lower end of drainage basins, where stream and river systems meet the sea and are mixed by tides. The coastal ecosystem includes saline, brackish and fresh waters, as well as coastlines and the transition lands from terrestrials to marine influences and *vice versa*. Around the world, nearly 1 billion people live along the 3,12,000 km long coastline. Besides, most fertile agricultural lands are found beside the coast industries prefer to be located close to the coast for easy discharge of their effluents. Thermal and nuclear power plants are also located on the coast for easy access to plentiful water for cooling. Ports and harbours on the coast are an important source of employment and overseas trade. Tourism flourishes on the coast owing to all the water related sports and scenic beauty. The Indian coastline runs around 8,129 km distributed along nine coastal states, two groups of islands and two union territories. The coastal belt comprises of a wide range of ecosystems extending from sandy beaches and mangroves to coral reefs and rocky shores.

Coastal ecology

The essential qualities of a coastal ecology are features, processes (limiters) modulators, and characteristics (Odum, 1971). The seashore, where the land meets the sea, is an area of continual changes. This ever-changing environment supports a great variety of living things many of which live nowhere along the ocean's edge. Coastal ecosystem classified into several types, depending on their surface: (i) beach, (ii) dunes, (iii) gravel shores, (iv) tide flat, (v) marsh land, and (vi) upland. Characteristic groups of organism live on each types of shore.

Biodiversity

Largest biodiversity in agriculture, horticulture and animal sciences, etc. is seen in this area. There is a big heritage of species and genetic strains in these coastal areas. Out of 7,00,000 plant species present on the earth, 45,000 plant species accounting for 6% are located in this region. The biota of a coastal ecosystem includes a great variety of plants, birds, fish, mammals and invertebrate organisms.

The marine biodiversity of India is outstanding in the entire south Asian region. Marine and mud crab culture has also lot of potential and is developing at a faster rate in these areas. Shrimp farming is predominant in shallow saline waterlogged soils along the coast. Freshwater prawn, pearl and oyster cultivation, etc. are increasing in these areas. It comprises of 26 species of fresh water turtles and tortoises and 5 species of marine turtles, which inhabit and feed in coastal waters and lay their eggs on suitable beaches found in India. Highest tiger population is found in the Sundarbans along the east coast adjoining the Bay of Bengal. Today they are most vulnerable in the region. Some species of whales like false killer whale, Balenoptera and humpbacked whales have been also reported. Of the 21730 species of fish found in the world, 2546 are found in India (11.7% of the world).

Corals – An underwater jungle

Coral reefs are a fairy tale world of beautiful colours and changing patterns. Some 4000 species of fish and 800 species of reef-building coral have been described to date, but the total number of species associated with reefs is probably more than 1 million. Coral islands or atolls develop from reefs that grow up around volcanic islands. In India, corals are found in (i) Gulf of Katchchh, off the western mainland coast, (ii) Mandapam group of islands in gulf of Mannar near Rameswaram, (iii) Andaman and Nicobar islands, and (iv) Lakshadweep islands.

Estuaries

There is an intermingling of marine and freshwater conditions wherever a river meets the sea. The flow of siltladen river water becomes slower and suspended material settles out to form sand banks. The increasingly shallow water over such deposits may be stationary at high tide; this allows deposition of finer material to further raise the level and form mud flats, which are exposed for a few hours daily at low tide. These areas may become colonized and develop into salt marsh.

Salt marsh

Pioneer plants invading mud flats have to face high salinity in addition to the instability and poor aeration associated with mud. The tendency to lose water by osmosis results in a state of physiological drought which few flowering plants can withstand; these plants are known as halophytes. Many are succulent, having water storage tissues, and their cell sap has a high osmotic pressure, which ensures water uptake from a strongly saline soil solution. Lack of oxygen is met by the provision of aeratior tissues within the plant, and mud instability by the development of long rhizomes or roots.

Coastal cliffs

Cliffs vary as habitats according to the nature and slope of the rock of which they are composed. Rocks that weather readily bear a richer and more varied flora than harder rocks such as granite. The first colonizers on bare rock are algae, lichens, and mosses. When these decay, the humus is collected in crevices and hollows with the mineral products of weathering to provide soil in which other plants can grow. Those plants, which do establish themselves, are maritime plants showing some degree of salt tolerance and adaptations to conditions of water storage.

Forests including mangroves

Forests occur predominantly on the hill slopes though many plantations also constitute an important part of coastal ecology. The forest coverage in the Andaman & Nicobar Islands is as high as nearly 88% of the total land area. Indiscriminate denudation of forests on the sloping lands accelerates runoff, sediment movement, nutrient loss, and hydrological degradation is conspicuous in the Western Ghats. The mangroves occur chiefly along the estuaries, creeks, deltas, saline flats and tidal marshes in the intertidal regions. India has an area of 4871 sq km (about 0.5 M ha) accounting for 0.15% of the geographical area of the country and about 2.1% of world's mangroves. Approximately 85% of the total mangroves in India are found in West Bengal, Gujarat and Andaman & Nicobar Island, with maximum area of 2135 sq km in West Bengal. The single greatest threat to mangroves worldwide is shrimp farming. Shrimp farming requires the clearing of mangroves to build ponds. Once the mangroves are ripped out, the coast is rendered unstable and many creatures lose their habitat. In addition to the loss of biodiversity, the destruction of mangrove areas also means the loss of access for these coastal communities to their only source of income. About 35 percent of mangroves worldwide have been lost in the last 20 years.

Crops and cropping Systems

Major crops of coastal areas are rice, pulses, millets, commercial crops viz., sugarcane, cotton, and unexploited horticultural crops viz., fruits, vegetables and aromatic and medicinal plants, plantation crops viz., coconut, arecanut, banana, cashewnut, tapioca. These also serve as shelterbelts and wind breaks. High value and low volume non-perishable species like pepper, cinnamon, cardamoms have great export potentials.

Livestock

Lot of animal germplasm is available in coastal areas. As many as 13 cattle breeds, 5 buffaloes, a sheep and 11 goat breeds are available in coastal areas. Livestock generates income and employment in this region. Waterlogged condition suits for duck and fishery systems. Coastal areas have well established dairy, piggery, fish, poultry and milk production systems. Out of 140 million improved layer populations and 1 billion broiler populations, 70 percent is concentrated in Orissa and West Bengal in the east coast.

Coastal pollution vis-à-vis soil and ecology

In its natural condition the ecosystem is a balanced network of biotic relationships that is all too easily upset by pollution and other man-made disturbances. A summary of the effect of such impacts on the ecological processes and its management is given in Table 1.

Most pollution in coastal India arises from land-based sources – industrial & domestic wastes, and agricultural runoff, etc. The coastal region in between Tuticorin and Thiruchendur receives heavy metals from various industries e.g., thermal Power plant, textile mill, copper smelting industry, alkali chemical industry and municipal sewage. Among all the metal the concentration of lead was relatively high and zinc was low in collected samples, because lead compound has been used in a wide variety of industrial application (Kumar and Kumaraguru, 2001). The concentrations of metals were also high in industrial areas located on the south east coast of India i.e., in the Gulf of Manner.

Heavy metals in the aquatic environment can become toxic to aquatic organisms and plants and can also reach to human beings *via* food chain as bioaccumulation. Kumar and Kumaraguru (2001) reported that marine i.e., algae *Enteromorpha intestimalis* showed greater accumulation of lead (63.2 ppm) when compared wth the other metals in the industrial site due to fly ash and other man made activities. In the domestic sewage dumping site, lead level was found to be in greater quantities compared to other metals. Marsh plant *Salicornia brachiata* showed greater accumulation of metals than the plant *Avicennia officinalis*. In both the plants monitored, lead level was found accumulated in greater quantities compared with other metals.

Coastal soil

Soil is a dynamic, living, nonrenewable resource whose condition is vital to both the production of food and fiber and to global balance and ecosystem function (Doran et al., 1996). Soils of coastal areas are generally deep to very deep having coarse sandy to fine loamy texture. The soils are calcareous, slightly to moderately saline and alkaline. In many coastal areas uncontrolled of mining of ground water has resulted in intrusion of seawater and development of high salinity (Velayutham *et al.*, 1998).

The coastal ecosystem is highly fragile and vulnerable to natural hazards, sea level rise and anthropogenic activities. Coastal belt has been located in the east as well as in the west. In the east coast it covers 4 major states viz., West Bengal, Orissa, Andhra Pradesh and Tamil Nadu, and I union territory viz., Pondicherry, while in the west coast 5 states viz., Gujarat, Maharashtra, Karnataka,

Table 1. *Natural and human impacts on coastal zones*

Impact	Process	Output	Environmental Management
Natural impact	Global warming, sea level rise, hurricanes, cyclones	Flooding of lowlying coastlines.	Coastal defences
		Loss of human life, habitat.	Weather predictive models, satellites.
Human impact	Industrial and domestic pollution	Decline in fisheries. Eutrophication.	Pollution monitoring.
	Over-exploitation of natural resources	Depletion of natural resources.	Managed resource exploitation.
	Habitat degradation	Loss of nursery grounds for fish.	Conservation protection.

Kerala and Goa, and 1 union territory viz., Daman & Diu are covered apart from Andaman & Nicobar and Lakshadweep islands. The east coast is lowlying with lagoons, marshes, beaches and deltas rich in mangrove forests. The western coastline has a wide continental shelf and is marked by backwaters and mud flats. In general, the features of coastal areas are (a) Influence of tidal waves and periodical inundation of soil by tidal water, (b) Shallow water table enriched with salt contributing to increase in soil salinity during winter and summer months, (c) Heavy rainfall (except in some parts of Gujarat) and cyclonic weather, (d) Poor surface and subsurface drainage conditions, (e) Lack of good quality irrigation water during dry period in certain areas, (f) Agriculturally poor lands and monocropping in some parts, (g) Undeveloped irrigation, (h) Seawater intrusion in aquifers, and (i) Threat from environmental and manmade pressures.

Coastal saline soil

Out of 49 million hectare area under salt affected soils in the south and southeast Asia about 27 million hectares (55%) are within coastal areas. According to Yadav *et al.* (1983), the salt affected soils in the coastal areas in India are spread over 2.52 million hectares, comprising about 30 percent of the total salt affected soils in India. Besides, 0.573 million hectare area is under mangrove vegetation.

In case of the saline soil, the salinity status in soil varies widely from ECe 0.5 dSm^{-1} in monsoon to 50 dSm^{-1} in summer. Mostly NaCl followed by Na_2SO_4 are the dominant soluble salts with abundance of soluble cations in the order Na>Mg>Ca>K, chloride as the predominant anion, and bicarbonate in traces. Physicochemical characteristics of some typical coastal saline soils are presented in Table 2. The soils are, in general, free of sodicity problem except in a few pockets in the south and west coast.

Acid sulphate soils

Acid sulphate soils contain sulphides (mainly pyrites, which become very acid when sulphides are oxidized to sulfates on drying; and usually have a pH of below 4 in water (Bloomfield, 1973). Acid sulfate soils cover large areas of temperate lands. In India presence of acid sulphate soils have been reported in the lowlying coastal areas of Kerala, Andaman and Nicobar islands and recently in the coastal areas of Sundarbans (Bandyopadhyay and Maji, 1995). Acidification of these soils is caused by a combination of abiotic and microbial oxidation of pyrites (FeS_2). Physicochemical characteristics of some acid sulphate soils are given in Table 3.

Table 2. *Physicochemical characteristics of some typical coastal saline soils*

Physicochemical characteristics	West Bengal (Kamalpur)[1] *Typic Endoaquepts*	Orissa (Balimunda)[2] *Vertic Fluvaquents*
pH (1:2)	6.5-8.0	6.1-7.9
ECe (dSm^{-1})	7.0-10.5	9.3-19.7
O.C. (%)	0.26-0.78	0.65-0.92
CEC {$cmol(p^+)kg^{-1}$}	19.7-21.6	25.7-28.9
ESP	10.9-15.2	4.7-19.2
SAR	10.5-12.1	12.9-31.7

Source: [1]Maji *et al.* (1998), [2]Maji and Bandyopadhyay (1996)

Table 3. *Physicochemical characteristics of some acid sulphate soils*

Physicochemical characteristics	Kerala (Arikalm, Calicut)	West Bengal (Nirdeshkhali, South 24 Parganas)
pH_s	3.5—4.8	4.0-5.9
ECe (dSm^{-1})	8.4-43.6	2.1-5.8
O.M. (%)	2.4-4.8	0.6-2.2
CEC {$cmol (p^+) kg^{-1}$}	14.7-69.2	19.4-23.4
ESP	5.8-20.5	11.6-20.6
SAR	-	3.9-5.4

Source: Maji and Bandyopadhyay (1995)

Many plants appear to be able to tolerate relatively large concentrations of H^+, although work using solution cultures indicates some root injury at low pH. It is probable, however, that Al and Mn toxicity are more important than that due to H^+. Phosphate deficiency is also very widespread in acid sulphate soils, as are deficiencies in Ca and K; whereas levels of exchangeable Mg may be high.

Coastal sand dunes

Coastal sand dunes are deficient in plant nutrients due to extensive leaching which occurs during their formation, transport and deposition. Dune fertilization is a useful management tool for improving the establishment and growth of new plants. If fertilization of sand dunes with urea is contemplated as a management tool it may be prudent to apply a nitrification inhibitor such as N-serve in order to minimize NO_3^- -N losses. On the debit side such a combination might enhance NH_4^+-N volatilization, thereby making desirable the addition of urease as well as nitrification inhibitor (Skiba and Wainwright, 1984).

Soil health

The health of soil is largely defined by soil function and represents a composite of its physical, chemical, and biological properties that (1) provide a medium for plant growth and biological activity, (2) regulate and partition water flow and storage in the environment, and (3) serve as an environmental buffer in the formation and destruction of environmentally hazardous compounds (Larson and Pierce, 1994). Soil quality or health has been conceptualized as a function and balance of sustainable productivity, environmental quality, and plant and animal health. Larson and Pierce (1991) proposed that a minimum data set (MDS) of soil parameters be adopted for assessing the health of soils. Starting with the MDS proposed by Doran *et al.* (1996) we have modified it (Table 4), which meets many of the aforementioned requirements of indicators for screening soil quality and health.

Soil quality or health does not depend just on the physical and chemical properties of soil, but it is closely linked to the biological properties of soil. There is a positive correlation between soil organic matter content and soil microbiological activity. Soil organic matter tends to be greater in cropping systems utilizing crop rotations than in continuous cropping and in systems utilizing animal manures rather than commercial fertilizers (Power and Doran,

Table 4. *Minimum data set of indicators for determining the quality or health of a soil.*

Indicator	Rationale for its use
	Physical
Texture	Retention and transport of water and chemicals
Depth of soil and rooting	Estimate of productivity potential and erosion, normalizes landscape and geographic variability
Infiltration and soil bulk density	Potential for teaching, productivity, and erosion
Water holding capacity	Related to water retention, transport, and erosivity
	Chemical
Total soil OM	Defines carbon storage, potential fertility, and stability
Active OM	Defines structural stability and food for microbes
pH	Defines biological and chemical activity thresholds
Electrical conductivity	Defines plant and microbial activity thresholds
Extractable N, P and K	Plant-available nutrients and potential for N loss; productivity and environmental quality indicators
	Biological
Microbial biomass C and N	Microbial catalytic potential and early warning of management effect on organic matter
Potential mineralizable N	Soil productivity and N supply potential
Specific respiration	Microbial activity per unit of microbial biomass
Microorganism numbers	Potential influence of such organisms as earthworms

Table 5. *Proposed soil health index*

Soil Health Index	Indicators				Organic C (%) (%)
	pH		ECe (dSm^{-1})		
	Alkaline	Acidic	Saline	Alkali	
-1	>10.0	<3.0	-	-	-
0	8.5-10.0	3.0-4.0	0-0.2 > 4.0	0-2.0	<0.50
1	7.2-8.5	4.0-5.5	2-4	2-4.0	0.50-0.75
2	6.8-7.2	5.5-6.8	0.2-2	>4.0	>0.75

1984). Of the changes observed, decrease in soil organic matter content and microbial biomass and increase in erodibility are strong indicators of decrease in soil quality. Microbial biomass and its activities are integral part of soil quality. Tripathi *et al.* (2001) suggested the need of organic supplements in counteracting the stress of soil salinity on microbial components of soil health.

Soil health index

Healthy soil is a combination of minerals, rock, water, air, organic matter (plant and animal residue), microorganisms including bacteria, fungi, protozoa, insects and worms. The intricate web carries out a process that continually repels the soil and maintains longterm soil fertility. Doran *et al.* (1996) suggested certain indicators to assess soil quality or health. By using these indicators of soil health Michael and Katherine (2003) proposed an index for assessing soil health (Table 5) based on following approach.

Each measured soil property is assigned an index number of -1, 0, 1 or 2 depending on whether its numerical value is above or below threshold values. Threshold values were selected based on known physiological responses of vegetation to soil properties, or in the absence of plant response data, threshold values were based on the relative distribution of soil property values in the entire database of soil samples. A soil property index of 0 indicates a suboptimal level of a nutrient or a potentially deleterious level of measured property. An index of 1 indicates an acceptable level of a property and an index of 2 indicates an optimal level. An index of -1 is assigned to exceptionally low pH and low Ca soils. All the individual index levels are summed to obtain an overall soil quality index. This summary index is divided by the number of measured soil properties used to calculate the index. Thus, missing values do not contribute to the index. The percentage is re-scaled by dividing by the maximum possible percentage. Low soil quality index values indicate an increased risk of soil health decline, while higher index values indicate a decreased risk of decline. Based on the above approach the proposed soil health index for coastal soils is given in Table 6.

EPILOGUE

Owing to the typical climatic, edaphic and geomorphic conditions along with largest biodiversity in agriculture and animal sciences, rich natural resources, on the one hand, and the negative effect of anthropogenic activities, on the other, the entire ecosystem is highly fragile and risk prone. Apart from this, the coastal areas are constrained with several soil health related problems. This calls for judicious and integrated use of the technologies so that ecology of the region is not affected. Some of the important strategies to achieve these objectives and maintain soil resources in good health are: (1) Integrated plant nutrient system through use of organic, inorganic and biotic source of nutrients in judicious combinations for different farming situations need to be developed, (2) Afforestation with mangroves and other trees as well as pasture development with appropriate grass species will help in soil conservation by way of preventing soil and wind erosion caused due to frequent cyclones associated with high rainfall, (3) Introduction of practices like *in situ* soil and water conservation and alternative land use, (4) One of the major soil health impeding problems of the coastal ecosystem is soil salinity, which severely limits crop growth and thereby, addition of various types of soil amendment agents like sand, rice husk or paddy straw, etc. are recommended, (5) Acid sulphate soils can be managed by controlling the water table, adding lime, selecting dry land crop varieties with tolerance to Al toxicity and rice to Fe toxicity, and where

Table 6. *Proposed soil health index for coastal soils*

Health Index	AESR No.	pH	ECe (dSm^{-1})	Organic C (C%)
West Bengal	15.1	2	1	0
	18.5	1	0	1 & 2
Orissa	18.4	2	0[$] & 1[#]	0
	18.5	1	0[$] & 1[#]	0
Andhra Pradesh	18.3	1	0[$] & 1[#]	2
	18.4	1	0[$] & 1[#]	2
Tamil Nadu	18.1	0	0[$] & 1[#]	0
	18.2	1	0[$] & 1[#]	2
Kerala	19.3	1 & -1*	0[$] & 1[#]	1 & 2*
Karnataka	19.3	1	0[$] & 1[#]	1 & 2
Maharastra	19.1	1	0[$] & 1[#]	1
	19.3	1	0[$] & 1[#]	1
Goa	19.1	2	0[$] & 1[#]	1
	19.3	2	0[$] & 1[#]	1
Gujarat	2.2	0	0	0
	2.4	1	0	0
Andaman and Nicobar	20.1	0 & 1	0	1 & 2
Lakshadweep	20.2	0	1	1
Pondichery and Karaikal	18.4	2	1	1

*Acid sulphate soil [$] in summer [#] in winter

deficiencies occur, improving the fertility of the soil, (6) Efficient water management practices to arrest waterlogging, soil salinization and soil sodification, (7) Proper selection of crops, cropping systems with inclusion of legumes and land uses in conformity with soil capability, (8) Control farm operations to protect coastal ecosystems from damage by fertilizers, biocides, sedimentation, and altered runoff. These chemicals, when used improperly, can pollute coastal waters.

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Inter-Relationships Among Different Physicochemical Characteristics of Salt Affected Soils of North-West Agroclimatic Zone of Gujarat

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Seventy-five surface soil samples (0-30 cm) were collected from the cultivated fields. The samples area were more or less affected by the marine sediments and hence salinity and/or sodicity to various extent. Most of the soils were sandy to sandy loam in texture and contained considerable quantity of $CaCO_3$ (64.3 g kg^{-1}). Dominant exchangeable cations were Ca^{2+}+, Mg^{2+} followed by Na^+ and K^+. Highly significant correlations were found for TSC, Cl^- and SO^-_4 with ECe of the soil. Similarly, highly significant correlations were found for SAR, SSP and pHs with ESP of the soil. Negative highly significant correlations were found for pHs and CO^{2-}_3 + HCO^-_3 with ECe of the soil. Among anions chloride and next to it sulphate governed the extent of salinity in North-West agro climatic zone.

(Key words: Salt affected soils, Physicochemical properties)

The ionic concentrations contributing to salinity in salt affected soils may have relations with the relevant physicochemical properties of soil. At present very meager information on this aspect is available in respect of north-west agroclimatic zone. Attempt has been made in this paper to generate information on this aspect.

MATERIALS AND METHODS

Seventy-five surface soil samples (0-30 cm) from the north-west agroclimatic zone of Gujarat having salinity/sodicity problems were collected from the cultivated fields. Soil samples were air dried, ground and passed through 2 mm sieve. Mechanical separates; $CaCO_3$ (Piper, 1950), organic carbon; saturation percentage; exchangeable cations, water soluble ions, pH and EC (Richards, 1954, Jackson, 1973) were determined from the saturation extract of soil. Correlation coefficients (r) were worked out statistically.

RESULTS AND DISCUSSION

The average pHs value (Table 1) of soil was 7.94 and it decreased with increase in salinity, especially in highly saline soils (7.75). The ECe ranged widely from 1.05 to 17.4 with a mean value of 7.10 dSm^{-1}. Under textural soil groups, it was highest in sandy soils and lowest in clay soils. The present findings are in accordance with the results reported by Patel and Patel (1988). The organic carbon content (Table 1) increased with increase in salinity. The $CaCO_3$ content of the soil indicated their calcareous nature. In textural groups, it increased with increase in clay content. These results are in line with the results obtained by Patel and Patel (1988). Large variation in clay content indicates the heterogeneity in their formation (Table1). Average clay content in soils having low salinity was higher than in medium and high salinity. The average sand content of soil was 67.0 % and it increased with salinity. The saturation percentage value increased with increase in clay content. Similar results were also reported by Patel and Patel (1988).

The dominant exchangeable cations were Ca^{2+}+ Mg^{2+} in all soils with an average value of 20.36 cmol (p+) kg^{-1}, which increased with increase in clay content. Similarly, exchangeable Na^+ also increased with increase in clay content (Table 2). The ESP increased with increase in clay content. In low and high salinity groups ESP values were higher than 15 indicating these soils have also problem of sodicity. The SSP values in all the soil groups were found more or less same. The SAR ranged widely between 3.6 and 59.0 with an average value of 18.8 (Table 2) and it increased with increase in salinity and sand content. These results are in agreement with those reported by Patel and Patel (1988).

Table 1. *Range and mean values of pH, EC, O.C., $CaCO_3$, SP, clay and sand of soils of north-west agroclimatic zone of Gujarat*

Particular soil group	pHs	ECe (dSm^{-1})	Organic carbon ($g\ kg^{-1}$)	$CaCO_3$ ($g\ kg^{-1}$)	Clay (%)	Sand (%)	Saturation percentage
1. Low salinity (7): ECe <2 dSm^{-1}	7.60-8.60 (8.17)*	1.05-2.00 (1.54)	0.76-4.20 (2.75)	16.0-168.5 (66.0)	8.0-26.9 (21.2)	36.0-77.7 (58.2)	21.9-58.6 (38.8)
2. Medium salinity(39): ECe 2-8 dSm^{-1}	7.30-8.50 (7.95)	2.20-8.00 (4.84)	0.80-8.02 (2.82)	3.0-224.0 (64.7)	1.0-46.5 (15.3)	11.2-92.9 (67.13)	27.5-58.3 (34.0)
3. High salinity (29):ECe> 8 dSm^{-1}	7.18-8.25 (7.75)	8.20-17.4 (11.50)	1.13-8.97 (3.58)	16.5-158.0 (55.8)	5.3-38.0 (15.3)	39.0-85.3 (69.0)	26.5-57.4 (35.7)
4. Clay (6): Clay% >30	7.69-8.50 (8.11)	1.25-9.30 (4.54)	2.68-5.15 (3.75)	52.5-170.0 (98.3)	34.3-46.5 (40.20)	11.2-39.0 (29.4)	47.3-58.3 (53.9)
5. Loam (38) : Clay% 15-30	745-8.60 (8.00)	1.05-13.0 (6.58)	11.4-8.97 (3.22)	5.0-224.0 (74.0)	4.5-30.0 (19.1)	35.9-77.7 (61.6)	26.6-48.5 (37.8)
6. Sand (31) : Clay% < 15	7.18-8.36 (7.84)	2.0-17.4 (8.25)	0.76-8.02 (2.82)	3.0-157.5 (45.6)	1.0-12.4 (7.6)	70.5-92.6 (81.3)	21.9-33.9 (27.8)
Overall (75)	**7.18-8.60 (7.94)**	**1.05-17.4 (7.10)**	**0.76-8.97 (3.20)**	**3.0-224.0 (64.3)**	**1.0-46.3 (16.0)**	**11.2-92.6 (67.0)**	**21.9-58.6 (34.7)**

Figure in the parenthesis indicates the number of samples & * Mean.

Table 2. ***Range and mean values of exchangeable cations, ESP, SSP and SAR of soils of North-West*** *arid agro-climatic zone of Gujarat*

Particular soil group	**Exchangeable cation (cmol(p+) kg^{-1})**			**ESP**	SSP	SAR
	Ca^{2+} + Mg^{2+}	**Na^+**	**K^+**			
1. Low salinity (7): ECe <2 dSm^{-1}	**10.2-31.6(19.8)***	**2.91-5.84 (4.17)**	**0.49-0.79 (0.51)**	11.0-28.2 (17.2)	63.0-81.8 (78.2)	7.4-12.6 (10.5)
2. Medium salinity (39): ECE 2-8 dSm^{-1}	3.10-43.2 **(20.30)**	**0.39-6.52 (2.89)**	**0.07-0.89** (0.30)	7.2-24.5 (12.3)	30.7-89.4 (69.6)	3.6-35.6 (14.4)
3. High salinity (29):ECE> 8 dS	5.45-39.1 (20.41)	**0.93-6.71 (3.55)**	0.10-0.74 (0.63)	4.2-29.6 (15.0)	63.4-93.8 (74.1)	12.3-59.0 (26.7)
4. Clay (6): Clay% >30	24.7-43.2 (34.8)	**4.37-6.52 (5.44)**	0.45-0.84 (0.63)	9.10-15.7 (12.6)	68.0-81.8 (75.9)	11.3-21.7 (14.8)
5. Loam (38) : Clay% 15-30	6.1-39.7 (22.48)	**0.88-6.52 (3.65)**	0.15-0.89 (0.46)	4.1-29.6 (14.6)	30.7-93.8 (73.0)	3.6-54.3 (18.3)
6. Sand (31) : Clay% < 15	3.1-26.1 (14.48)	0.39-6.71 (2.41)	0.07-0.65 (0.28)	7.5-26.0 (13.5)	46.0-93.0 (70.0)	3.6-59.0 (20.3)
Overall (75)	**3.1-43.2 (20.36)**	**0.39-6.71 (3.27)**	**0.07-0.89 (0.39)**	**4.1-29.6 (14.0)**	**31.7-93.8 (72.2)**	**3.6-59.0 (18.8)**

Figure in the parenthesis indicates the number of samples & * Mean.

Table 3. *Correlation coefficient (γ) for physicochemical properties of soils of north-west agroclimatic zone of Gujarat*

Soil group	ECe vs TSC	ECe vs pH	ESP vs pHs	ESP vs SAR	ESP vs SSP	ECe vs Cl^-	ECe vs SO_4^{2-}	ECe vs $CO_3^{2-}+HCO_3^-$
Low salinity(7)	0.4252	-0.714	0.4928	0.8475++	0.4310	0.7490+	0.7342	0.0025
Medium salinity(39)	0.7997+	-0.3428++	0.4160++	0.5120++	0.5222++	0.7785++	0.3690+	-0.1998
High salinity(29)	0.8660++	-0.2256	0.1278	0.4566++	0.4978++	0.9316++	0.4650++	-0.1469
Clay (6)	0.9974++	-0.9519+	0.4204	0.2608	0.9106++	0.9789++	0.6638	-0.4595
Loam (38)	0.9824++	-0.6018++	0.3610++	0.5622++	0..6432	0.9709++	0.7250++	-0.3329
Sand (31)	0.9748++	-0.1659	0.1148	0.4528++	0.3169	0.9704++	0.6772++	-0.6801++
Overall(75)	**0.9309++**	**-0.4603++**	**0.3044++**	**0.6342++**	**0.5042++**	**0.9302++**	**0.6434++**	**-0.3665++**

Figures in the parenthesis indicates the number of samples, +, ++ Significant at 5 and 1 percent level, respectively.

Highly significant correlations were observed between ECe and TSC of saturation extract for all the soil groups (Table 3) except those under low salinity. Negative highly significant correlations were found between ECe and pHs for overall soils, medium salinity and loamy soils. Significant correlation was found between ESP and pHs for overall, medium salinity and loamy soils. Highly significant correlations were observed between ESP and SAR for all the soil groups. The correlation coefficients were found highly significant between ESP and SSP in medium, high salinity and overall soils. Highly significant correlations for chloride and sulphate contents with ECe were observed, indicating clearly the presence of marine salts in the soil. These results are in conformity with the findings of Patel and Patel (1988). Negative highly significant correlation was found between ECe and CO_3^{2-} + HCO_3^- for overall and sandy soils.

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Rapid Appraisal of Salinity for Soils of North-West Agroclimatic Zone of Gujarat Using Various Dilute Aqueous Extracts

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Seventy-five surface (0-30 cm) soil samples were collected from the cultivated salt affected soils of north-west agro climatic zone of Gujarat and were analyzed for different physical and chemical properties. The results revealed highly significant correlations (r = 0.9301 to 0.9421) to exist among ECe, $EC_{2.5}$ and EC_5. High correlation co-efficient (r) and regression coefficient (b), high percentage of variances (R^2) in case of $EC_{2.5}$ and EC_5 were observed and hence, their limits can be utilized instead of ECe for salinity appraisal.

(Key words: Salinity appraisal, Soil water extract, Correlations)

High degree of correlation has, however, been obtained between ECe and EC of dilute soil solutions of the salt affected soils (Patel and Patel, 1992). Such systemic work has been lacking in north-west agroclimatic zone of Gujarat. With a view to rapidly appraise the salinity using EC of various soil: water aqueous extracts of north-west agroclimatic zone of Gujarat, the present investigation was undertaken.

MATERIALS AND METHODS

Twenty surface (0-0.30 m) soil samples from each of 22 *talukas* of this zone having salinity/ sodicity problems were collected from the cultivated fields. In all 440 soil samples were collected from which 75 soil samples were selected so as to cover a wide range of EC, textural classes and geographical locations in the zone, and were subsequently analyzed for different physicochemical properties like ECe and EC of various aqueous extract, saturation percentage, individual ions, exchangeable cations, clay, O.C., $CaCO_3$ and pH (Table 1) using standard methods (Richards,1954 and Jackson, 1973). The soil samples were categorized into three salinity group viz., low (ECe < 2.0 dS m^{-1}), medium (ECe 2-8 dS m^{-1}) and high (ECe >8 dS m^{-1}).

Table 1. *Physicochemical properties of salt affected soils of north-west agroclimatic zone of Gujarat*

Particulars	Range	Mean
Saturation percentage	21.9 - 58.6	34.7
Clay (%)	1.0 - 46.3	16.0
Organic carbon (g/kg)	11.2 - 92.6	67.0
CaCO3 (g/kg)	3.0 - 224.0	64.3
pHs	7.03 - 8.60	7.90
ECe dS/m	1.05 - 17.40	7.10
ESP	4.10 - 29.60	14.00
Exch. Ca+Mg [cmol(p^+)/kg]	3.10 - 43.20	20.36

RESULTS AND DISCUSSION

The data (Table 2) revealed that the average EC of the soils were 7.08, 1.42 and 0.78 dS m^{-1} in saturation, 1:2.5 and 1:5 soil:water extracts, respectively. The data on TSC (Table 2) revealed that there was an abrupt change in TSC (cmol(p^+)/kg) of 1:2.5 and 1:5 soil:water extracts while going from saturation to 1:5 aqueous extracts. Further, it was observed that the percent increase in $TSC_{2.5}$ decreased with increase in salinity indicating low solubility of sparingly soluble salts at higher salinity.

Table 2. *Average EC (dS/m) and TSC (cmol(p^+)/kg) of various soil:water extracts*

Particulars	Soil group			
	Low salinity (7) ECe < 2dS/m	Medium salinity ECe (39) 2-8 dS/m	High salinity (29) ECe > 8dS/m	Overall (75)
ECe	1.54	4.84	11.42	7.08
$EC_{2.5}$	0.53	1.03	2.16	1.42
EC_5	0.26	0.54	1.18	0.78
TSCe	0.696	1.840	4.74	2.86
$TSC_{2.5}$	1.505	3.030	6.26	4.10
TSC_5	1.566	3.073	6.36	4.21

Figure in the parenthesis indicates the number of samples.

***Table 3.** Regression equation and correlation coefficients of $EC_{2.5}$ and EC_5 with ECe and their statistical tests of significance*

Soil : water extracts	Soil group	Regression equation (y = a + bx)	Correlation coefficient (r)	Standard error of estimate (Sy.x)
1:2.5	Low salinity (7)	$ECe=1.2511+0.5476EC_{2.5}$	0.2525	0.3938
	Medium salinity (39)	$ECe=0.9669+3.7582^{**}EC_{2.5}$	0.7529**	1.710
	High salinity (29)	$ECe=-0.9819+5.5690^{**}EC_{2.5}$	0.8479**	0.944
	Overall (75)	$ECe=-07623+5.5238^{**}EC_{2.5}$	0.9421**	1.391
1:5	Low salinity (7)	$ECe=1.3670+0.3411EC_5$	0.1328	0.4080
	Medium salinity(39)	$ECe=1.4318+6.0072^{**}EC_5$	0.7313**	1.773
	High salinity (29)	$ECe=0.9757+8.849^{**}EC_5$	0.8070**	1.052
	Overall (75)	$ECe=-0.4043+9.6381^{**}EC_5$	0.9301**	1.391

Figure in parenthesis indicates the number of samples

** Regression coefficient (b) and correlation coefficient (r) were significant at 1 percent

***Table 4.** Classification of coastal soils of north-west agroclimatic zone, based on EC (dS/m) of different soil water extracts*

Designation particulars	Very low saline	Low saline	Moderate saline	Saline	Highly saline
Saturation extract					
Limits of EC*	<2.0	2.00-4.00	4.00-8.00	8.00-16.00	>16.00
Distribution of samples(%)	10.66	20.00	30.66	36.00	2.67
1:2.5 Soil:water extract					
Limits of $EC_{2.5}$	<0.50	0.50-0.90	090-1.60	1.60-3.00	>3.00
Distribution of samples(%)	8.00	23.00	29.33	37.00	2.67
1:5 Soil:water extract					
Limits of EC_5	<0.25	0.25-0.45	0.45-0.85	085-1.70	>1.70
Distribution of samples(%)	9.33	23.00	30.33	36.00	1.33

* Salinity classes are based on Schofield scale

The correlation values (Table 3) improved with the increased in salinity. Highly significant correlation coefficients between ECe and EC of different soil:water extracts were observed in high salinity and overall soil groups. These results are in line with these reported by Patel and Patel (1992). It was revealed that the regression coefficient (b values) between the ECe and EC of the various soil : water extracts were highly significant in medium, high and overall soil groups, while in low salinity groups, the regression coefficients were non-significant (Table 3). The values of regression equation coefficient (b) increased with the increase in salinity. Similar results were also reported by Patel and Patel (1992). The prediction of ECe (2.0 to 25.0 dS m^{-1}) from $EC_{2.5}$ with greater precision was possible by using the regression equation for overall soils as the sample size was high.

Using regression equations for overall soils, the limits of $EC_{2.5}$ and EC_5 were calculated for different salinity groups as suggested by Schofield (1942). The data (Table 4) revealed that 10.66, 20.00, 30.66, 36.00 and 2.67 percent samples were found under very low saline, moderately saline, saline and highly saline classes, respectively in case of saturation extract. More or less the same distribution of samples were observed in cases of 1:2.5 and 1:5 soil : water extracts.

From the above results it can be concluded that limits of $EC_{2.5}$ can be safely utilized for predicting ECe due to very high values of correlation coefficient and vary high percentage of variance in their regression equations.

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Need for Geomorphic Mapping in Terms of Physicochemical Analysis of the Sewage Fed Bidyadhari River Carrying Effluents from the Greater Calcutta

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Water quality of the river Bidyadhari gradually worsens due to admixture of industrial effluents with the domestic sewage that passes through the different canals which ultimately finds its opening in the Bidyadhari main stream. Heavy metals in the domestic sewage may cause biological magnification in both flora and fauna. The domestic sewage may be helpful in the production of biodegradable fertilizer from the accumulated sewage sludge. It is now urgently needed to map the upper and lower wetland limits in terms of physicochemical analysis in Bidhyadhari river basin, which sustains the livelihood of the bulk of population of this area of Sundarbans.

(***Keywords***: *Bidyadhari river, Domestic sewage, Industrial effluents, Biological magnification, Physicochemical parameters, Biodegradable fertilizer, Natural waste treatment plant).*

Bidyadhari River has a very circuitous tidal course in the district of North 24 Parganas, West Bengal. It has the special characteristic of carrying the tidal domestic sewage along with others which are thrown by a series of artificially made canal named Bagjola Khal, Bhangor kata khal, Central Lake canal, Krishnapur canal, etc. All these canals now carry effluents from different industries. Bidyadhari river is tidal almost over its entire length within its upper limit up to Tehatta at the upstream.

As a result the sewage laden brackish water moves towards extreme upstream up to Tehatta that leads to no use of river water for domestic as well as agricultural purposes. It is observed that the industrial effluents play an important role in the adjoining wetland ecosystem as the discharges are being productively utilized in the aquaculture and are also in demand to irrigate the adjoining lowland agricultural efforts (Chattopadhyay *et al.*, 2001). Present inclusion of industrial effluents in the domestic sewage may start the appearance of heavy metals in the water or nutrients that may cause biological magnification in both flora and fauna (Chattopadhyay *et al.*, 1999). Accordingly, attempts were made to study the physicochemical and biological conditions of water flowing through Bidyadhari river. Temperature, DO, BOD, COD, TDS, Conductivity, TSS, pH, etc. are recorded from six different spots at the Bidyadhari river namely Haroa (1), Kulti (2), Ghusighata (3), Minakhan (4), Malancha (5) and Dhamakhali (6). Biological magnification sometimes have harmful effects and even highly carcinogenic to human body. It is now urgently needed to map the upper and lower wetland limits in terms of physicochemical analysis in Bidhyadhari river basin, which sustain the livelihood of the bulk of population of this area of Sundarbans. Geomorphic mapping will be helpful to the people surrounding the Bidhyadhari river through the sectorwise utilization of river water for different purposes (Wetzel, 2001). Geomorphic mapping is further helpful by identifying the location area of sewage sludge accumulation. Removal of this sewage sludge from the river bed is not only helpful for easy navigation along the river, it will further act as the bio-degradable fertilizer free of cost to the poor farmer of grass root level.

MATERIALS AND METHODS

Water samples from the six different spots (Table 1) namely Haroa (1), Kulti (2), Ghusighata (3), Minakhan (4), Malancha (5) and Dhamakhali (6) from the north to south direction along the tidal stretch of Bidyadhari river were collected in the month of October, 2002 for the estimation of physicochemical parameters of the water. Water of the above said six stations along the tidal river course of Bidyadhari were collected in polythene bottles of 1 litre capacity for the estimation of pH, salinity, conductivity, TSS, TDS, Turbidity, BOD, COD, DO, oil & grease, etc. (Ewing,1985).

RESULTS AND DISCUSSION

Dhamakhali being nearer to sea shows the highest TDS level. The same is the case for Malancha, Minakhan, Ghusighata and Haroa (Table 1). The high level of TDS in case of Kulti may be due to contamination of wastewater of different industries with the surface water of the canal flowing towards Kulti.

The TSS level in all the sampling points is well below the permissible limit (Table 1). This may be due to the settling of pollutants in all the canals flowing towards the Bidyadhari River. The comparatively higher level of TSS in case of Kulti may be due to unfavorable hydrodynamic condition in that region.

BOD level in all the sampling points is also below the permissible limit (Table 1). The surface water flowing through the Bidyadhari river carries some organic waste coming from the different manmade canals. The microorganisms are decomposing these organic matters in presence of sunlight and dissolved oxygen (DO) which are available abundantly in all those canals. This is the reason of low level of BOD in those regions of Bidyadhari River.

The same is the case for COD level at different sampling points of Bidyadhari River except for Kulti which shows the highest COD level (Table 1). This may be due to contamination of industrial wastewater in the surface water near Kulti region of Bidyadhari River (Hellinger, 2001).

The pH and oil & grease level (Table 1) of the surface water of Bidyadhari River at all sampling points have been observed to be well below the permissible limit. This favorable pH (Table 1) as well as the oil & grease concentration help also in the decomposition of organic matter by the microorganisms.

Tabel 1. *Analysis of water samples collected from different spots of Bidyadhari river*

Sample No and Location	pH	Salinity (ppt)	Turbidity (NTU)	TDS (ppm)	DO (mg/L)	TSS (mg/L)	BOD (mg/L)	COD (mg/L)	Oil &Grease (mg/L)
1. Haroa	7.25	3	17	460	9.2	0.0355	2.412	20	0.071
2. Kulti	7.18	4	8	730	0.0	0.3500	4.824	92	0.112
3. Ghusighata	7.02	4	9	590	0.4	0.0010	4.02	60	0.094
4. Minakhan	7.14	5	12	670	2.2	0.0015	1.6	72	0.437
5. Malancha	7.12	5	15	760	4.8	0.0130	4.824	52	0.243
6. Dhamakhali	7.32	8	10	1950	6.4	0.0100	1.608	68	0.695

CONCLUSIONS

Scientific information and environment analysis on the concentrations of different pollutants from the domestic sewage on the Bidyadhari river water and the resultant effect on bioaccumulation and biomagnification are little known till date. The cumulative effects on human body due to consumption of the agricultural and aquacultural products from the wetland areas adjacent to the Bidyadhari river are yet to be studied. It is apparent, however, from the present study that the wetland ecosystem adjacent to the Bidyadhari river plays an important role in pollution amelioration acting as a natural waste treatment plant (Das and Datta, 2000). Sunlight and D.O. help in purifying the waste water which are admixtured to the Bidyadhari river water after being released by several man-made wastewater canals from the greater Kolkata. Feasibility test (Ghosh, 1999) through analysis of environmental chemistry considering the result of major environment parameters reveals that the water quality of the Bidyadhari river is still tolerable for the existence of living creatures in the riverine aquatic environment. Only the sewage sludge present in the domestic sewage released by the canals causes impediment to inland navigation, sedimentation of riverbed. Therefore, political will and social awareness are needed to restrict further pressure on both the products and the producers existing in the adjacent wetland areas of the Bidyadhari River.

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Effect of Long Term Application of P and K Fertilizers to Coastal Saline Soils

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The coastal saline soils of Sundarbans are rich in available P and K and generally the crops do not respond to the application of P and K fertilizers. The results of a long term field experiment after 22 years of application and omission of P and K fertilizers to these soils under rice-fallow and rice-maize (fodder) cropping sequences have been discussed. The doses of N (0, 50 &100 kg ha^{-1}), P (0,11 & 22 kg ha^{-1}) and K (0, 21 and 42 kg ha^{-1}) for rice were reduced to half when applied to maize. Both maize and rice responded to application of N fertilizer. The application of P fertilizer did not show any response of crops initially. The plots receiving no P fertilizers continuously for 10 years showed significant decrease in yield of crops grown in *rabi*, while it was omission for 13 years in case of rice grown in *kharif*. Application of K or its omission had no effect on yield of crops in both the seasons. The nutrient status of the soils indicated that application or omission of K fertilizers did not have any effect on available K status of soil. However, decline in available P status of soil was reordered due to continuous omission of P fertilizer. Application of higher doses of P (22 kg P ha^{-1}) increased the available P status of soil, particularly when P was applied without N. Improvement of soil health in terms of soil microbial properties (microbial biomass carbon, basal soil respiration, fluorescein diacetate hydrolyzing activity, acid and alkaline phosphates activities, and urease activity) was observed due to application of higher doses of N and P fertilizers. Use of K fertilizer also indicated improvement in soil microbial properties. Results suggest that regular application of N fertilizer is essential for higher yield of crops and application of P @ 5.5 kg ha^{-1} for each crop of maize and 11 kg ha^{-1} for each crop of rice is necessary for maintaining P fertility status of coastal saline soils of Sundarbans. Application of K can be omitted without affecting yield of crops and K fertility status of soil.

*(**Key words:** Long term fertilizer addition, Nutrient status, Microbiological properties, Coastal saline soil)*

Coastal saline soils of West Bengal are generally rich in P and K fertility status (Bandyoopadhyay and Bandyopadhyay, 1984, Bandyopadhyay, 1990) and crops usually do not respond to application of P and K fertilizers due to which those fertilizers are not generally recommended (Biswas *et al.*, 1985). The higher availability of P and K in salt affected soils in India has also been reported by others (Chhabra, 1985, Bandyopadhyay *et al.*, 1985)). The results of the long term experiments in India show that the deficiency or imbalance of nutrients may develop in soil after continuous omission of specific nutrient(s) and soils also differ in their buffering capacity against depletion of nutrients (Nambair, 2004). The sufficiency/ deficiency of nutrient in soil also depends to a great extent on the types of crops grown and the crop rotation followed (Nambair, 2004). The supply of balanced amount of nutrients in soil is especially important for salt affected soil since the salt tolerance of crops is enhanced through supply of balanced nutrients to soil (Richards, 1976). Thus the recommendation of fertilizers for salt affected soils should essentially be based on long term studies. Fertilizer recommendation based on short term experiments may lead to development of nutrient deficiency or nutrient imbalances in soil and reduce crop productivity (Nambair and Abrol, 1989). With these in view the present experiment was conducted on coastal saline soil of West Bengal to study the long term effect of omission and addition of N, P and K fertilizers to soil on availability of nutrients and crop yields.

MATERIALS AND METHODS

A long term field experiment was conducted for twenty two years on coastal saline soil at the experimental farm of Central Soil Salinity Research Institute, Regional Research Station, Canning Town. The soil at the experimental site was silty clay in the texture, having illitic clay mineral, CEC 16.2 cmol (p+) kg^{-1}, pH (1:2) 6.7, salinity (ECe) 2-16 dSm^{-1} (varying with season, least in *kharif* and maximum in *rabi/* summer), available N (alkaline permanganate) 320 kg ha^{-1}, available P (Olen's) 20.2 kg^{-1}, and available K (NH_4OAC) 472 kg ha^{-1}. The treatments consisted of eight different combinations of N, P and K fertilizers laid out in randomized block design with three replications. Rice-fallow and Rice-maize (fodder) crop rotations were followed in the experiments. Rice (cv. Pankaj) was grown in *kharif* and maize (cv.African tall) in *rabi*. The doses of N (0,50 & 100 kg ha $^{-1}$), P (0, 11 & 22 kg ha $^{-1}$), and K (0, 21 & 42 kg ha $^{-1}$) fertilizers for rice was reduced to half when applied to maize. N was applied in three splits while P and K were applied as basal. The pH, salinity and chemical properties of the soil was determined following standard methods described by Black (1965). Microbiological properties of soil viz., microbial biomass carbon (Jenkinson, 1994), soil respiration (Alef, 1995), fluorescein diacetate hydrolyzing activity (Casida *et al.*, 1964) acid and alkaline phosphatase (Tabatabai and Premner, 1969) and urease (Tabatabai and Premner, 1972) activates were also analyzed for estimating microbial activities in soil.

RESULTS AND DISCUSSION

The results after twenty years of long term application of N, P and K fertilizers added singly or in combination showed that both maize and rice responded to application of N and P fertilizers but didn't respond to K fertilizer (Table 1). The significantly higher yield was recorded with the application of N and P fertilizer over control indicating the positive response of N and P fertilizer on the yield of both maize and rice. However, the application of P fertilizers did not show any response on yield of crops initially. The plots receiving no P fertilizer continuously for 10 years showed significant decrease in yield of *rabi* crops while it required omission of 13 years in case of rice in *kharif*. The yield of maize and rice at control was at par with K treatments without N and P. The yields at N and NK treatments were also at par. Thus, application of K or its omission had no effect on yield of crops in both the seasons. The non-significant difference in yield of maize and rice among NP, NPK and $N(PK)_{1/2}$ treatments revealed that the effect of the half dose of P fertilizer (5.5 kg ha^{-1} for maize and 11 kg ha^{-1} for rice) was same as full dose of P(11 kg ha^{-1} for maize and 22 kg ha^{-1} for rice) so far as the yield of crops was concerned in the salt affected coastal soils in the Sundarbans region of West Bengal.

The P and K fertility status of soils both in rice-fallow and rice-maize crop rotations revealed that application or omission of K fertilizer did not show any effect on available K status of soil (Table 2). However, available P content of soil decreased in treatments where soil was cultivated continuously without P fertilizers. The decrease was more when N was added without P while application of higher doses of P without N increased the available P status of soil considerably compared to initial status of soil. This was due to the fact that application of N fertilizer resulted in increased yield of crop, which caused increased uptake of P from soil. In the control treatment, the available P in soil decreased to 10.2 and 9.8 kg ha^{-1} in rice-fallow and rice-maize crop rotations, as against the initial value of 20.2 kg P ha^{-1}, over a period of 22 years of cultivation without any N, P and K fertilizers. The larger decrease in available P of soil was also reported by Mandal *et al.* (1985). Increase in available P content in soil was observed when P was added alone or in combinations with N and/or K. The maximum build-up of available P in soil was noticed when higher doses of P were applied without N fertilizer. The

Table1. Yield of crops at different fertilizer treatments under rice-fallow and rice-maize crop rotations (t ha $^{-1}$)

Treatment	Dry matter yield of maize	Grain yield of rice (Rice- fallow)	Grain yield of rice (Rice-maize)
Control (0:0:0)	3.7	1.7	1.8
N (100:0:0)	6.6	2.9	2.9
NP (100:22:0)	8.0	3.4	3.3
NK (100:0:42)	6.6	2.9	2.9
P (0:22:0)	4.8	2.2	2.4
K (0:0:42)	3.5	1.7	1.7
NPK (100:22:42)	8.1	3.4	3.4
$N (PK)_{1/2}$ (100:11:21)	7.8	3.4	3.4
CD (P=0.05)	0.7	0.4	0.4

Table 2. *Available P and K (kg ha⁻¹) content in soil under rice-fallow and rice-maize crop rotations*

Treatment	Rice -fallow		Rice- maize	
	P	K	P	K
Control (0:0:0)	10.2	475	9.8	480
N (100:0:0)	7.9	450	7.4	455
NP (100:22:0)	36.6	490	40.0	470
NK (100:0:42)	8.0	460	7.7	520
P (0:22:0)	45.7	520	46.4	500
K (0:0:42)	10.0	450	9.7	460
NPK (100:22:42)	37.0	440	41.3	495
N $(PK)_{1/2}$ (100:11:21)	24.0	510	25.0	475

Table 3. *Microbial biomass and soil microbiological & enzyme activity at different fertilizer treatments*

Treatment	MBC	BSR	FDA	Acid P	Alk P	Urease
Control (0:0:0)	147	1.2	39	535	107	32
N (100:0:0)	194	1.8	47	747	208	45
NP(100:22:0)	225	2.35	60	821	265	69
NPK(100:22:42)	268	2.58	80	1027	312	82
$N(PK)_{1/2}$(100:11:21)	206	2.28	72	956	277	72

results, thus, supported the findings of Rao and Sharma (1978) who observed an increase in available P content of soil with continuous application of P fertilizer. There was little increase in available P of soil at $N(PK)_{1/2}$ treatment after 22 years of continuous cropping indicting almost no shift in the phosphorus status of soil.

Twenty-two years of continuous application of K fertilizer in both rice-fallow and rice-maize crop rotation did not change the K status of soil. It indicated that the soil has a high reserve of K and replenishment from the reserve source was quite fast. This could be due to the facts that the soil was rich in illitic clay minerals and there was a regular build-up of salt during the dry periods accumulating considerable amount of salts in soil of which K salts were among the few major components.

Soil microbial activities determined after the harvest of maize was found to have increased over control due to addition of fertilizers (Table 3). The soil microbial/ enzyme activities such as microbial biomass carbon (MBC), basal soil respiration (BSR), fluorescein diacetate hydrolyzing activity (FDA), activities of acid phosphate (Acid P), alkaline phosphatase (AlK P) and urease enzymes were maximum when higher doses of N and P fertilizers were applied to the crops. The application of K fertilizer also indicated improvement in soil microbial properties. The higher values of MBC, BSR and FDA at the higher does of fertilizer may be due to the fact that higher underground biomass production and its addition to in the soil served as carbon and energy sources for proliferation of soil microorganisms resulting in enhanced microbiological and their enzyme activities.

It may be concluded from the experimental results that application of N fertilizer for each crop is essential for higher yield on coastal salt affected soils of Sundarbans, West Bengal. Application of P @5.5 kg ha⁻¹ for each crop of maize and 11.0 kg ha⁻¹ for rice is necessary for maintaining P fertility status but application of K fertilizer may be omitted without affecting yield of crops and K fertility status of soil.

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Carbon Sequestration in Coastal Soils

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A review of the available literature shows that over the past century, anthropic activities have contributed to a large increase in carbon dioxide (CO_2) and other green house gases in atmosphere. The rapid increase in atmospheric CO_2 has resulted in human induced global warming. The impact of rise in climatic temperature on agriculture may be very detrimental and it is likely to be more serious in coastal zones. Agriculture is considered to be a major source for C emission to the atmosphere. Various agricultural activities contribute CO_2 to the atmosphere. Agriculture can be an integral part of the solution, rather than a problem, for averting global warming, as it can be a sink for carbon. Carbon sequestration in agricultural soil may be one of the most cost effective ways to slow down the processes of global warming by reducing the concentration of carbon in atmosphere. Judicious land use, improved soil and plant management technologies, conservation agriculture, restoration of degraded lands, etc. can also offer substantial benefits by improving soil fertility, soil tilth, increasing agricultural productivity and other outcomes that may aid local population economically, socially and environmentally. There are certain uncertainties and limitations to C sequestration in agricultural lands especially in coastal regions where it is influenced by number of biotic and abiotic stresses. Carbon sequestration through suitable land use and management practices can alleviate the adverse effect of climatic changes and at the same time it may provide better environment for sustainable agricultural development in coastal areas through improving soil and water quality.

(*Key words:* *Carbon sequestration, Coastal soils, Global warming*)

Impact of global changes in climate

The possibility of global warming due to rapid increase in greenhouse gases particularly, carbon dioxide (CO_2) is receiving increased attention (Post *et al.*, 1990, Wood, 1990) since, such climatic changes may result in increased temperature and drought over present agricultural areas. The mean global surface temperature has increased by about 0.3 to 0.6 °C since the last 19th Century, and by about 0.2 to 0.3 °C over the last 40 years (IPCC, 1996). The impact of rise in climatic temperature on agriculture may be very detrimental. Seshu and Cady (1984) estimated a decrease in rice yield at the rate of 0.71 t ha^{-1} with increase in minimum temperature from 18 to 19°C and decrease of 0.41t ha^{-1} with a temperature increase from 22 to 23°C. The increase in mean air temperature by 2°C could decrease rice yield at the rate of about 0.75 t ha^{-1} within high yield areas and about 0.06 t ha^{-1} in low yield coastal region (Sinha and Swaminathan, 1991). Rao and Sinha (1994) in their crop simulation study estimated that under a 2 x carbon dioxide climate change scenario, the wheat yield could decrease by 28-68% without considering the carbon dioxide fertilization effect. It was estimated that the world's maize production could drop by approximately 10 % due to rise in global temperature (Colter, 2003). Even with adaptation by farmers of their cropping patterns and inputs, in response to climate change, the loss of farm level revenue is estimated to range between 9 and 25% for a temperature rise of 2 to 3.5°C (Kumar and Parikh, 1998). The impact of global warming is likely to be more serious in coastal zones since, it may result into loss of land and population displacement due to rise in sea level, increase in flooding of lowlying coastal areas, loss of productivity and employment in agriculture resulting from inundation, salinization, and damage of aquaculture industry. It was estimated that a 1m rise in sea level due to global warming may lead to land loss of 6000 km^2 and displace nearly 7 million people from their home in India (Nicholls *et al.*, 1995).

Agriculture : Sources and sinks for carbon

Agriculture is considered to be a major source for emission of greenhouse gases. It releases large quantity of CO_2 through various agricultural activities such as clearing and burning of forest for crop fields and pastures, transforming virgin soils into cultivated land, burning of crop residues and fossils fuels, etc. The annual net release of carbon from agriculture has been estimated as $0.8x10^5$g, or about 14% of current fossil fuel emissions (Schlesinger, 1995). The contribution of CO_2 released to the atmosphere from agricultural land represents 20-25% of the total amount released due to human activities (Duxbury *et al.*, 1993). Modernization of agriculture for feeding the increasing world population, therefore, dictates a consequential challenge of increasing agriculture production without increasing the risks of greenhouse gas emission and degradation of environment.

Agriculture can also be a sink for carbon. It is generally believed that soils, like other sinks (e.g. vegetation), have an inherent upper limit of storage of carbon in terrestrial ecosystems. Soils contain an estimated $1.5 x 10^8$g of carbon, twice of that in the atmosphere and three times the level held in terrestrial vegetation (Post *et al.*, 1990, Schlesinger, 1990). As the soils are the most important sink for carbon, the carbon sequestration in soil will, therefore, provide a prospective way of mitigating the increasing atmospheric CO_2 and an alternative strategy to slow down the process of global warming.

Factors affecting soil C sequestration

The carbon is stored in the soil as organic matter. Soil organic matter (SOM) can be referred to as 'black gold' because of its vital role on soil quality (Reicosky, 2002). It represents a key indicator for soil quality both for agricultural and environmental (C sequestration and air quality) functions. Carbon sequestration and increase in SOM will have a direct positive effect on quality, fertility, environment and resilience of soil and sustainability of agriculture (FAO, 2001). The C stocks in soil depend on large number of abiotic and biotic factors. Temperature is perhaps the most important factor which affects soil C sequestration. Soil C sequestration is generally recognized as the greatest potential for C mitigation is in the tropics (Sauerbeck, 1993). About 32% of total global soil C is under tropical climate (Ne'meth *et al.*, 1997). The soil C sequestration varies from 0.1-0.2 t C $ha^{-1} yr^{-1}$ in semiarid region to 0.2-0.5 t C $ha^{-1} yr^{-1}$ in humid regions of tropics (Pretty and Ball, 2001). SOM accumulates best at low temperature in acid parent material and in anaerobic condition (Batjes and Sombrock, 1997). Abiotic factors such as soil texture, soil reaction and carbonate status, soil depth, elevation, slope, soil types etc., greatly influence soil C sequestration (Bronson *et al.*, 1997). The lowest soil organic carbon (SOC) can be expected within pH range 5.0 to 6.0. Below pH 5.0, reduced biological activity due to acidity may slow down the decomposition of organic matter, thus soils contain more SOC. Multiple regression analysis with SOC and various abiotic factors indicated that the SOC content will decrease by 15% per unit increase in pH; increase by 1% and 0.7% per increase in clay and silt content, respectively; increase by 4% per 100 m increase in elevation, and decrease by 0.3 % per percent increase in slope.

Changes in land use pattern and management practices greatly influence C sequestration in soil. Large amounts of SOM and carbon are lost from soil following deforestation and subsequent conversion to grazing and agricultural land, draining of peat lands, intensive plowing, etc. (Reicosky and Lindstrom, 1994, Reicosky *et al.*, 1997). Deforestation may result in 20 to 50 % loss of stored carbon (Eswaran *et al.*, 1993). Long term agricultural experiments indicated typically exponential decline in SOM after first cultivation of virgin soils, and continuing steady loss over many years (Robert *et al.*, 2001, Smith, 1997, Tilman, 1998). It has also been established that SOM can be increased to new higher equilibria with sustainable management practices. The C sequestration can be increased following conservation agriculture (Lal, 1999, Reicosky, 2002). Adoption of conservation tillage reduces emissions and sequesters more carbon (Kern and Johnson, 1993), and improves SOC (Martel, 1994). The change from conventional tillage to no-tilth can sequester on an average 57 ± 14 g C $m^2 yr^{-1}$ (Tristram and Post, 2002). Adoption of appropriate farming system and use of cover crops provide another option for terrestrial carbon sequestration. Mixed crop rotations and use of cover crops improve soil organic carbon (Haynes *et al*,. 1991, Kay, 1990, Oades, 1993). A substantial increase in SOM and carbon in systems was observed due to incorporation of legumes and/ or manures (Drinkwater *et al.*,1998, Petersen *et al.*, 2000, Tilman, 1998). Afforestration and conversion to improve pasture are important strategies for soil C sequestration. The rate of average global C sequestration was estimated to be 33.8 or 33.2 g C $m^2 yr^{-1}$, respectively, due to changing land use from agriculture to forest or grassland (Post and Kwon, 2000). Conversion of arable land to agroforestry results in increase soil carbon sequestration (IPCC, 2000). The effect of various land management practices or land uses on soil carbon sequestration is given in Table 1.

Table 1. *Effects of land management practices or land use on C sequestration in tropical areas (humid and sub-humid)*

Management practices/ land use	C sequestration (t C ha^{-1} yr^{-1})
Crop lands	
Conservation tillage	0.2-0.5
Mulch farming or plant cover	0.1-0.3
Conservation agriculture	0.3-0.8
Composting	0.2-0.5
Nutrient management	0.2-0.5
Grassland and pastures	0.1-0.2
Afforestation	4.0-4.8
Agroforestry	0.2-3.1

Soil microbial activity is an important biological process governing C sequestration in soil. Microbial biomass carbon (MBC) is emerging as a sensitive and reliable indicator for assessing changes in SOC. Because of its low turnover time (Paul, 1984), microbial biomass reacts much more quickly to changes in management than does total organic matter content. The larger proportional changes in microbial biomass than in SOM (Sparling, 1991) makes MBC a more sensitive indicator of organic matter flux than changes in total or organic carbon. This is particularly useful for monitoring changes in SOM when levels of the latter are low (O'Donnell *et al.*, 1994). MBC/SOC ration is considered to be a sensitive measurement of availability of residue C in soil (Follett, 1997).

Future research needs

The process of C sequestration in agriculture is very complex. There are certain uncertainties and limitations to C sequestration in agricultural lands especially in coastal regions where it is influenced by number of biotic and abiotic stresses. The effect of different C level controlling factors like soil type, climatic conditions, land uses, agricultural practices, etc. is not very clearly understood. The biogeochemical and pedogenic mechanisms responsible for C allocation into pools of varying longevity and how the key processes are manifested at the molecular, microscopic, soil aggregate, landscape and regional scales are also not clearly understood (Metting *et al.*, 2001). The present state of knowledge could not provide appropriate and convenient system of direct measurements to quantify CO_2 fluxes influenced by agricultural management practices (Houghton *et al.*, 1983) and land use systems. However, quantification of CO_2 fluxes under different agricultural management systems is essentially needed for basic and applied researches to understand the natural phenomena controlling soil C sequestration for developing new management technologies for developing agricultural production with a minimum impact on environmental quality.

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Effect of Bioresources on the Nutrient Availability and Microbial Activity in Degraded Coastal Soil

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A Laboratory incubation experiment was carried out to study the effect of various bioresources on the physicochemical properties, nutrient availability and microbial population of the degraded coastal soil. The soil was sandy clay loam with alkaline reaction having pH 8.94 and EC 1.92 dS m^{-1}. The different bioresource treatments evaluated were control, 75 percent recommended N and P with 25 % of N substituted by *Sesbania rostrata* and azospirillum, and 25 percent P substituted through enriched farmyard manure and phosphobacterium, alongwith their combinations constituting 9 treatments replicated thrice in a randomized block design. The results of the study indicated that the various bioresources were significant in reducing the salinity and sodicity and increasing the nutrient availability and microbial population of the degraded coastal soil. Of different bioresources, 75 % N and P alongwith Sesbania and enriched FYM proved their superiority in reducing the pH (8.25), EC (1.22 dS m^{-1}) and ESP (19.30) and increasing the nutrient availability (135.27, 6.65 and 142.27 ppm of N, P, K, respectively). Application of different bioresources also resulted in increased microbial activity of soil by registering higher population at azospirillum, phosphobacterium and total microbes.

***(Key words:** Bioresources, Nutrient availability, Microbial population)*

The soils in coastal areas are degraded and are poor in fertility and productivity. High salinity and sodicity of these soils make poor nutrient and microbial availability which result in substantial reduction in the productivity of crops. The application of bioresources including organics and biofertilizers would greatly benefit these soil in increasing the fertility and productivity by their effect on reducing the salinity and sodicity and increasing the nutrient and microbial availability.

MATERIALS AND METHODS

A laboratory incubation experiment was carried out to study the effect of various bioresources on the physicochemical properties, nutrient and microbial availability of degraded coastal soil. The experimental soil was collected from Alappakkam village in Cuddalore district of Tamil Nadu state. The soil represented sodic nature and the textural class of sandy clay loam with pH 8.92, EC 1.92 dS m^{-1} and ESP 30.44. Soil had 0.24 % of organic carbon and 224, 8 and 241 kg ha^{-1} of available N,P,K, respectively. The different treatments evaluated in this study included; T_1- control (100% NPK), T_2- 75% N + *Sesbania rostrata*, T_3- 75 % N + azospirillum, T_4- 75 % P + enriched FYM, T_5 - 75 % P + phosphobacterium, T_6- 75% NP + *Sesbania rostrata* + enriched FYM, T_7 – 75 % NP + *Sesbania rostrata* + enriched FYM, T_8 – 75 % NP + azospirillum + enriched FYM, T_9 + 75 % NP + azospirillum + phosphobacterium. The treatments were replicated thrice in a randomized block design.

The soil samples were processed and 200g soil was placed in 500 ml plastic cups. To this calculated amount of gypsum at 50 % GR (2.54 t ha^{-1}) was added and water was flooded and drained after three days. Calculated quantities of fertilizers and bioresources were added as per the treatment schedule. Water was added to maintain submerged condition and incubated for a period of 90 days. Periodic soil samples at 30, 60 and 90 days after incubation (DAI) were drawn, processed and analysed for pH, EC, ESP, organic carbon and available NPK using the standard procedure of Jackson (1973). The microbial population viz., azospirillum (most probable number method), phosphobacterium and total microbes (Standard plate count) were estimated using the methods described by Black *et al.* (1965).

Table 1. *Effect of bioresource treatments on the pH, EC, ESP of soil*

Treatments	pH			EC (dS m^{-1})			ESP		
	30 DAI	60 DAI	90 DAI	30 DAI	60 DAI	90 DAI	30 DAI	60 DAI	90 DAI
T_1	8.89	8.88	8.87	1.90	1.86	1.84	28.75	28.50	28.20
T_2	8.66	8.49	8.29	1.62	1.43	1.32	25.42	23.61	21.65
T_3	8.84	8.82	8.81	1.88	1.86	1.84	28.51	28.16	27.78
T_4	8.74	8.59	8.40	1.74	1.59	1.45	26.36	25.18	24.13
T_5	8.85	8.83	8.82	1.88	1.86	1.84	28.65	28.15	27.61
T_6	8.65	8.45	8.25	1.55	1.40	1.22	24.95	21.95	19.30
T_7	8.68	8.48	8.28	1.61	1.46	1.31	25.40	23.50	21.22
T_8	8.73	8.58	8.37	1.76	1.62	1.46	26.35	25.43	24.32
T_9	8.84	8.83	8.80	1.85	1.84	1.82	28.30	27.88	27.51
SEm$\pm$	0.03	0.04	0.03	0.02	0.03	0.02	0.80	0.94	0.88
CD (P=0.05)	0.06	0.07	0.05	0.04	0.05	0.03	1.59	1.88	1.76

DAI-Days after incubation

RESULTS AND DISCUSSION

The addition of different bioresources significantly decreased the pH, EC and ESP of soil at all stages of incubation (Table 1). Among the various bioresources, 75 % NP with *Sesbania* and enriched FYM (T6) recorded the lowest pH(8.25), EC (1.22 dS m^{-1}) and ESP (19.30). This was followed by the treatment T_2. The reduced pH, EC and ESP might be due to prolonged decomposition under reduced pH favouring the organic acid production and mineralisation processs, which, in turn, contributed to the improvement in physicochemical properties. Similar observations were also reported by (Swarup, 1986, Saravanan *et al.*, 1991).

All the bioresources applied to the soil proved their efficiencies in increasing the organic carbon and available major nutrient status of the soil (Table 2). The organic carbon increased with the days of incubation. The combined application of *Sesbania* and enriched FYM recorded the maximum amount of organic carbon (0.52 %) which was followed by *Sesbania* + phosphobacteria (0.46 %) as compared to control (0.25 %).

The highest available NPK was registered under the combined application of 75% NP with *Sesbania* and enriched FYM at all stages of incubation. At 90 DAI, the available NPK recorded with this treatment was 135.27, 6.65 and 142.27 ppm, respectively. This was followed by the application of 75 % NP with *Sesbania* and phosphobacteria combination which registered 133.73, 6.47 and 142.40 ppm of N,P,K, respectively. The lowest NPK was recorded in control. Increased nutrient availability with bioresources might be due to i) favourable soil environment created by bioresources by way of reduced pH and EC coupled with formation of organo-mineral complexes and ii) the increased activity of native small and less active microflora and applied microbes, and their influence on the nutrient transformation. The present findings corroborated the earlier reports of (Azam,1990, Subba Rao, 1993).

Addition of all the bioresources increased the microbial population of the degraded coastal soil (Table 3). The populations were increased upto 60 DAI and started declining thereafter. At 60 DAI the maximum population of azospirillum was recorded in the treatment which received 75 % NP + azospirillum and enriched FYM (1.27 X 10^{-6} g^{-1} soil) and phosphobacterium (9.00 X 10^{-6} g^{-1} soil) in 75 % NP + *Sesbania* + phosphobacterium. In the case of total microbes, the highest bacteria (29.33 X 10^{-6} g^{-1} soil), fungi (12.67 X 10^{-6} g^{-1} soil) and actinomycetes (15.00 X 10^{-4} g^{-1} soil) were recorded in the treatment T_6 (75 % NP + Sesbania and enriched FYM). The availability of readily mineralized C and N and improvement in physicochemical properties of soil under the present study might have improved the growth of different microbes. This finding corroborated the earlier report of Sparling *et al.* (1991).

Table 2. *Effect of bioresource treatments on the organic carbon and available major nutrient contents of soil*

Treatments	Org. Carbon (%)			Alkaline NH_4OAC-K (ppm)			Olsen-P (ppm)			$KMnO_4$ –N (ppm)		
	30 DAI	60 DAI	90 DAI	30 DAI	60 DAI	90 DAI	30 DAI	60 DAI	90 DAI	30 DAI	60 DAI	90 DAI
T_1	0.24	0.25	0.25	118.42	119.05	120.87	4.28	4.32	4.35	120.57	124.06	125.66
T_2	0.34	0.40	0.44	125.72	129.85	132.94	5.50	5.75	5.90	135.00	138.56	141.77
T_3	0.25	0.25	0.26	122.50	127.43	131.87	4.35	4.40	4.45	124.18	125.36	126.57
T_4	0.29	0.35	0.39	124.65	127.60	129.87	5.75	5.95	6.22	130.75	132.52	134.67
T_5	0.25	0.26	0.26	119.21	119.37	121.53	5.35	5.55	5.75	124.46	124.52	126.97
T_6	0.38	0.47	0.52	128.56	132.00	135.27	6.10	6.35	6.65	136.85	140.33	142.27
T_7	0.35	0.43	0.46	125.89	129.95	133.73	5.90	6.23	6.47	136.00	139.57	142.40
T_8	0.30	0.35	0.39	124.56	129.27	132.93	5.98	6.15	6.37	130.80	132.97	135.03
T_9	0.25	0.26	0.26	122.78	127.56	130.20	5.40	5.62	5.82	125.02	125.16	126.33
SEm±	0.02	0.03	0.03	2.87	4.06	3.93	0.24	0.18	0.26	3.95	3.84	4.56
CD (P=0.05)	0.03	0.05	0.06	5.73	8.12	7.86	0.48	0.35	0.52	7.89	7.68	9.12

Table 3. *Effect of bioresource on the microbial population of soil*

Treat Ments	Azospirillum (x 10^{-6} / g soil)			Phosphobacterium (x 10^{-6} / g soil)			Bacteria (x 10^{-6} / g soil)			Fungi (x 10^{-5} / g soil)			Actinomycetes (x 10^{-4} / g soil)		
	30 DAI	60 DAI	90 DAI	30 DAI	60 DAI	90 DAI	30 DAI	60 DAI	90 DAI	30 DAI	60 DAI	90 DAI	30 DAI	60 DAI	90 DAI
T_1	0.21	0.26	0.23	2.33	3.67	2.67	14.33	17.67	15.33	3.67	5.33	4.00	5.00	6.33	5.67
T_2	0.44	0.68	0.55	3.67	5.33	4.67	17.67	23.00	19.33	6.00	8.33	6.33	8.00	10.66	8.67
T_3	0.84	1.05	0.95	2.33	3.00	2.67	14.67	17.67	15.67	4.67	7.00	5.33	6.67	8.33	7.67
T_4	0.38	0.56	0.44	4.67	6.33	5.33	16.67	20.00	17.67	4.00	6.33	4.33	5.67	7.33	6.67
T_5	0.24	0.27	0.25	6.00	7.33	6.67	15.00	16.67	14.33	5.00	6.67	5.33	7.00	8.00	7.33
T_6	0.66	0.86	0.75	5.67	8.33	6.67	21.67	29.33	24.67	8.33	12.67	9.67	12.33	15.00	13.67
T_7	0.42	0.60	0.53	6.67	9.00	7.67	19.33	23.67	20.00	7.67	9.67	7.67	8.67	10.33	9.00
T_8	0.95	1.27	1.09	5.33	5.00	4.33	19.00	21.67	19.67	5.33	6.33	6.00	8.00	10.33	8.68
T_9	0.88	1.12	1.05	5.67	6.66	5.00	16.00	17.67	16.33	4.67	6.67	5.00	7.00	8.66	7.33
SEm±	0.04	0.03	0.01	0.03	0.03	0.03	0.44	0.69	0.53	0.18	0.43	0.32	0.20	0.36	0.27
CD (P=0.05)	0.07	0.05	0.02	0.06	0.05	0.06	0.88	1.38	1.06	0.36	0.85	0.63	0.40	0.72	0.54

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Characterization and Classification of Cultivated Coastal Salt Affected Soils of Kachchh Region of Gujarat

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Twenty surface (0-30 cm) soil samples from each of the nine *talukas* of Kachchh district were collected from the cultivated coastal salt affected soils and were analyzed for physical and chemical properties. The results revealed dominance of Ca^{2+} and Mg^{2+} among the exchangeable cations, and among the water soluble ions, dominance of Na^+ and Cl^-. The soils of Kachchh district were poor in organic carbon, alkaline in reaction and calcareous in nature. More than half (60.3%) of the cultivated soils of Kachchh district were saline in nature, followed by saline-sodic (25.7%) and sodic (14.0).

***(Key words:** Characterization, Saline, Saline-sodic, Sodic soils)*

It is estimated that about 1.245 million hectare of land are affected by salinity and sodicity problems, or both, in the coastal and inland areas of Gujarat. The characterization of these soils have not been done earlier, which are reported in this paper.

MATERIALS AND METHODS

Twenty surface (0 – 30 cm) soil samples from each of the 9 *talukas* of Kachchh district having salinity/sodicity problems were collected from the cultivated field and prepared for physical and chemical analyses. The soil pH, EC and water soluble ions were estimated from 1:2.5 soil:water extract. For predicting the value of ECe from the value of $EC_{2.5}$ extract, 35 soil samples were selected as to cover a wide range of EC, textural class and geographical locations. These soil samples were analysed for EC and pH of saturation extract, 1:2.5 and 1:5 soil:water ratio extracts. Soils were analysed for their EC, pH and exchangeable cations as per standard methods (Richards, 1954). The soil organic carbon, $CaCO_3$ and sulphate were determined by standard methods (Jackson, 1973).

RESULTS AND DISCUSSION

The range and mean values (Table 1) of water soluble cations showed higher proportion of Na^+, which was followed by Ca^{2+}, Mg^{2+} and K^+. In case of anions, the highest overall mean value of 12.8 me^{-1} was noted for Cl^- and it was followed by CO_3^{2-} + HCO_3^-, and the least was SO_4^{2-}. These results are in conformity with an earlier report of Kanzaria *et al.* (1982). The overall ranges and mean values (in bracket) of exchangeable cations of 0.7–31.3 (15.7) of Ca^{2+}, 0.5 – 21.4 (8.15) of Mg^{2+}, 0.18 – 8.85 (2.76) of Na^+ and 0.05–0.99 (0.36) of K^+ cmol (P^+) kg^{-1} soil were recorded (Table 1). In Anjar *taluka*, Ca^{2+} content was higher as compared to that noted in the soils of other *talukas*. Mundra *taluka* registered the highest value of Na^+. This results are in conformity with the results obtained by Dubey *et al.* (1986).

The pH value varied from 7.0 to 8.8 with a mean value of 7.95 for the entire Kachchh district indicating the soils were alkaline in reaction (Table 2). The percent distribution of soil samples into different pH classes as suggested by CSSRI, Karnal (Anon., 1974) showed that 84.4 percent of the soil samples had pH less than 8.4 and 14.4 percent soil samples were categorised in moderate alkali group. The lowest mean $EC_{2.5}$ values of 0.19 dSm^{-1} was obtained in soils of Abdasa *taluka* and highest mean value of 2.36 dSm^{-1} was registered in Nakhtrana *taluka* (Table 2). The distribution of EC values into five classes as suggested by USDA (Richards, 1954) and utilizing the regression equation $EC_e = -0.564 + 5.774^{**} X\ EC_{2.5}$ ($r = 0.964^{**}$) developed in the present study showed that 21 percent samples had ECe < 2.0 dSm^{-1}, 15 percent had low salinity (2.0 to 4.0 dSm^{-1}), and the rest 64 percent samples had ECe > 4.0 dS m^{-1}. The overall ESP value ranged from 3.37to 33.9 with a mean value of 11.3 (Table 2). The distribution of the samples into various ESP classes

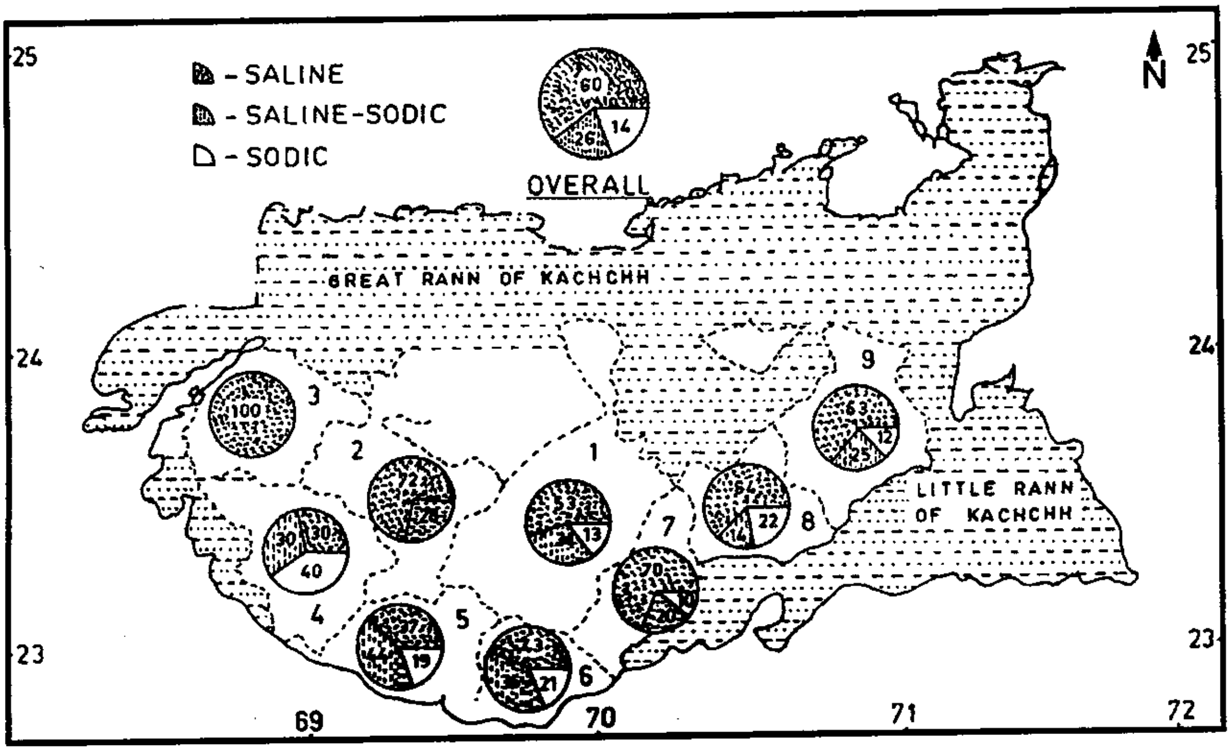
Table 1. *Taluka-wise range and mean values of content of water soluble (1:2.5) and exchangeable ions in soils*

Sr.	*Talukas*	Water Soluble ions (me/l)							Exchangeable Cations (cmol (P+) / kg)			
		Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO_3^{2-}+ HCO^{3-}	Cl^{-}	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}
1	Bhuj	0.40-6.0	0.20-7.6	3.86-51.0	0.07-0.79	1.40-4.80	1.5-49.1	0.23-8.60	2.55-26.6	2.20-13.9	0.39-5.50	0.07-0.71
		2.43	2.08	15.30	0.30	2.61	14.50	2.63	14.70	7.73	2.59	0.26
2	Nakhtrana	0.80-17.2	0.40-12.8	3.74-74.6	0.16-0.55	1.70-5.3	2.80-83.5	0.09-15.3	3.40-26.9	1.25-21.4	1.20-4.64	0.05-0.48
		4.21	3.03	21.70	0.35	2.51	22.50	3.63	13.10	9.57	2.15	0.33
3	Lakhpat	0.3-12.5	0.24-5.1	2.00-44.0	0.15-0.51	1.2-2.9	1.00-50.5	0.18-8.60	0.70-29.3	0.50-17.9	0.18-2.89	0.10-0.55
		2.48	1.62	11.00	0.32	2.02	10.70	2.36	11.50	7.47	1.42	0.35
4	Abdasa	0.30-6.5	0.20-4.3	2.00-30.5	0.05-0.31	1.3-3.8	1.00-28.5	0.09-9.10	5.85-29.9	3.95-13.5	1.25-5.39	0.18-0.99
		1.23	0.79	8.82	0.19	2.30	6.78	1.63	17.90	8.09	2.91	0.53
5	Mandvi	0.40-4.4	0.20-2.8	3.44-70.8	0.03-0.65	2.0-6.6	0.80-66.4	0.33-8.03	6.30-31.3	3.45-14.7	2.02-6.71	0.19-0.72
		1.50	0.94	17.00	0.21	3.36	13.70	2.31	17.30	8.79	4.45	0.48
6	Mundra	0.40-2.2	0.20-2.4	4.54-25.4	0.05-0.33	2.0-5.4	2.6-25.1	0.32-3.15	7.80-24.7	3.15-15.0	1.50-6.51	0.21-0.74
		1.03	0.74	10.80	0.21	3.41	7.76	1.21	18.20	9.12	3.53	0.41
7	Anjar	0.20-6.0	0.30-16.8	27.5-26.0	0.08-0.44	1.8-4.4	1.00-28.0	0.12-6.08	2.85-30.4	3.60-17.03	0.62-8.85	0.11-0.53
		1.78	1.25	11.00	0.23	3.13	9.50	1.58	19.10	8.53	3.82	0.37
8	Bhachau	0.20-25.6	0.30-16.8	2.35-45.4	0.08-0.48	1.5-3.7	0.85-74.3	0.12-9.71	6.00-27.8	2.02-13.4	1.07-3.36	0.11-0.53
		3.41	2.60	10.40	0.26	2.32	12.00	1.77	17.70	7.68	2.29	0.30
9	Rapar	0.3-10.1	0.2-8.0	2.57-45.8	0.05-0.45	1.0-4.5	0.80-50.0	0.08-9.40	2.27-28.6	1.48-14.2	0.56-4.93	0.06-0.55
		4.02	2.92	17.10	0.24	2.81	17.70	3.00	11.70	6.39	1.63	0.23
	District average	0.20-25.6	0.20-16.8	2.00-74.6	0.05-0.79	1.0-6.6	0.80-74.3	0.08-15.3	0.70-31.3	0.50-21.4	0.18-8.85	0.05-0.99
	District mean	2.45	1.77	13.70	0.25	2.72	12.80	2.23	15.70	8.15	2.76	0.36

Table 2. Taluka-*wise range and mean values of some chemical parameters of the soils*

Sr.	*Talukas*	$pH_{2.5}$	$EC_{2.5}$	ESP	$CaCO_3$ (g kg^{-1})	Organic C (g kg^{-1})	Clay content (%)
1	Bhuj	7.45-8.45 (7.89)	0.36-4.70 (1.61)	3.69-17.2 (10.40)	4.0-155.0 (38.8)	1.57-8.97 (4.5)	1.80-16.1 (8.20)
2	Nakhtrana	7.00-8.40 (7.71)	0.46-8.10 (2.36)	3.37-30.6 (10.70)	3.0-228.0 (37.6)	1.14-9.03 (5.2)	7.75-10.00 (8.81)
3	Lakhpat	7.00-8.20 (7.71)	0.23-5.60 (1.28)	4.10-13.2 (8.20)	3.0-250.0 (69.3)	0.80-6.91 (3.5)	1.00-7.00 (3.74)
4	Abdasa	7.20-8.63 (7.89)	0.19-3.10 (0.91)	3.73-28.2 (11.30)	20.0-155.0 (72.2)	0.58-5.92 (3.0)	12.00-15.85 (13.58)
5	Mandvi	7.00-8.65 (8.04)	0.25-7.20 (1.65)	4.48-33.9 (15.70)	17.0-123.0 (54.4)	1.33-8.02 (4.0)	10.00-15.70 (12.00)
6	Mundra	7.43-8.60 (8.14)	0.35-2.33 (0.99)	5.92-21.3 (12.20)	37.5-187.0 (94.6)	1.33-5.91 (3.8)	9.00-14.50 (12.30)
7	Anjar	7.65-8.80 (8.10)	0.28-3.20 (1.23)	4.62-25.1 (12.40)	13.5-223.0 (92.4)	1.15-9.55 (4.6)	2.00-8.75 (6.40)
8	Bhachau	7.20-8.70 (8.05)	0.26-7.50 (1.37)	3.58-19.1 (9.60)	16.0-245.0 (69.0)	0.53-6.63 (2.6)	16.00 - 22.80 (19.90)
9	Rapar	7.30-8.60 (8.00)	0.20-5.70 (2.08)	3.7-22.8 (10.80)	18.5-122.0 (41.6)	0.76-5.92 (2.3)	8.75 - 16.25 (11.20)
	Overall	7.00-8.80 (7.95)	0.19-8.10 (1.50)	3.37-33.9 (11.30)	3.0-250.0 (63.3)	0.58-8.59 (3.7)	1.00 - 22.80 (10.30)

Value in paranthesis indicates mean



1 - BHUJ, 2 - NAKHATRANA, 3 - LAKHPAT, 4 ABDASA, 5 - MANDVI,
6 - MUNDRA, 7 - ANJAR, 8 - BHACHAU, 9 RAPAR

Fig. 1. *Distribution of salt affeted soils in Kachchh*

as suggested by CSSRI (Anon., 1974) revealed that 50 percent samples were categorised in safe group and 40 percent into moderate group. The soils of Kachchh region are sandy to sandy loam in texture (Table 2). The lowest clay content was registered in the soils of Lakhpat *taluka* and the highest in Bhachau *taluka*. The $CaCO_3$ content ranged from 3.0 to 250.0 g kg^{-1} with a mean value of 63.3 g kg^{-1} indicating the calcareous nature of soil. The soils of Kachchh region were poor in organic carbon status. These results are in conformity with the results obtained by Kanzaria *et al.* (1982).

The ECe values were obtained from $EC_{2.5}$ using the regression equation. Of the 180 samples 60.3 percent samples were grouped as saline soils followed by 25.7% as saline-sodic and 14.0% as sodic soil (Fig. 1). This clearly showed that saline soils are dominant in the Kachchh region followed by saline-sodic soils.

This information can be useful in developing management practices for these salt affected cultivated lands.

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Effect of Phosphate Solubilizers on Wheat under Coastal Saline Soil Condition

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A field experiment was conducted to test the phosphate solubilizers with and without 50 % recommended dose (RD) of water soluble (DAP) and insoluble rock phosphate (RP) sources of P on wheat. The results revealed that application of 50 % RD of P in the form of DAP + seed inoculation with *Geotricum spp.* recorded 6.9 %, and 50 % RD of P in the form of RP + seed inoculation with *Issatchentia orientates* recorded 3.1 % higher grain yield of wheat over their full RD. The seed inoculation with *Bacillus sphaericus* and *Geotricum spp.* alongwith 50 % RD of P through DAP and RP registered higher uptake of P by grain and straw. The seed inoculation with *Pseudomonas cepacia* and *Issatchentia orientates* alongwith 50 % RD of P through DAP and RP registered higher available P after harvest of crop.

(***Key words:*** *Phosphate solubilizers, Wheat yield, DAP, Rock phosphate, Saline soil*)

Microbial solubilization of P from rock phosphate has also been studied under Indian conditions (Gaur and Gaind, 1992). But no efforts were made to study the effect of P solubilizing microorganisms on yield of wheat under coastal saline soil condition. Therefore, the present investigation was designed to study the effect of phosphate solubilizers on yield of wheat in coastal saline soil.

MATERIALS AND METHODS

A field experiment was conducted on coastal saline soil during *rabi* 2001 in RBD at Agricultural Research Station, G.A.U., Khapat (Dist. Probandar) growing wheat cv. GW-496. Two phosphate solubilizing bacterial strain B_{17}: *Bacillus sphaericus* and B_{28}: *Pseudomonas cepacia* and two yeast culture Y_{11}: *Issatchentia orientates* and Y_1: *Geotricum spp.* were isolated from saline soils by the Life Science Department of Bhavnagar University and were used to inoculate the seeds. Bacterial cultural had 10^8 cells mL^{-1} and yeast culture had 10^7 CFU mL^{-1}. The different treatments were T_1: Recommended Dose (RD) of P through DAP, T_2: 50 % RD through DAP, T_3: T_2 + seed inoculation with B_{17}, T_4: T_2 + seed inoculation with B_{28}, T_5: T_2 + seed inoculation with Y_{11}, T_6: T_2 +seed inoculation with Y_1, T_7: RD through rock phosphate (RP), T_8: 50 % RD through RP, T_9: T_8 + seed inoculation with B_{17}, T_{10}: T_8 + seed inoculation with B_{28}, T_{11}: T_8 + seed inoculation with Y_{11}, T_{12}: T_8 + seed inoculation with Y_1, T_{13}: Seed inoculation with B_{17}, T_{14}: seed inoculation with B_{28}, T_{15}: seed inoculation with Y_{11} and T_{16}: seed inoculation with Y_1. The experimental soil has texture silty loam, $EC_{2.5}$ 2.8 dSm^{-1}, $pH_{2.5}$ 8.5, $CaCO_3$ 36 g kg^{-1}, ESP 8.5, O.C. 5.6 g kg^{-1}, available P_2O_5 31.4 kg ha^{-1}, and available K_2O 450 kg ha^{-1}. The RD of N @ 120 kg ha^{-1} was applied in two equal splits at basal and at 21 days after sowing as urea, whereas P @ 60 kg P_2O_5 ha^{-1} was applied as per the treatment. At maturity, representative plant and soil samples were collected and analyzed (Jackson, 1973).

RESULTS AND DISCUSSION

The data (Table 1) showed that 50 % RD through DAP + seed inoculation with Y_1 (T_6) produced significantly higher grain yield over 50 % RD (T_2). The seed inoculation with B_{17} alongwith water soluble (T_3) and insoluble (T_9) sources of P had edge over B_{28} (T_4 and T_{10}) in enhancing grain yield, however reverse was true for straw yield. The yeast culture Y_{11} (T_{15}) produced significantly higher grain yield over bacterial culture treatment (T_{13} and T_{14}), but was at par with Y_1 (T_{16}). However, significantly higher straw yield was observed under T_{14} over T_{13} and was found at par with T_{15} and T_{16}. The yeast culture Y_{11} (T_{15}) had significant influence on plant height over T_{13} and $T_{16,}$ but was at par with T_{14}. The increase in crop yield with bacterial or yeast culture inoculation was possibly due to mobilization of native as well as fixed form. Similar findings were reported by Dubey (2000) and Qureshi and Narayansami (1999).

The bacterial culture B_{17} (T_3) and yeast culture Y_1 (T_6) alongwith 50 % RD of P through DAP registered higher P uptake by grain and straw.

Table 1. *Effect of phosphate solubilizers on yield attributes, yield and P uptake by wheat*

Treatments	Yield attributes		Yield (kg ha^{-1})		Plant analysis				Soil analysis		
	Plant height (cm)	Ear head length (cm)	Grain	Straw	Grain		Straw		P_2O_5	$EC_{2.5}$ (kgha^{-1})	$pH_{2.5}$ (dSm^{-1})
					P content (%)	P Uptake (kg ha^{-1})	P content (%)	P Uptake (kg ha^{-1})			
T_1: RD (DAP)	78.0	8.73	4097	6087	0.205	8.40	0.046	3.15	48.5	1.23	7.97
T_2: ½ RD (DAP)	63.9	8.67	3361	5452	0.199	6.71	0.043	2.32	41.0	1.43	7.93
T_3: ½ RD (DAP) + B_{17}	67.1	8.33	3872	5035	0.201	7.79	0.056	2.85	46.0	1.50	7.90
T_4: ½ RD (DAP) + B_{28}	65.2	8.53	3361	5160	0.211	7.10	0.050	2.55	48.5	1.57	7.93
T_5: ½ RD (DAP) + Y_{11}	67.5	9.20	3434	5820	0.226	7.75	0.057	3.29	54.7	1.23	8.03
T_5: ½ RD (DAP) + Y_1	66.3	8.67	4368	6340	0.228	9.94	0.056	3.56	52.2	1.47	7.97
T_7: RD (RP)	67.6	9.00	3747	5900	0.201	7.53	0.053	3.13	56.0	1.37	7.97
T_8: ½ RD (RP)	69.1	9.00	3608	5459	0.195	6.99	0.050	2.70	48.5	1.40	8.00
T_9: ½ RD (RP) + B_{17}	64.6	8.27	3802	4771	0.214	8.11	0.065	2.82	49.8	1.40	8.03
T_{10}: ½ RD (RP) + B_{28}	64.9	8.07	3111	5205	0.229	7.13	0.052	2.67	52.2	1.27	7.97
T_{11}: ½ RD (RP) + Y_{11}	69.8	9.07	3865	4723	0.201	7.91	0.052	2.46	58.2	1.27	8.00
T_{12}: ½ RD (RP) + Y_1	62.9	8.27	3486	4743	0.219	7.64	0.059	2.82	53.5	1.40	8.03
T_{13}: B_{17}	62.0	8.33	2945	4764	0.211	6.19	0.054	2.55	49.8	1.63	7.97
T_{14}: B_{28}	65.8	7.53	3177	6226	0.213	6.81	0.046	2.83	44.8	1.40	8.03
T_{15}: Y_{11}	69.2	8.33	4045	5254	0.211	8.55	0.049	2.56	48.5	1.40	8.03
T_{16}: Y_1	61.5	8.73	3611	5242	0.207	7.49	0.048	2.50	53.5	1.40	7.97
SEm ±	2.2	0.31	190	361	0.008	0.51	0.003	0.25	2.8	0.17	0.06
CD (P=0.05)	6.4	0.88	550	1052	0.023	1.47	0.009	0.72	8.1	NS	NS

Almost similar effects of phosphate solubilizers were observed with 50 % RD of P through RP. The bacterial culture B_{28} (T_{14}) and yeast culture Y_{11} (T_{15}) had edge over B_{17} (T_{13}) and Y_1 (T_{16}), respectively in enhancing the P uptake by grain and straw.

The bacterial culture B_{28} (T_4) and yeast culture Y_{11} (T_5) alongwith 50 % RD of P through DAP registered higher available P after harvest of the crop compared to B_{17} (T_3) and Y_1 (T_6), respectively (Table 1). Similar beneficial effect of phosphate solubilizers were observed with 50 % RD of P through RP or inoculated with seed only. The EC and pH values were not affected significantly. This marginal decrease in EC and pH value was possibly due to organic acids produced by fertilizers and phosphate solubilizers (Dubey, 2000).

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Growth Dynamics of Different Tree Species Grown on Coastal Alluvial Soil and its Effect on Soil Properties

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A field experiment was conducted (1988-1997) on coastal alluvial soil with 12 tree species at Agricultural Research Station (Fruit), G.A.U., Mahuva. The results revealed that the highest survival and better growth in terms of height and girth of the trees were found under *Prosopis juliflora*, followed by *Accasia arabica*, *Adansonia digitata* and *Selvadora persica*. In general, there was no marked change in salt content (EC) of soil during the 10 years of study but the ESP values were considerably increased, maximum under *Prosopis juliflora* followed by *Adansonia digitata*, *Accasia arabica*, and the least under *Selvadora persica*.

*(**Key words**: Growth dynamics, Plantation crop, Coastal soil, Soil properties)*

Cultivation of plantation crops on a coastal soil helps in maintenance of ecological balance and also provides employment to a sizable population in the country. But no such information is available on growth dynamics of different tree species grown on coastal soils, which prompted the present investigation to be undertaken.

MATERIALS AND METHODS

A field experiment was conducted (1988-1997) on coastal alluvial soil at Agricultural Research Station (Fruit), G.A.U., Mahuva having 12 treatments (tree specie) viz., T_1: *Propopis juliflora*, T_2: *Casuarina equisetifolia*, T_3: *Eucalyptus tereticernis*, T_4: *Sepindus trifoliotus*, T_5: *Cordia dicholoma*, T_6: *Servadohara persica*, T_7 *Tamanarindus indica*, T_8: *Adansonia digitata*, T_9: *Dithecolobium soman*, T_{10}: *Zizyphus jujuba*, T_{11}: *Pongamia dinnata* and T_{12}: *Accasia arabica*. The tree species from T_1 to T_8 were planted during *kharif* 1988, while T_9 to T_{12} during 1989. Eighteen trees for each species were planted at a distance of 5.0 x 5.0 m in three rows having six trees in each rows. The experimental soil was of alluvial origin having texture silt loam, $EC_{2.5}$ 0.42 dSm^{-1}, $pH_{2.5}$ 8.03 and ESP 2.76 (Richards, 1954). The gap filling of tree species were carried out wherever necessary during the *kharif* season. The trees were irrigated with saline well water (EC 13 dSm^{-1} and SAR 17.1) at an interval of 30 days after withdrawal of monsoon in earlier years. The height and girth of different trees species were recorded.

RESULTS AND DISCUSSIONS

Establishment and growth of seedlings

The results revealed that there was maximum survival in case of *Prosopis juliflora* (100%) and *Acacia arabica* (100%) followed by *Adansonia digitata* (89%) and *Selvadora persica* (89%). For the sake of brevity the data on survival rate of different tree species are not presented here. During the year 1992 two species, and in 1994, most of the tree species were grazed and damaged severly by stray cattles.

The height of trees were progressively increased with increase in age (Table 1) The maximum growth was recorded in *Prosopis juliflora* (67.5 cm) followed by *Accasia arabica* (57.5 cm) and *Adansonia digitata* (30.0 cm). The growth of *Selvadora persica* was very slow (27.5 cm).

Effect on soil properties

The minimum salt content was recorded under *Adansonia digitata* (0.44 dSm^{-1}) and maximum under *Selvadora persica* (0.58 dSm^{-1}) in surface soil. The salt content increased with increase in soil depth under *Prosopis juliflora* and *Accasia arabica* treatment (Table 2).

The maximum ESP was observed under *Adansonia digitata* (8.50 %) and minimum under *Selvadora persica* (3.18 %) in surface soil. The ESP values increased with increase in soil depth. There was no marked change in salt content of soil during the 10 years of study in comparison to initial values, but ESP values were considerably increased (Table 2).

***Table 1.** Average height and girth (cm) of different tree species at different period of growth*

Treatments	Height of the trees (cm)							Girth of the trees (cm)					
	1988	1989	1990	1991	1992	1993	1994	1992	1993	1994	1995	1996	1997
T_1	90	270	322	-	533	633.3	702.5	43.3	53.3	60.0	63.9	66.0	67.5
T_2	20	37	64	57*	76.2	50.0	*	-	6.0	*	*	*	*
T_3	20	54	80	*	*	*	*	-	-	*	*	*	*
T_4	12	29	58	50*	*	*	*	-	-	*	*	*	*
T_5	31	44	71	39*	73.3	93.3	-	-	8.0	*	*	*	*
T_6	24	37	69	138	144.5	196.6	235.5	-	13.3	18.5	21.6	22.7	27.5
T_7	22	36	63	65	90	80.0*	-	5.0	7.0	*	*	*	*
T_8	27	48	85	195	288	356.6	390.2	13.6	20.6	22.8	23.8	26.0	30.0
T_9	-	-	44	39*	73.3	50.0	-	1.2	5.0	*	*	*	*
T_{10}	-	-	53	62	96.6	113.3	-	1.2	6.0	*	*	*	*
T_{11}	-	-	36	35*	31.6	55.0	-	1.3	5.3	*	*	*	*
T_{12}	-	-	195	279	483	553.3	608.3	36.6	46.6	50.2	52.8	53.8	57.3

* The tree species were destroyed or severely damaged by stray cattle.

***Table 2.** Average effect of different tree species on EC and ESP of the soil at different depths (cm) after monsoon (1998)*

Trees	$EC_{2.5}$ (dSm^{-1})			ESP		
	0-15	15-30	30-45	0-15	15-30	30-45
Prosopis juliflora	0.53	0.95	1.23	7.27	23.50	32.00
Accasia arabica	0.53	0.55	0.64	7.87	13.20	18.40
Adansonia digitata	0.44	0.62	0.60	8.50	21.55	25.51
Selvadora persica	0.58	0.50	0.51	3.18	9.08	12.83
Initial	0.42	0.64	0.70	2.76	3.39	3.28

An overview of the results indicated that the highest survival and better growth in terms of height and girth of the trees were obtained with *Prosopis juliflora* followed by *Accacia arabica, Adansonia digita* and *Selvadora persica* under coastal alluvial soil.

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Use of Ninhydrin Method in the Assay of Microbial Biomass Carbon in Coastal Soil

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The fumigation extraction method was used to investigate the relationship between microbial biomass carbon (MBC) and biomass ninhydrin reactive nitrogen (B_{Nin}) in soils collected from agricultural experimental farm, Central Soil Salinity Research Institute (CSSRI), Canning Town and from different farmers' fields located in different blocks of Canning, West Bengal in the month of September, January and May. The soils varied with respect to their organic carbon content and ECe. The B_{Nin} was highly correlated with MBC ($r = 0.98$); the factor for conversion of B_{Nin} into MBC was MBC = 30.16 B_{Nin}. Measurement of B_{Nin} could be used as a useful and sensitive assay of MBC in coastal soils.

*(**Key words**: Microbial biomass carbon assay, Ninhydrin reactive nitrogen)*

Microbial biomass is considered as an important attribute of soil quality. A number of methods have been developed for microbial biomass estimation. Among the methods, the fumigation extraction method has been found to be more rapid and reliable. A 24-hour $CHCl_3$ fumigation was followed by immediate extraction and usual measurement of carbon in the extract (Vance *et al.*, 1987). Subsequently, Amato and Ladd (1988) showed that the amount of B_{Nin} extracted from soil by 2(M) KCl following $CHCl_3$ fumigation was a reliable method and sensitive indicator of the amount of soil microbial biomass. The advantage of this method was that the ninhydrin reactive-N released from fumigated soil was mainly derived from the biomass, rather than from both biomass and non-biomass sources. The ninhydrin reactive nitrogen, being mainly amino acids and NH_4-N, was easily determined using colorimetric methods. However, no uniform conversion factor has been proposed for all soils and climatic situations for the estimation of MBC by measuring B_{Nin}. For more precise quantification of MBC by B_{Nin} content, it would be necessary to determine the specific biomass C : B_{Nin} ratio for each soil before commencement of an experiment (Joergensen, 1996). Such information for coastal saline soil is totally unknown. Present report deals with the relation of B_{Nin} to MBC in coastal saline soil.

MATERIALS AND METHODS

The present study was carried out with the soils (0-15 cm) collected from 9 (S_1-S_9) different rice-based cropping systems in the months of September, 2002 and January and May, 2003. The soils were collected from the agricultural experimental farm, CSSRI, Canning Town and from different farmers' fields located in different blocks of Canning. Microbial parameters were determined with the sieved field moist soils, while the physical and chemical properties were determined with air dried soils. The textural composition (International pipette method), pH (1:2.5 water), electrical conductivity of saturation extract (ECe) and organic carbon of soils were determined following standard methods (Jackson, 1967).

Determination of MBC

It was performed according to Vance *et al.* (1987). Two portions (25 g each) of the moist soil were accurately weighed. One portion was immediately extracted with 100 ml 0.5 (M) K_2SO_4 for 30 minutes in an oscillating shaker at 200 rpm and then filtered. The extract was used for carbon determination. The fumigation of soil was carried out in a vacuum desiccator lined with wet tissue paper containing a vial with soda lime and alcohol free chloroform. Following incubation at 25°C for 24 hours, chloroform was removed by repeated evacuations. The soil was then extracted and filtered in the same way as mentioned for the unfumigated sample. The organic carbon in the extract was measured by digesting 8 ml of filtred extract with 2 ml 0.4(N) $K_2Cr_2O_7$ and 15 ml of $H_2SO_4 : H_3PO_4$ mixture (2:1), followed by determining the residual dichromate with 0.04(N) ferrous ammonium sulphate using ferroin as indicator. The MBC was calculated as follows viz., MBC= EC/0.38, where, EC= (extracted organic carbon from fumigated soil – extracted organic carbon from non-fumigated soil).

Determination of B_{Nin}

It was performed according to Jenkinson (1994). The fumigated as well as non-fumigated soils were extracted with 2(M) KCl. Ninhydrin reactive nitrogen in the extract was determined by treating 1 ml of filtrate with 0.5 ml of ninhydrin reagent in water bath for 25 minutes. After cooling 9.5 ml of ethanol water (50 %) was added, mixed thoroughly and absorbance was measured at 570 nm with KCl solution as blank. Ninhydrin reagent was prepared by dissolving 0.8 g of ninhydrin and 0.12 g of hydrindantin in 30 ml dimethyl sulphoxide, followed by addition of 10 ml lithium acetate buffer (pH 5.2). The ninhydrin reactive nitrogen per gram of oven dried soil was calculated from a calibration curve. For this, 2 ml of each leucine standard (0,2.5,5,7.5,10 ug N ml^{-1}) mixed with 1 ml ninhydrin reagent was heated in water bath for 25 minutes, cooled to room temperature and then mixed with 9.5 ml of ethanol water thoroughly. The absorbance was measured in a spectrophotometer at 570 nm. The difference between the ninhydrin reactive - N in fumigated and non-fumigated soils gives the ninhydrin reactive-N of biomass of the soil sample.

RESULTS AND DISCUSSION

Physical and chemical properties of soils

All the soils, except S_3 and S_4, were silty clay (Table 1). The S_3 and S_4 were loam and clay loam, respectively (data not shown). In terms of the pH of soils S_1, S_2 and S_8 were neutral to slightly alkaline, varying from 7.2 to 7.8 while, S_3, S_7 and S_9 were acidic, varying from 5.1 to 5.49 (Table 1). The soils S_4 and S_5 had pH 6.1 and 6.7, respectively. Seasonal variation in pH was not conspicuous. Based on mean ECe values, the soil S_1, S_2 and S_8 had low salinity

Table 1. *Physical, chemical and microbiological properties of soils*

Treatment	pH	Electrical Conductivity (dSm^{-1})	Organic-C (%)	Microbial biomass-C (MBC)(ug g^{-1})	Biomass Ninhydrin nitrogen B_{Nin} (ug g^{-1})	MBC/ B_{Nin}
Month						
September	6.33	2.7	0.91	305	9.8	-
January	6.15	8.3	0.98	307	10.2	-
May	6.16	13.8	0.96	254	7.8	-
Mean	6.21	8.3	0.96	289	9.3	-
CD (p=0.05)	NS*	0.16	NS	8.98	0.186	-
Soil						
S_1	7.2	2.3	1.41	446	15.8	28.23
S_2	7.8	3.5	0.87	275	8.4	32.74
S_3	5.1	14.7	1.02	268	8.5	31.53
S_4	6.1	16.3	0.69	199	5.4	36.85
S_5	6.7	15.7	0.52	125	3.4	36.76
S_6	5.2	6.4	0.89	284	8.7	32.64
S_7	5.5	7.1	1.04	312	10.6	29.43
S_8	7.2	3.1	1.07	344	11.4	30.17
S_9	5.1	5.3	1.03	346	11.1	31.17
Mean	6.2	7.3	0.95	289	9.3	31.07
CD (P=0.05)	0.32	0.28	0.041	15.56	0.32	-
SxT	0.56	0.48	0.071	26.96	0.56	-

* Not significant

(ECe less than $4dSm^{-1}$), while the soils S_6, S_7 and S_9 were moderately saline (ECe between 5.3 - 7.1 dSm^{-1}), and the soils S_3, S_4 and S_5 were highly saline (ECe between 15 - 17 dSm^{-1}). Data indicated marked seasonal variation in soil ECe reaching to peak salinity value in May. The soil varied with respect to their mean organic carbon content, the maximum being found in S_1 (1.41%) and the minimum in S_5 (0.5%). Seasonal variation in soil organic carbon content was not statistically significant.

Microbial parameters

Both MBC and B_{Nin} differed remarkably among the soils (Table 1). The highest microbial biomass in S_1 soil could be related to its highest organic carbon content (Jenkinson and Ladd, 1981) and also for its lowest salinity. Lowest MBC and B_{Nin} in S_5 soil was due to lowest level of organic carbon and the highest salinity. The soils in respect to MBC could be ranked as $S_9>S_8>S_7>S_6>S_2>S_3>S_4$. In contrast, the order of B_{Nin} values were $S_7>S_8>S_9>S_6>S_3>S_2>S_4$. These differences could be due to different extractants used. Seasonal variation in microbial biomass was prominent. The lowest MBC and B_{Nin} values of soils were observed in May which was due to the increase in salinity and lower moisture content probably due to enhanced summer heat in this period.

Relationship between MBC and B_{Nin}

The MBC of the soils was positively and significantly correlated with B_{Nin} (Fig.1). The regression equation for the relationship between MBC and B_{Nin} with the intercept fitted through zero was MBC= 30.16 B_{Nin}.(r =0.98).

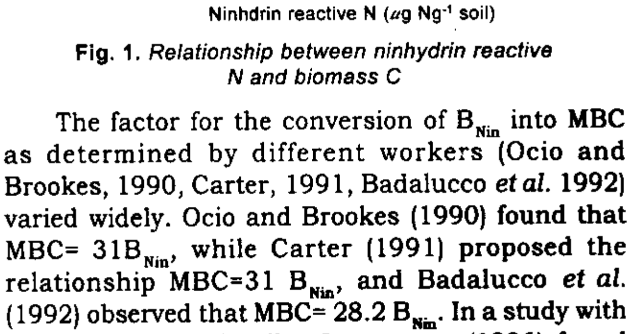

Fig. 1. *Relationship between ninhydrin reactive N and biomass C*

The factor for the conversion of B_{Nin} into MBC as determined by different workers (Ocio and Brookes, 1990, Carter, 1991, Badalucco *et al.* 1992) varied widely. Ocio and Brookes (1990) found that MBC= 31B_{Nin}, while Carter (1991) proposed the relationship MBC=31 B_{Nin}, and Badalucco *et al.* (1992) observed that MBC= 28.2 B_{Nin}. In a study with 110 widely varied soils, Joergensen (1996) found different conversion factors for different pH groups. He suggested : MBC= 22 B_{Nin} at soil pH > 5 and MBC= 35.3 B_{Nin} at soil pH = 5. The conversion factor as found in present study was close to those reported by Ocio and Brookes (1990) and Carter (1991).

Present study indicated that the MBC in coastal saline soil could be assayed by ninhydrin method using the conversion factor of 30.16. For more precise information, study should be taken up with wide range of soils.

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Session
On
Water management and drainage for coastal soils

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Isotope Tracer Techniques for Water Resources Management

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Though water resources management and water technology are part of agricultural sciences, it is observed that the specialists in this field are not familiar enough to the extent to their counterparts in other disciplines cited. The way isotope technique is a part of training to the students of agriculture, it has not found a place in the curriculum dealing with water technology or water resources management, which has been reviewed. Source and estimation of groundwater recharge, source of groundwater, salinity and pollution, surface water and groundwater interconnection, aquifer-aquifer interconnection, dating of groundwater, seepage from canal, reservoirs and tunnels, and sedimentation of lakes are some of the examples of application of isotope based techniques to water resources management programmes. In conclusion, isotope tracer techniques, a modern research tool, has been in use in India almost for the past four decades to solve many of the problems in relation to hydrology and water resources management. However, there is not enough interaction between the hydrologists and agricultural water technologists, on the one hand, and isotope hydrologists and expert in isotope chemistry and physics, on the other. Lack of adequate facility, shortage of trained manpower, general notions that isotopes are harmful, high cost of equipment are some of the reasons for this. It is expected that with development of techniques involving stable and natural isotopes, availability of necessary facility and increase in the trained manpower, the technique will be within the reach of the researchers.

*(**Key words**: Isotope tracer techniques, Water resource management, Hydrology)*

Some of the different molecules of water resulting from the combinations of various isotopes of hydrogen and oxygen are $^1H^1H^{16}O$, $^1H^2H^{16}O$, $^1H^3H^{16}O$, $^1H^2H^{18}O$, etc. However, their relative abundance in nature varies to a great extent. Of the many isotopic forms of water that exists, the natural abundance of some of them are given in Table 1.

Water molecules substituted by Deuterium (D) and Oxygen-18 for normal hydrogen and oxygen atoms are stable whereas those with a tritium substitution for normal hydrogen (HTO) are radioactive owing to the radioactive nature of tritium. However, the level of radioactivity associated with water is, fortunately, extremely low and as such the living beings are free from any radiation effects arising out of it. $H_2{}^{17}O$ has very low abundance and is not of any significance in hydrology. Though the level of $HT^{16}O$ is extremely low, of the order of 10^{-14} ppm, the tremendous advancement achieved in the field of analytical techniques and instrumentation has made it a suitable tracer in many of the hydrology related investigations.

Table 1. *Natural abundance of different isotopic water species*

Sl. No.	Water species	Normal abundance (ppm)
1.	$H_2{}^{16}O$	997680
2.	$HD^{16}O$	320
3.	$H_2{}^{18}O$	2040
4.	$H_2{}^{17}O$	370
5.	$HT^{16}O$	10^{-14}

Isotope techniques are in use in India and elsewhere for water resources development and management programmes for more than three decades. However, isotope hydrology as a science is not familiar to water technologist as in the case of nuclear medicine and nuclear agriculture to the specialists in medicine and agriculture. The way nuclear medicine is a part of training to the students of medicine, isotope techniques to the students of agriculture, it has not found a place in the curriculum dealing with water technology or water resources management, which has been reviewed.

Isotopes in water resources management

Tritium and Carbon-14 along with a number of other nuclides exist in the environment as a result of continuous production in the atmosphere by cosmic ray induced reactions, as a consequence of thermonuclear explosions, operation of nuclear power plants and other industrial activities. Therefore, measurements of concentration changes environmental isotopes. This is based on the fact that surface waters have stable isotope composition significantly different from that of groundwater. Generally rivers originate from high altitudes and hence, have depleted stable isotope contents compared to groundwaters in the plains. The groundwater is predominantly recharged by local low altitude precipitation which is comparatively enriched with stable isotopes. Hence, as the isotopic composition of the river and groundwater are different, the groundwater contribution to the river or vice versa could be ascertained.

A surface water system like lake or a reservoir is an evaporating body and hence its stable isotopic content gets enriched compared to the shallow groundwater nearby. This difference could be used to determine the contribution of surface water to the groundwater.

Investigation on two groundwater bodies separated by an impermeable layer of sediments could be studied using either deuterium or ^{18}O provided the two water bodies are isotopically different. This technique was used to study the interconnection between the shallow and deep zone in the Cauvery Delta region in Thanjavur, Tamil Nadu.

Artificial radioactive isotope applications in water resources management

A number of artificial radioactive isotopes are in use in hydrology and water resources management programmes. Details of some of the important radioactive isotopes used in water related applications are given in Table 2 which also gives the maximum permissible concentration (MPC) of the respective radiotracer in drinking water. The ideal radio tracer for hydrological application is tritium as HTO which has fairly a long half life of 12.42 years. However, the long half life makes it not suitable for short term investigations. Another disadvantage associated with it is that it can not be detected and quantified insitu. The advantage of radiotracers are their high sensitivity of detection. They can be detected even at dilutions of 10^{12}. Conventional chemical tracers are 3-4 orders of magnitude less sensitive to detection.

Recharge of precipitation to the groundwater

Artificial tracer methods have extensively been used in India and other countries to estimate rates of infiltration in the unsaturated zone for determining the direct rainfall recharge to the groundwater. The method involves tagging a horizontal layer at a certain depth below the root zone with a suitable tracer followed by monitoring the tracer profile at regular intervals. Radiotracers are usually used as they have good detection sensitivity and hence can be introduced in small quantities without large disturbances to the soil or its moisture content. Tritium as tritiated water is the most commonly used tracer, although others like gamma emitting ^{60}Co as $K_3{}^{60}Co(CN)_6$ has also been used to take advantage of *in situ* detectability in the field.

Table 2. *Radioisotopes generally used as tracers in hydrology and water resources management.*

Isotope	Half life	Nature of radiation	MPC
Tritium	12.42a	Beta	$3x10^{-3}$
Carbon-14	57.30a	Beta	$2x10^{-3}$
Chromium-51	27.00d		$2x10^{-3}$
Bromine-82	35.50h	Gamma	$4x10^{-5}$
Iodine-131	8.05d	Gamma	$2x10^{-3}$
Phosphorus-32	14.20d	Beta	$2x10^{-5}$
Gold-198	64.80h	Gamma	$5x10^{-5}$
Sodium-24	15.02h		$3x10^{-5}$

MPC : Maximum permissible concentration in drinking water

Stream discharge measurements

Undulating topography, frequent falls, bends, meandering nature are the general features associated with water flowing through hilly regions where discharge measurements using conventional method like the one based on current meters are difficult to carry out. In such situations, discharge measurements following tracer balance approach can be adopted. The method also does not require cross-sectional profile of the stream. The important precondition of the tracer method, the requirement of complete mixing of the tracer is also easily met with as favoured by the undulating topography and other features of the water way mentioned above. A number of discharge measurements have been carried out in the country, particularly of hilly streams using this technique.

Delineation of hydraulic boundaries of a catchment

Environmental isotope techniques have established their utility in investigating the hydraulic interconnections. Even though topographically isolated, catchments may be hydraulically interconnected as; aquifer-aquifer,

aquifer-stream or inter-basin. Hydrogeological approaches to this type of problem require good piezeometric maps and pumping test data. If the systems with which inter-relation is suspected to occur are different in isotopic composition, stable isotopes like ^{2}H and ^{18}O along with ^{3}H and ^{14}C are the most suitable isotopes to solve this type of problem.

As a part of the hydrological study to investigate the feasibility of artificial recharge of groundwater aquifers in the Cauvery delta, an isotope study was carried out to verify whether the shallow and deep aquifers are interconnected or not. The shallow aquifer waters are found to be more enriched in ^{2}H and ^{18}O than deep aquifer, mostly due to recharge from surface channels. The source of recharge to deep aquifer is possibly from remote outcrop areas. Hence, it was concluded that these aquifers are not interconnected.

Identification of source of water available to plants

The use of stable isotopes of hydrogen and oxygen in studies of plant water relations has dramatically improved our ability to link plants to their water source through non-destructive means. ^{2}H and ^{18}O can be used as a tracer to compliment the information on spatial patterns of water uptake gained from studying rooting patterns. A good number of studies have successfully used stable isotopes to understand and indirectly measure the depth of water uptake and to identify the source of water available for plants in a wide variety of environments. For example, it was successfully demonstrated that crops and adjacent wind breaking trees in Niger competed for the same water source in areas where the trees were shallow-rooted and could not gain access to deep water in the aquifer at 35 m. Interestingly, in these areas where the water table was shallow (6-8 m), the same trees and crop plants did not compete for water because they used moisture from different soil depths.

Partitioning of evapotranspiration

Groundwater may discharge directly to the atmosphere by moving upwards through soil or by the transpiration of plants. In catchments where water tables are extensive or shallow, this diffuse discharge flux can be an important component of the water balance. It can also have environmental consequences as it causes increase in salinity levels, which may restrict the growth of native or agricultural plants.

Stable isotopic signatures of water in soil, vegetation and atmosphere are used to partition soil evaporation and plant transpiration from total evapotranspiration. Discharge of saline groundwater from eucalyptus forests in sites of Monoman and Chopwilla Island on the flood plain of the River Murray, South Australia was determined directly by first measuring transpiration rates from forests and then partitioning the transpiration flux into groundwater discharge and soil water depletion. This partitioning was achieved by identifying the source of transpired water with naturally occurring stable isotopes of water.

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Irrigation Management in Coconut Plantation

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A study was conducted at CPCRI on irrigation management in coconut. It was found that yield of coconut with drip irrigation @ 30 litres per palm per day during January to May was comparable to basin irrigation @ 600 litres per palm per week. There was 67 percent saving of water in drip irrigation. Drip irrigation demonstration for coconut with 50 litres per palm per day in various districts of Kerala by CWRDM during 1985-88 has shown that the yield of nuts improved significantly from 3rd year after start of the irrigation.

(***Key words*** *: Irrigation management, Methods of irrigation, Stress management, Coconut)*

One of the critical resources in coconut production is the availability of water. Though the coconut growing regions in the coastal belt are endowed with high rainfall, the rainy period is confined to few months during the monsoon season. The palm experiences moisture stress and drought conditions for varying periods extending upto 6-7 months in an year. In the coconut growing region other than the coastal belt coconut has to be grown throughout the year by supplemental irrigation. The adverse effect of moisture stress on the productivity of coconut has been well established. Utilization of the available water in most effective manner by optimizing irrigation schedules and by adopting soil moisture conservation practices with water harvesting measures assume particular significance in coconut cultivation.

Unfavourable soil and climatic conditions create moisture stress from December to May and this necessitate coconut palms to be irrigated. Non-availability of water during summer months (Dec-May) is the most critical for coconut production especially in North Kerala. By drip irrigation, soil moisture is maintained near to field capacity and further water loss due to seepage and other losses is avoided.

Effect of moisture stress on coconut

1. Increases in the rate of frond shedding and slowing-up of frond production resulting in reduced leaf area and light interception.
2. Induces greater stomatal resistance, reduced transpiration rate and lower leaf water potential.
3. Affects the inflorescence production and further results in shedding of buttons and young nuts.
4. Nut size gets reduced resulting in low *copra* content.

Water requirement of young palms

The evapotranspiration rates of 5 year-old coconut palms (cv. West Coast Tall) grown in an oxisol on the West Coast of India increased from 2.9 mm day^{-1} in Dec. to 5.5 mm day^{-1} in April, and decreased to 2.3 mm day^{-1} in June following the onset of monsoon rain. Consumptive use of water by 6 year-old palms with a leaf area index of 2.4 during the observation period (Nov. 1986 to May 1987) was of the order of 3.3 mm day^{-1} and ranged from 2.7 to 4.1 mm day^{-1}. The crop coefficient values were 0.54, 0.73, 0.60 and 0.65 for Penman, Blaney-Criddle, radiation and US Class-A pan methods, respectively.

In West Coast of India, regular irrigation during Dec-May is essential for establishment and optimum growth. In other regions of the country, irrigation is generally given throughout the year as and when required. Nelliat (1968) reported that irrigation with 45 litres of water once in 4 days combined with application of 0.15 m^3 of red earth in planting pits prior to planting in littoral sandy soil resulted in quick and vigorous growth of young palms. Similar results were also reported from coconut research station, Nileswar, where 40 litres of water twice a week resulted in vigorous growth of seedlings. Pitcher irrigation in areas of water scarcity by burying the earth pots of 20 litre capacity at a distance 75 cm from the shoot on either side of the seedling and filling the pots periodically with water supplied sufficient moisture for establishment and vigorous growth of seedling. The total water requirement was 1591 and 1533 mm per year for maintaining 80 to 100 percent of available soil moisture and 60-100 percent of available soil moisture respectively. Mulching with coir dust reduced water requirement by about 40 to 55 percent.

Water requirement of adult palms

In coconut, initiation and differentiation of vegetative and reproductive primordia and enlargement of cells are very sensitive to moisture stress. The palm is mostly grown under rainfed condition by the vast majority of coconut growers particularly in the major coconut growing State of Kerala. Excess moisture during the monsoon period which varies from four to six months and moisture stress during summer is a common phenomenon in the West Coast of India. Saseendran and Jayakumar (1988) computed the mean yearly consumptive use of coconut to be 1,126 mm (37 l $palm^{-1}$ day^{-1} for a basin area of 12 m^2). The yearly irrigation requirement was estimated to be 4,656 l $palm^{-1}$ spread over the non-monsoon months of December to May.

The mean annual water requirement of coconut plantations in Kerala was 1126 mm (37 litres per palm daily for a basin area of 12 m^2) and the mean annual irrigation requirement was 338 mm (4656 litres per palm for a basin area of 12 m^2), spread over the non-monsoon months of January- May and November and December, respectively (Saseendran and Jayakumar, 1988).

Soil and climate based irrigation schedule study for coconut in South Kerala, India indicated that requirements of water varied according to the type of soil. Yield became stable under adequate irrigation water supply, observed during different periods of the year. The annual irrigation and water requirements in this treatment, during the non-rainy period, were determined as 538 mm and 1093 mm, respectively. The consumptive use during this period was estimated as 272 mm with an irrigation : cumulative pan evaporation ratio of 1.02. Application of 40 litre water twice a week was found essential for establishment and early growth of coconut (cv. CRIC 60) in the dry zone of Sri Lanka (Liyanage and Mathes, 1989).

Response of coconut to irrigation

Irrigation and fertilizers brought about precocious flowering in T X GB coconut hybrids. Development and precocity of dwarf coconut palms production varied under different irrigation frequencies from 6 to 28 litres per plant per day. During the third year, an average yield of 118 fruits per plant was obtained and no significant differences were found among the treatments. More than 4 decades of research in Sri Lanka have indicated that coconut cv. CRIC65 is capable of producing a sustained higher yield than cv. CRIC60 in the absence of adverse soil water deficit (Peries, 1994). The cumulative yields of nuts and *copra* were 50% higher in CRIC65 than in CRIC 60 over a period of 32 years.

Financial analysis of irrigation investments in existing and new plantations of coconuts in mixed cropping system indicated that investment in irrigation was financially feasible.

Studies on the effect of mulches and irrigation on young coconut plants in coastal Karnataka indicated better growth under drip irrigation and coir pith mulch (Uthaiah *et al.*, 1989). Dwarf X West African Tall coconut hybrids planted in a dry climate with supplementary irrigation and NPK fertilizers gave *copra* yields of 4.1-4.3 t per ha per year in contrast to 3.4-3.6 t per ha per year recorded under low management input (Daniel *et al.*, 1991).

A seven-year trial with basin irrigation applied during dry periods at 82 gallons per palm weekly or fortnightly, or at 164 gallons per palm fortnightly indicated that total *copra* yield increased from 3488 to 5377 lb ha^{-1} due to weekly applications in drier years and from 5011 to 6311 lb ha^{-1} in wetter years (Abeywardena, 1979). In 3-year trials with 3 coconut cv. Malayan Dwarf Yellow, Malayan Dwarf Green and Malayan Dwarf Red (13 to 16 year-old palms), irrigation on alternate days was highly effective to enhance the yield compared to irrigation at fortnightly intervals.

Irrigation methods for coconut

Irrigation methods commonly adopted in coconut gardens are flooding, basin, sprinkler or perfo-spray and drip irrigation.

Flood irrigation

This kind of irrigation was in use prior to introduction of Microsystems of irrigations. However, this practice of irrigation is still in use in some of the coconut growing areas of Tamil Nadu, Andhra Pradesh and Karnataka. Most of the coconut growing soils of Kerala are not suitable for this type of irrigation. If there is no dearth for water, one can go for flooding but there are many problems associated with this type of irrigation.

Basin irrigation

In basin irrigation water is applied in the basins of 1.8 to 2.0 m, which is the active root zone of coconut. Irrigation channels are provided in between two rows and each basis is connected with the channel. In this method there will be some loss of water due to deep percolation, seepage and evaporation. However, this loss is reduced when basins are irrigated through hose pipes (Dhanapal *et al.*, 1999), where only limited area of the coconut field is wetted. Application of 200 litre of water once in 4 days in the coconut basin in red sandy loam soil is sufficient to bring about significant yield increase in coconut.

Sprinkler or Perfo-irrigation

Sprinkler irrigation or perfo-sprays are most suited to inter or mixed cropping systems, where the entire surface requires wetting. Perfo-irrigation is a kind of sprinkler irrigation where small holes are formed throughout the pipe length through which water is forced out in small sprinkle.

Systematic studies based on the climatic approach on irrigation requirement of West Coast Tall (WCT) coconut palms were conducted at CPCRI Kasaragod during 1976-1985 in red sandy loam soil. The response to three depths of irrigation water (IW) viz., 20,40 and 60 mm at three frequencies based on IW/CPE ratio of 1.00, 0.75 and 0.50 were studied. Palms irrigated with 20 mm of water at IW/CPE ratio of 1.00 produced the highest cumulative yield of 918 nuts per palm followed by the same depth of irrigation at 0.75 IW/CPE ratio (872 nuts per palm). The mean yield of the palm under the above treatment viz., IW/CPE ratio of 1.00 and 0.75 with 20 mm IW were 123 and 121 nuts per palm per year, respectively (Anon., 1988).

Drip irrigation

Water is applied over a long period to meet the water requirement. To avoid wastage and to suit the infiltration rate water is applied at frequent intervals. Water is applied near or into the plants root zone.

Water spread

In trickle irrigation the water distribution for different soils is an important factor to be understood before initiation of irrigation as the volume of roots wetted has relationship with the quantities of water uptake. Soil water distribution is determined by the soil properties and by the way water is added and withdrawn from the profile.

A minimum of 15 to 20 percent of the active root zone should be wetted to absorb the water required by the palms. Results of the experiment conducted at CPCRI has shown (water spread from a single point source) that at least four emitters are required for the laterite and red sandy loam soil, whereas for the sandy soil, six emitters are required. Water spread recorded in these soils is shown in Table 1.

***Table 1.** Moisture distribution pattern in coconut basin under drip irrigation*

Soil Type	Water spread (cm)		% active root zone wetted *
	Horizontal	Vertical	
Laterite soil	60	100	28.8
Red sandy loam	61	115	31.0
Sandy soil	34	110	10.2

* For four emitters

Emitter/Microtube placement in the coconut basin

Studies on the coconut root absorption indicate that 0.75 m to 1.25 m away from the bole is the active absorption zone and hence it is recommended to place the emitter/microtubes in the centre of this zone (1 m away from bole).

Effect of drip irrigation for nut yield

Based on a study conducted at Kozhikode, it was concluded that yield of coconut with drip irrigation @ 30 litres palm^{-1} day^{-1} during January to May was comparable to basin irrigation @ 600 litres palm^{-1} week^{-1}. Thus, there was 67 percent saving of water in drip irrigation. Drip irrigation demonstration for coconut with 50 litres palm^{-1} day^{-1} in various districts of Kerala by CWRDM during 1985-88 has shown that the yield of nuts improved significantly from 3rd year after start of irrigation.

Significant response in nut yield has been reported due to drip irrigation in different soil types when compared to the yield in rainfed control palms. In the drip irrigated experiments with West Coast Tall palms, the palms under different levels of drip irrigation showed significantly higher yield than the rainfed palms. Among the irrigated treatments, higher level of irrigation (66% and 100% of Eo) recorded significantly more number of nuts (89.8 to 98.2 nuts per palm per year) compared to the lower level of irrigation (33% of Eo, yielding 52.6 nuts per palm per year) under drip. In the experiment with high yielding hybrid, COD x WCT, pooled data on nut yield for six years (1993-99) showed no significant difference among levels of drip irrigation at 66 and 100% of Eo and between the drip and basin irrigation. Drip irrigation at 33% of Eo failed to produce significant yield increase over rainfed control. The highest nut yield (119.7 nuts palm^{-1} year^{-1}) was however observed under the drip irrigated treatment at 100 percent of Eo, which and was on par with the treatment drip irrigation with 66 per cent of Eo (113.6 nuts) and the basin irrigation (116 nuts).

Table 2. *Influence of irrigation and mulching and their interaction on coconut nut yield (pooled data for four years) in littoral sandy soil*

Irrigation treatment	Nut yield/palm/year		
	No mulch	Mulch	Mean
T1: 66% of Eo through drip	57.5	78.4	66.2
T2: 100% of Eo through drip	65.6	78.4	72.0
T3: 133% of Eo through drip	53.2	66.6	59.9
T4: 100% of Eo (Basin irrigation)	59.9	63.4	61.6
T5: Rainfed	30.1	23.7	26.8
Mean	53.3	61.4	-

(Dhanapal *et al.*, 1998)

Coconut yield under drip irrigation with 30 and 45 litres per day per palm was at par with basin irrigation at 600 litre per palm per week. The main reasons for 34 percent water saving in the 66 percent of Eo through drip treatment were the reduction in the quantity of applied water and avoidance of loss due to deep percolation. Though more water was applied under 100 and 133 percent Eo under drip and basin irrigation, it did not contribute towards higher yield, probably because the excess water might have moved beyond the root zone and was not used by the palms. Venkiteswamy *et al.* (1997) reported that nut yield under drip irrigation at 100 percent of Eo was at par with basin irrigation at IW/CPE ratio of 1.0.

In drought prone gravelly soils of the Andigama series (Red Yellow Podzolic) in Madampe, Sri Lanka, irrigation through four drippers placed equidistant in the circumference of a circle of radius 100 cm around the base of the tree and discharging water at the rate of 30 litres h^{-1} for 2.5 h wetted a large volume of soil in the effective root zone (Arachchi, 1998).

A trial conducted to evaluate the economic viability of trickle irrigation on a full bearing coconut plantation in the south Saurashtra region of Gujarat, India indicated that it could save 45-50% water over surface irrigation without any significant reduction in yield (Kapadiyal *et al.*, 1998). With the water thus saved one hectare extra could be brought under irrigation thereby increasing the net income of the farmers.

The available soil moisture was higher by 22.2 to 28.8 percent in the drip irrigated basins under mulch compared to drip without mulch. In basin irrigation also, on fourth day after irrigation, the available soil moisture stored in the mulch treatment was 36.8 to 37.6 mm and it was 18.2 to 19.9 mm in the absence of mulch indicating higher level of moisture depletion. Similarly, there was reduction in the soil temperature under irrigated, mulched plots by 1.6 to1.7° C compared to non-mulched rainfed plots at 15 cm depth. Drip irrigation alongwith mulching will be a useful practice with regard to both soil moisture conservation and soil temperature regulation in case of littoral sandy soil (Maheswarappa *et al.*, 1998).

Pooled data on nut yield for four years showed that there was no difference among drip irrigation treatments in littoral sandy soil and between drip and basin irrigation (Table 2). Nut yield under all irrigated treatments were at par with each other but were significantly superior to that of rainfed control.

Based on a study conducted at Kozhikode, it was concluded that yield of coconut with drip irrigation @ 30 litres per palm per day during January to May was comparable to basin irrigation @ 600 litres per palm per week. Thus, there was 67 percent saving of water in drip irrigation. Drip irrigation demonstration for coconut with 50 litres per palm per day in various districts of Kerala by CWRDM during 1985-88 has shown that the yield of nuts improved significantly from 3rd year after start of the irrigation

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J. Indian Soc. Coastal agric. Res., 22(1&2), 86-91, 2004 **Invited paper**

Use of Simulation Models for Identifying Waterlogged Areas

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Over-exploitation of groundwater and excessive irrigation in major canal commands have posed serious problems of water table management in India. Borewells are drilled and canal networks commissioned without proper assessment of their impacts on ground water behaviour. Falling and rising water levels are two major consequences of improper planning and use of ground water and surface water resources in the country. In several parts of India declining ground water levels are in the order of 1-2 m per year. At the same time, in some irrigation commands water table rise is as high as 1 m per year. Therefore, it is essential to carry out the impact analysis of ground water utilization and canal irrigation on ground water behaviour. Ground water models can be used to simulate the effects of various development, management and use scenario on the ground water behaviour to predict the water table rise or fall. In the present study undertaken in the Indo-Gangetic plains of western Uttar Pradesh of India ground water table simulation was done using the PMWIN for the years 1990-91 and 1994-95 to calibrate and verify the model. The simulation revealed that the predicted water table fluctuations were by and large in close agreement with the observed water table fluctuations. An attempt was made to study the effect of anticipated irrigation canal network in the study area and it has shown water table rise by 1.5 m in both the stress periods. Although the spreading of waterlogging and salinity has been monitored in some command areas, no data on future prediction of the waterlogging and salinity in the irrigation commands has been developed in India. The use of models for the delineation of waterlogged, potential and critical areas for waterlogging has been shown in this paper.

(***Key Words***: *Groundwater, PMWIN, MODFLOW, Canal seepage, Waterlogging*)

Though the development of tubewell irrigation has contributed significantly to the increase in food production and reduction in poverty, sustainable development and management of this resource has posed many challenges in recent years. The major problems associated with the ground water development and management are over-exploitation in several parts of the country, waterlogging and salinity due to rising water table in major irrigation commands, and ground water pollution. The number of ground water structures in the country increased from 4 million in 1950-51 to 18 million in 1996-97 (Thakkar, 1999). If over-exploitation of ground water has posed problems in ground water irrigated areas, large areas in major irrigation commands suffer from waterlogging and salinity due to seepage and excessive irrigation. This has over-shadowed the planned benefits from the irrigation projects. On the basis of past developments, it is estimated that the rate of spread of waterlogging and salinization in coming years may increase from 30,000 to 60,000 ha per year (Singh, 1998).

Ground water models play an important role in conducting ground water studies and analysing future scenario. If constructed properly, the models represent the complex relations among the inflows, outflows, change in storage, and movement of water and many other important features in the ground water system. A well defined model approximates the aquifer process and gives an idea about the behaviour of the ground water system in response to different stresses (Hawkins *et al.*, 1983). Ground water models can be used to estimate the response of the system to various development options and provide insight into appropriate management strategies (Houstan *et al.*, 1983). An accurate estimation of water table fluctuations helps in controlling the changes in ground water regime by selecting an appropriate scheme of recharging and pumping (Manglik, 1998). In this paper, an attempt has been made to calibrate and validate a ground water flow model and demonstrate its application in identifying the waterlogged area.

MATERIALS AND METHODS

Study area

The study area was located in Bulandshahar district in Uttar Pradesh falling under western parts of Indo-Gangetic plains lying between 28° to 28°45'N latitude and 77°15' to 78°30' longitude (Fig. 1).

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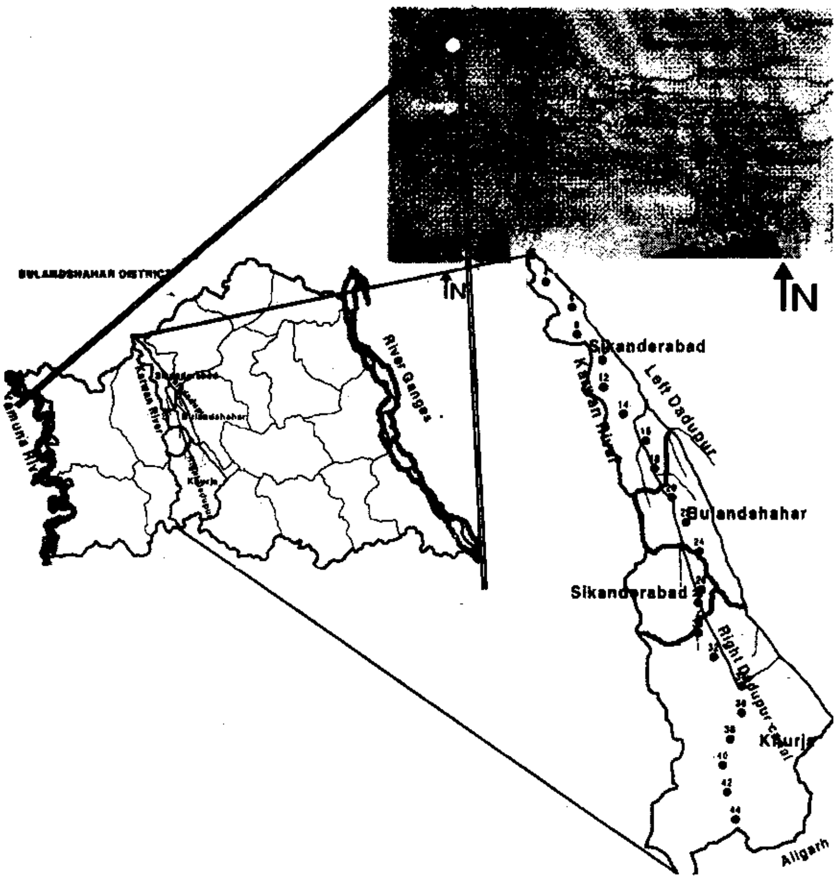

Fig. 1. *Location of the study area*

Bulandshahar district is drained by river Ganga in East, Yamuna in West and their tributaries namely, Kali, Nim and Karwan. The district lies on the quartenary alluvium comprising sand, silt and clays of various proportions. The soil profile description revealed that most of the top 3 m depth was clay loam. Depth of tubewell was restricted to only the first aquifer, which in general behaved as unconfined aquifer. Impervious layer was encountered at 91.46 m in Sikanderabad, 73.17 m in Bulandshahr, and 79.26 m in Khurja blocks below ground surface.

The annual average rainfall in the district varies from 670-800 mm, most of which is received in 3 months (June to October) of monsoon period. The mean monthly maximum relative humidity in the morning and evening is 83 and 72%, respectively during the month of August, and mean monthly minimum being 36 and 19%, respectively during the month of April.

The longterm ground water table fluctuations data showed that the depth to water table in Bulandshahar district varied from 3 m to 14 m spatially in the pre-monsoon month i.e., May. Only in the 19% of the district area, the water level less than 5 m below ground level (b.g.l.) had been observed and in the rest of the area the water levels were greater than 5 m. Close to canal, the depth to water level ranged between 3 to 5 m, which can be classified as potential waterlogged area.

An area of 36867 ha bounded between the Left Dadupur distributary of upper Ganga Canal and Karwan river (Fig. 1) was selected for simulation. The simulation area covered parts of Sikanderabad, Bulandshahar and Khurja blocks of the Bulandshahar district. The study area was irrigated by ground water and canal water both. Excessive seepage from the unlined distributary, minors and water courses and over-exploitation of the ground water in some part were adversely affecting the ground water equilibrium. The long term data of cropping pattern and ground water utilization revealed that area under crops increased from 340734 ha in 1990-91 to 345976 ha in 1994-95, and number of ground water withdrawal structures increased from 35945 in 1990-91 to 37907 in 1994-95 (Anon., 1994, 1995, 2000 a,b).

Table 1. *Input and output parameters for processing MODFLOW for windows*

1. Input parameters	Representation in the model
1. Mesh size	Columns x Rows
2. Layer type	Confined/Unconfined/both etc.
3. Boundary conditions	Constant Head/Varying Head/No flow
4. Top and Bottom elevation of the aquifer	Above mean sea level
5. Stress periods and Time steps	Monsoon, non-monsoon, months and days etc.
6. Starting Values	Initial Hydraulic heads
Aquifer properties	
7. Horizontal & Vertical Hydraulic Conductivity	
8. Transmissivity	
9. Specific yield / Effective Porosity	
Time dependent parameters	
10. Well draft	Pumping Rate
11. River flow	Hydraulic conductance of the riverbed, head, bottom elevation
12. Recharge	Recharge Rate
13. Evapotranspiration (ET)	Maximum ET rate, ET surface elevation, ET extinction depth
2. Output parameters	
1. Hydraulic Head	Above mean sea level
2. Drawdown	Depth
3. Cell-by-cell flow terms	Volume
4. Water Budget (Zone/Cell wise)	Volume

The top of the aquifer elevation ranged from 194 m to 207 m above mean sea level. Inflows to the aquifer system were from canal seepage, infiltration from the rainfall, inflow from the neighboring aquifer and return seepage from irrigation, etc. The outflows from the system were groundwater pumping, outflow from the aquifer and evapotranspiration.

Model details

To conduct the simulation of the ground water table fluctuations, a ground water flow model, PMWIN was selected. PMWIN is a simulation system for modeling ground water flow and transport processes with the modular three-dimensional finite difference ground water model MODFLOW of U.S.Geological Survey, the particle tracking model PMPATH for Windows, the solute transport model MT3D, and the parameter estimation program PEST (Wen-Hsing *et al.*, 2002). The area was divided into 324 square grids of 1.17 km^2 each. The time domain was divided into stress periods and time steps matching the pre-monsoon and post-monsoon periods. Input required and output generated by the model are given in Table 1.

Classification of waterlogged areas

The following are the common approaches to express the water table depth below soil surface for classifying the waterlogged areas.

i. Depth to water table, pre-monsoon (April/May)

ii. Depth to water table, post-monsoon (October/ November)

iii. Average water table depth over a season or year

iv. Sum of excess water days above a specified depth of Water table

Even though, all the four approaches are of interest for one or other purpose the most important approach appears to be defining waterlogged areas based on the depth of water table during pre-monsoon or post-monsoon periods. A low water table in pre-monsoon is essential to avoid salinity build-up in the root zone depth and successful crop production of monsoon period (*kharif*) crops. Equally, important is the optimal low water table in post-monsoon, keeping in view the timely planting of the winter (*rabi*) crops.

Keeping the above points, the following norms are suggested for the classification of different categories of waterlogged areas.

Pre-monsoon criteria

i. **Waterlogged area** : Water table within 2 m from ground level.

ii. **Critical areas** : Water table from 2 to 3 m below ground level.

iii. **Potential areas** : Water table from 3 to 5 m below ground level.

Post-monsoon criteria

i. **Waterlogged are** : Water table within 1 m from ground level.

ii. **Critical Areas** : Water table from 1 to 2 m below ground level.

iii. **Potential Areas** : Water table from 2 to 3 m below ground level.

RESULTS AND DISCUSSION

Results of the simulation are presented through Figs. 2 to 4. For better graphical presentation, comparison of the observed and predicted water table behaviour has been done for the middle cells of the alternate rows i.e., 2,4,6,.....44.

Calibration of model

Calibration of the model was done for the year 1990-91. Calibration results are presented in Fig. 2, which compares the results of observed and predicted water table fluctuations in the post-and pre-monsoon periods. It can be seen from the figure that, in general, the predicted and observed water tables are in close agreement.

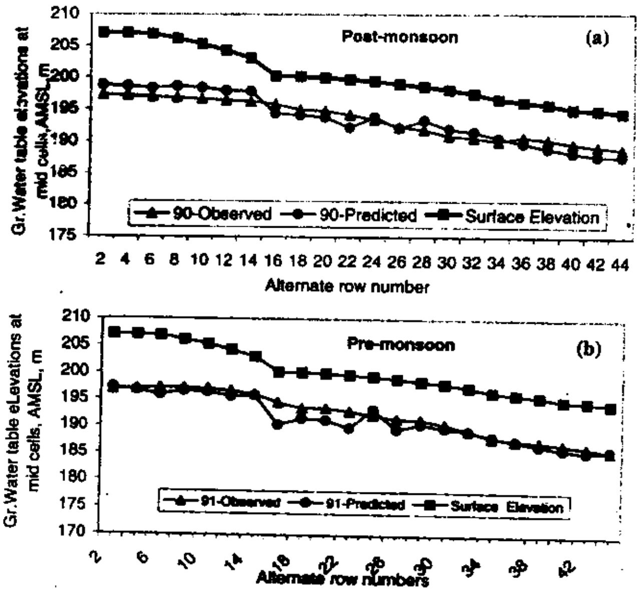

Fig. 2. *Comparison of predicted and observed groundwater table with respect to ground surface elevations during 1990-91 (AMSL - Above Mean Seal Level)*

Scenario analysis

It was expected that the spread of conjunctive use of ground water with surface water, especially in Punjab, Haryana and Western Uttar Pradesh of India, would substantially reduce waterlogging, but there were no studies to establish this (Thakkar, 1999). Therefore, it was essential to analyse the impact of these factors on ground water behaviour, so that appropriate corrective measures could be suggested for sustainable utilization of ground water resources. In order to study the effect of existence of canal system and parallel ground water pumping, scenario analysis was carried out incorporating the various levels of ground water pumping and recharge. The scenario generated through simulation are described below.

Prediction of water table fluctuations with increased canal seepage

To study the effect of increased recharge through canal seepage (anticipated introduction of new canal network) on ground water table rise, a simulation was carried out by increasing the recharge rate to 1.5 times of the 1994 recharge. The results are presented in Fig. 3. It could be seen from the Fig. 3 (a,b) that pre- and post-monsoon watertable has gone up by about 1.5 m on an average. It is also observed from the figure that in the middle reaches of the study area, watertable has come up to the ground surface, which may create a waterlogging situation. This kind of behaviour of the ground water table should be kept in mind, while planning for a new canal network in the study area.

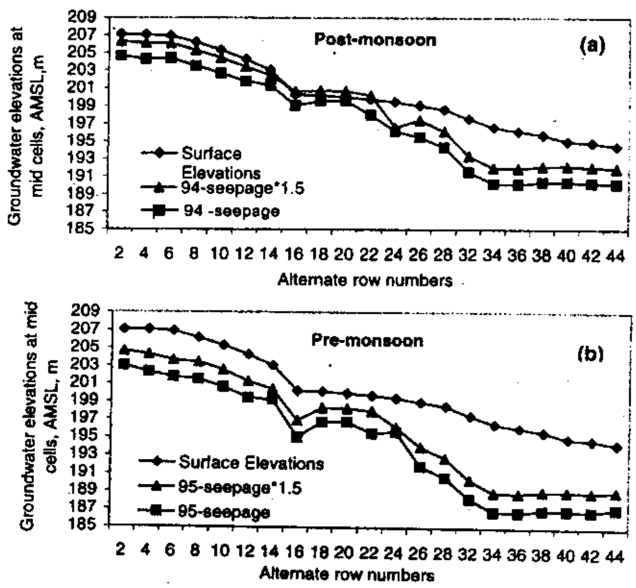

Fig. 3. *Predicted groundwater tables when canal seepage was increased by 1.5 times of 1994-95*

Table 2. Post-and pre-monsoon waterlogging conditions in 1994-95

Sl. No.	Name of the Block	Total area ha	Critical area ha	Potential area ha
Post-monsoon -1994				
1.	Sikanderabad	9836.66	262.73	755.35
2.	Bulandshahar	4568.5	1437.06	1020.14
3.	Khurja	22462.6	197.22	376.69
Pre-monsoon -1995				
4.	Sikanderabad	9836.66	24.59	607.51
5.	Bulandshahar	4568.5	0.0	2661.24
6.	Khurja	22462.6	0.0	349.96

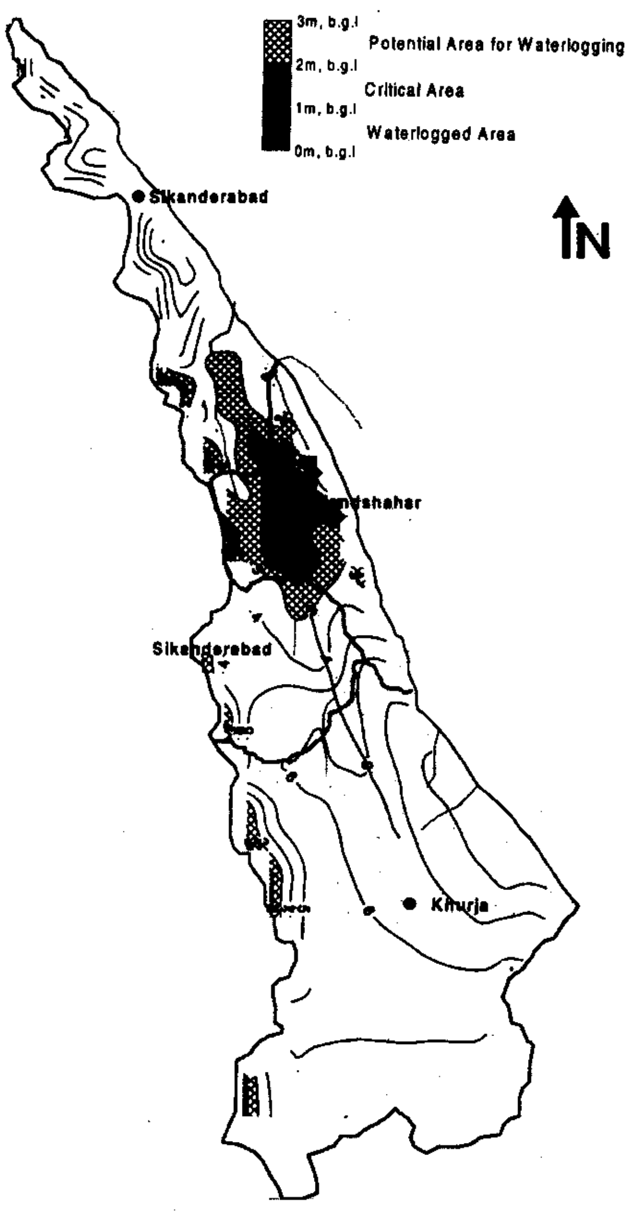

Fig. 4. *Water table condition during post-Monsoon 1994 (Predicted with MODFLOW)*

Identification of waterlogged areas

From the above results, it is interpreted that the rise of water table due to canal seepage is compensated by the fall of water table due to ground water pumping to a greater extent. This reveals that the conjunctive use of ground water with surface water reduces the problem of waterlogging substantially, and recharge of ground water through canal seepage reduces the problem of ground water table decline to a great extent. Therefore, this kind of simulation study will help in evolving an appropriate conjunctive use plan for proper utilization of surface and ground water resources without causing the problem of waterlogging and depletion of ground water resources.

In order to identify the waterlogged area and critical or potential are for waterlogging, the criteria described in the earlier section were used. The simulated results of the year 1990-91 and 1994-95 were used for delineation of these areas. Isobath maps were drawn for both the pre- and post-monsoon simulations. To generate the contour maps, computer software SURFER 3.2 was used which has interpolation capabilities and better display properties.

The results of the simulation were used to delineate the waterlogged regions in the study area in the year 1990-91 and 1994-95. The delineation was done using the criteria described earlier and some of the results are presented in Fig. 4 and Table 2 which revealed the potential and critical areas for waterlogging in parts of Sikanderabad, Bulandshahar and Khurja blocks falling under study area.

CONCLUSIONS

Simulation results revealed that the predicted values of water tables are in close agreement with the observed value in pre- and post-monsoon period of the simulated years. Using the model, it was possible to predict the potential and critical waterlogged areas, if the parameters for simulation are estimated carefully. Though the irrigation is intensive in the study area, absence of extensive waterlogging can be attributed to the outflow of the aquifer into the adjoining areas and proper drainage facilities. In Indian irrigation commands, with the help of ground water flow models, the future soilwater regime can be predicted well in advance to combat any eventuality.

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Practical Approach for Reclamation of Deltaic Waterlogged Areas

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Conventional surface drainage measure alone could not fully reclaim the lowlying waterlogged area of Mahanadi coastal delta because of flat, saucer shaped topography. This was integrated with land modification technology to cater lowland pockets in the suffered area for arriving at a total solution package for the system. Hence, a lowlying pocket of a poor farmer's area (2212 m²) was developed into a raised bed system-cum-pond in 1:2.7 ratio which could not be drained through surface drainage measure. The technology of two small ponds in the system, one in 1022 m² and the other in 600 m², was to cater the requirement of fish seeds, which was not available in that area during July-August. The benefit accrued from the system was 40% more than the adjoining lowland. A scaffold covering 15% area of small pond was constructed and hung over to create additional space for creeper vegetables. The additional net economic return from the modified landform system over the prevailing landform system was estimated at Rs. 30,682 ha⁻¹. Benefit-Cost Ratio after 3 years data showed marked improvement than conventional system.

***(Key words:** Surface drainage, Integrated farming, Raised bund, Economics)*

About one-third of the world's population (about 2 billion) is living along the seas within100 km from the coastline. In this strip, the deltas and lowlying areas are found and the main impediment for production is waterlogging. The main cause of waterlogging in coastal area is due to drainage congestion, which is due to flat topography, saucer shaped land, higher time of concentration and ingress of high tidal water into the rivers/creeks. Some of the hydrological situations that are encountered in the coastal waterlogged areas are limited water during the seedling stage, excess water at transplanting as well as at later growth stages, excess water during initial period and less water during later growth period, and seawater intrusion during cyclone to cropped area. Keeping this in view a practical approach was attempted for reclamation of waterlogged area in Mahanadi delta system in Biswanathpur village of Puri district.

MATERIALS AND METHODS

The total geographical area of Biswanathpur was 396.95 ha out of which 134.16 ha was waterlogged in which severity in waterlogging in relation to crop damage was only in 62 ha. In this 62 ha, nothing grew throughout the year. This situation was created due to the higher elevation of land surrounding this patch namely, the Bhubaneswar-Balipatna Road on one side and Bodhakhandi village on other side. The climate was subtropical and subhumid with distinct characteristics of high annual rainfall (1482 mm), high relative humidity (74-95%) and high summer temperature (41°C). The soils were fine textured Mahanadi alluvium, underlain by heavy clay and silt deposits with impeded drainage and poor transmission characteristics. The soil fertility status is high and capable of producing bumper crop yield if brought under suitable drainage measures and agro-production techniques. The rainfall and evaporation data for last 10 years were analysed on probalistic basis. On an average, the water level appeared above surface from 3rd week of June, reached maximum during first week of August, started receding after that, and remained above ground for nearly six months in a year. Watertable depth below ground level varied form 5 cm to 167 cm during post- monsoon period (December to June). For alleviating waterlogging, surface drainage system was developed. Still some area was left which could not be drained by main system due to topography. Therefore an alternate land modification approach was considered.

Methodology for land modification

In this system, a lowlying holding of 2212 m² was developed into raised bed and pond areas in 1:2.7 ratio by excavating earth from two ponds i.e., from 1622 m² area (one 1022 m² + and the other 600 m²) and spreading it uniformly over 590 m². The pond side slope was protected with normal grass and sometimes creeper above grass. The raised bed

Table 1. *Yield and economics of pond and raised bed system*

Season	Crop	Crop yield (q)	Gross return (Rs)	Cost of cultivation (Rs)	Net return (Rs)
Kharif	**Ladies finger**	2.08	2496.00	543.00	1953.00
	Brinjal	3.00	3000.00	271.00	2729.00
Rabi	**Tomato**	1.20	1200	302.00	898.00
	Ladies finger	2.08	2496	543.00	1953.00
Summer	Chilli	2.00	1800	1357.00	443.00
***Bund* plantation**	Pumpkin	0.50	200	50.00	150.00
	Papaya	3.00	900	150	750.00
	Banana	9 bunch	1350	81	1269.00
	Cowpea	0.5	250	15	235.00
	Green leaf	0.05	50	10	40.00
Pond	Bitter gourd	0.62	620	35.00	585.00
	Fingerling	1200 nos.	1200.00	450.00	750.00
	Big fish	0.75	3150.00	950.00	2200.00

*A space of 183 m^2 for vegetables and 224 m^2 for bund vegetables and 90 m^2 for scaffold was earmarked

height was 1m from local ground surface and *bund* was 0.3m above raised bed to avoid inundation by accumulated rainfall and runoff in surrounding plot reaching a maximum height of 0.85 m above the ground during peak monsoon. The methodology of planning two ponds was that in the small pond frylings would be cultured and after 6 to 8 weeks, frylings being converted into fingerlings would be left in the big pond as availability of fingerling was limited during that period. A combination of bamboo-coir rope scaffold was constructed and laid over 15% area of 2nd pond (90 m^2) to provide additional space for the spread of creeper vegetables, which required limited land for root anchorage (Anon., 2003). Different vegetables were grown on small plot basis in the modified bed in *kharif* and in *rabi* for 3 consecutive years (2001 to 2003). The pond water was utilized for fish rearing and protective irrigation during *rabi* and summer. The same crops were simultaneously grown in the adjacent undeveloped lowlying areas on a small scale for comparative evaluation with same agro-production technique and management.

RESULTS AND DISCUSSION

The economics of raising crops in the modified land system has been presented in Table 1. The net return from adjacent lowlying area (2212 m^2) was Rs. 4898. In the adjacent lowlying land only paddy was grown with very low yield (1 t ha^{-1}) in *kharif*, whereas in modified system different types of *kharif* vegetables like ladies finger and brinjal were successfully grown.

Economics of the system

The comparative economics of vegetable cultivation, fish cultivation and *bund* plantation are presented in the Table 1. Economics of the system is presented in Table 2. The annual cost of the system was taken as 10 percent of the construction cost excluding cost of cultivation for vegetable or fishes, etc. It is seen from the data that on an average the B.C ratio was 2.45 in comparison to control

Table 2. *Economics of the system*

Cost Items	Cost of type of improvement (Rs)	
	Pond-Raised Bed	Low lying land
Two pond system	2200.00	-
Scaffold	70.00	-
Cost of cultivation	4757	6920
Gross return	18712	11,878
Net return	11,685.00	4898.00
B: C Ratio	2.45	0.70

(0.70). When bund plantation would come into effect and the system would be integrated with duckery and poultry, and the B.C. ratio should increase in next few years. It is proposed to start poultry and duckery next year. On the other hand in the modified landform system the net benefit was Rs. 11,685, which accounted for Rs 52,825 ha^{-1} $year^{-1}$. Maximum benefit was due to the increase in cropping intensity, integrating *bund* plantation, and fishery in the system, as well as better utilizing the pond area through coir rope scaffold for creeper vegetables. It was seen that the adjoining lowlying land of 2212 m^2 area rendered a net monetary return of Rs. 4898 $year^{-1}$ equivalent to Rs. 22,142 ha^{-1} $year^{-1}$.

CONCLUSIONS

The modified landform system alongwith two pond system is a feasible practical approach alongwith conventional surface drainage measures in the vast lowlying area of coastal delta of Mahanadi basin. This simple cost effective technology adopted in a poor farmer's field in lowlying area on participatory basis can easily be extended to all resource poor farmers of this region.

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Drainage System for the Reclamation of Coastal Saline Soils of Pondicherry Region

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Bahour soils in the coastal region of Pondicherry are characterized by the black montmorillionte clay. The ground water salinity and the ferrous sulphide hikes are problems leading to crop injuries reported in the recent periods. Lack of drainage had substantially enhance soil salinity. Here, the clay layer is underlain with palaeotype bed having thick succession of sands. Hence the open drainage system and also vertical drain lines are the suggestive measures for the saline soil reclamation.

(***Key words:*** *Open surface drainage, Vertical drainage, Sulphide in soil)*

Bahour soils in the coastal Pondicherry region in this Union Territory had been developed in the alluvial plains of the flat lands. This Soil Series is a member of Montmorillionite Isothermic family of the Vertic Ustropepts. The vertic development was due to the transformation of calcite, mica, then iron and manganese in mineral phases. In the closeby village of Kuruvinatham, the quartz deposition was done by river meandering. This Soil Series is in association with the Mannadipet Series.

Recently in Bahour, the farming has been under threat due to ground water salinisation which in turn had affected the soil, eventhough the Pondicherry coastal zone is in the zone of active dynamic recharge of fresh water replinishable annually. The drainage facility was not provided so far to remove the built-up salinity in soil. Further, the Bahour soil show black colouration due to transformation of sulphate to sulphide ions. The experts from the Agricultural Research Institute, Karaikal had termed this as acid sulphate soil. The soil salinity and sulphide injury had adversely affected the rice productivity. Hence, artificial drainage system is needed for remedy.

Characteristics of vertisols of bahaour series

Bahour soils are characterized as sub-angular blocky but hard, firm, sticky and plastic. The vertisols of the Bahour series have in general pH 8.3, clay 55 to 65%, silt 10%, swelling 65%, CEC 40 Cmol$(p^+)kg^{-1}$, infiltration rate 2 to 3 mm hr^{-1}, dispersion 28%, CaCO3 >10%, NPK status, Low-medium, and micronutrient status in Cu, Zn and Bo as deficient (Murthy *et al.*, 1992).

Status of water quality

Due to failure of monsoons during the past two years of 2002 and 2003, the drought situation prevailed. The extraction of ground water was executed from below 200m depth, and stopped with salt water intrusion into aquifer took place indicated by rice in salinity. Further, the sulphate transformation to sulphide ions in redox condition had injured completely the rice crops grown in this area. Hence, it is recommended to avoid the application of the organic manures and the sulphate chemicals in this soil.

Suggestion for drainage facilities by drainage pattern

Drainage provides benefit of oxygen diffusion to the root zone, warming of soil, avoidance of nutrients losses and salt build-up in upper soil layers. The surface drainage not only includes the removal of excess water by land grading/ smoothing/field drains but also the diversion of water so that it does not reach the area to be protected. Design of surface drainage system is dependent on topography, climate, geological conditions, soils, crops grown and cultivation practices adopted.

For drainage in bahour soil series it is recommended that the slopes (<0.5%) and the ridges should be minimal, surface drainage through V-trapezoidal open ditch channel with lateral drains spaced 30 m apart to remove the excess water periodically to the main outlet, and finally to divert this water to the main roadside drainage at a distance of 4 km away.

Since a granular thick sandbed layer is underlain in the Bahour Soil Series, the soil salinity can be reduced by leaching with fresh water in the permeable layer. The thick sandy soil absorbs the salt water quickly. Hence, it is suggested to explore vertical drainage also. A series of small well rings of 60-120cm diameter are dug out preferably in the main channel by removing the clay barrier at the top spaced at a distance of minimum 200m in the outlet canal. The rings are required to be provided with fine asbestos grits to avoid clay plugging.

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Seawater Intrusion in Mangrol Coastal Aquifers: Possible Technical and Institutional Measures

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The Mangrol coast of Saurashtra, Gujarat is heavily affected by seawater ingression. Netravati basin which forms part of this coastal tract is the study area of IWMI-AKRSP collaborative project on salinity mitigation in coastal Saurashtra. Three villages located at head, middle and tail reaches of the basin and having varying degrees of seawater ingress were selected as sample villages and systematic data collection was carried out for a period of three years from 2000. Data relating to rainfall, recharge, pumping, ground water quality, crop, cropping pattern, yield and profitability to farmers were collected based on 90 observation wells located in the three selected villages; in addition, baseline data of all the 25 villages located in the basin and secondary data from Salinity Prevention Cell were also collected. The data analysis indicates that over-extraction of ground water exceeds 300 % of recharge in drought years, and there is landward movement of seawater ingression which varies with rainfall. Using rainfall- recharge relationship (developed in this study), a procedure is devised to control over-extraction of ground water which, if implemented with stakeholders participation, salinity level can be reduced to an allowable limit of 2000 ppm of TDS in the next 10 years.

(Key words: Seawater intrusion, Watershed, Technological interventions, Ground water, Economics)

Netravati watershed of Mangrol coastal belt of Junagadh district, Gujarat is a small coastal watershed of about 197 square kilometer; it is affected by seawater ingress which has perceptible landward movement during years of drought. From among 25 villages within the watershed three villages viz., Kankasa, Chandwana and Karamdi-Chingaria located at a distance of approximately 5, 8 and 12 km, respectively from the coast were selected for this study. Kankasa is a salinity affected village occupying about 813 ha; Chandwana is at the fringe of salinity affected area with a geographical extent of about 1023 ha, while Karamdi-Chingaria occupying 864 ha is located in the upper reach of the watershed and is free from salinity for drinking and domestic purposes. Salinity intrusion being a major problem in this coastal reach, technological interventions like artificial recharging, construction of spreading channels and tidal regulators, etc. were introduced by the government and non-government organizations working in the area to arrest seawater ingress. However, they lack systematic and holistic approach and no proper managerial interventions were made hitherto to alleviate the menace of seawater ingress. Therefore, a scientific study was undertaken to determine the effectiveness and efficacy of such interventions in watershed context considering climatic, geo-hydrological and social factors to offer possible technical and institutional measures to effectively arrest the seawater ingress.

MATERIALS AND METHODS

In three villages viz., Kankasa, Chandwana and Karamdi-Chingaria selected as sample villages intensive data collections were carried out in addition to collecting baseline data from all the villages located within the watershed; the detailed data collection included water level variation in 30 sample wells from each sample village (both recharged and non-recharged), pumping details, crops grown and other socio-economic and hydro-meteorological data; water quality data were collected both during pre-and post-monsoon seasons. The data collection was carried out for three years for Kankasa and one year for the other two villages. In addition, secondary data have also been collected from agencies working in this watershed.

RESULTS AND DISCUSSION

Important characteristics of selected villages

Agriculture is a major source of occupation for 65 percent population of the watershed followed by livestock on which only six percent population depends. A total of 77 percent land was under cultivation in the watershed, out of which 66 percent land was irrigable. According to the census data 2001, 25 percent watershed area was irrigated against 21 percent irrigated area of the Mangrol *Taluka*. Hardly four percent land was under forest, which indicated limited opportunities for soil and water conservation in the common land. Well density and well depth were increasing while depth to ground water from land surface increased in all three villages indicating over-development of ground water. Out of total gross cropped area of the watershed, *kharif* groundnut occupied 85 percent, followed by wheat with 36 percent, *rabi* bajra with seven percent, *kharif* bajra with two percent and coconut with three percent. Cropping pattern shows that agriculture economy of the area largely depends on *kharif* crops.

Rainfall

An analysis of regional rainfall pattern of the last 42 years showed that maximum amount of rainfall occurred in the month of July in wet (good rainfall) years, August in dry (low rainfall) years, and September in normal rainfall years. Number of below mean annual rainfall years is more than above mean annual rainfall years. Intensity of daily rainfall was very high. As much as half the annual rainfall in wet years occurred in one day. In a monsoon season, there were only five days that received more than 100 mm rainfall, even in the wettest year 1988. Sometimes, rainfall in dry years (below normal years) could not generate sufficient runoff to recharge the exploited ground water aquifer, while high intensity rainfall in above mean annual rainfall years generated surplus runoff that could not be stored by the existing storage structures and hence such rejected runoff emptied into the sea. The rainfall pattern suggests that more number of large and small storage structures is required in the upper and middle reaches of the watershed along with seawater ingress preventing structures in the coastal belt.

Ground water recharge

Kankasa is endowed with miliolite lime stone geology, having permeability of about 200 metre per day with three percent specific yield; Chandavana is situated in Guj formation geology with low to moderate permeability of 60 metre per day with two percent specific yield; and Karamdi is having Deccan trap geology with low permeability of 25 metre per day with less than one percent specific yield (SIPC, 2002). There are no homogeneous extensive aquifers in this region. Aquifer characteristics varied from village to village.

Water level (measured from ground level) variations is maximum in deep well in all the villages. Similarly, water level in shallow well with and without recharge structure varied from 0 to 3.7 m and 1.5 to 4 m, respectively, while in deep well it varied from 1.4 to 8.6 m and 2.2 to 9.2 m, for with and without recharge structures, respectively. Water level variations showed that water depth was increasing in the wells after rainfall. However, water level in wells with and without recharge structure did not differ significantly, but the pattern of recharge with rainfall remained the same. There were two possible reasons for this behaviour: first, 70 percent of sample wells were having recharge structures; second, all wells irrespective of their recharge status were having horizontal bores that were drilled to different depths within wells. These horizontal bores expedited the recharge movement due to infiltrated runoff water received from the surrounding areas.

Total recharge volume[1] of Kankasa village for different years has been estimated using data on annual rainfall, average recharge depth and specific yield of geological formation (Table 1). The recharge depth as a function of rainfall showed that for every 100 mm of rainfall, the recharge depth increased by 0.8m.

Table 1. *Ground water recharge in Kankasa*

Year	Rainfall (mm)	Avg. Recharge depth (m)	Recharge volume in (ha-m)
2001	743	6.52	156.1
2002	277	2.14	51.3
2003 (June-July)	389	3.17	75.9
2003	686	4.65	111.3

Ground water draft

Pumping of well water was higher in deep wells and hence irrigated (wetted) land was also higher for deep wells. Wetted land received on an average 18 hours of irrigation per hectare per year. This amount of pumping was equivalent to an estimated groundwater draft of 0.55 ha-m per well per year. If we assume that all 289 wells located in Kankasa is in use, then the total quantity of groundwater draft comes to 158.81 ha-m, which is more than three times the effective utilizable groundwater recharge[2] (43.6 ha-m).

Ground water quality

Time series data collected from Salinity Ingress Prevention Circle (SIPC)[3] indicated that Shill village was the most affected by seawater intrusion

[1] Recharge volume = Average recharge depth (Maximum well water level - Initial well water level) during monsoon in m.

[2] Effective groundwater recharge is 8.5 per cent in the region (SIPC, 2002)

[3] SIPC has its own observation wells located across the Netravati watershed

as its ground water contained more than 8000 parts per million (ppm) of total dissolved solids (TDS). TDS was one of the indicators used to measure the effect of seawater intrusion in the study. After 1993, TDS content of ground water in Kankasa was rapidly increasing (Fig. 1). Comparative pre-monsoon TDS between 1990 and 1999 indicated that ground water TDS was very high in Kankasa, however, it came down with increase in distance from the Shill coast landward (Fig. 2). Similarly, TDS content in Chandvana ground water was gradually increasing (Figs. 1&2), however, TDS content of Bhatsimroli (adjoining village of Karamdi) ground water was fluctuating, which indicated that the village had inland salinity problem. Fig. 1 & 2 showed clear trend of gradual seawater intrusion from sea towards inland. However, last two years' TDS content in Kankasa village was showing declining trend mainly because of good rainfall years that raised a hope to restrict the process of seawater intrusion.

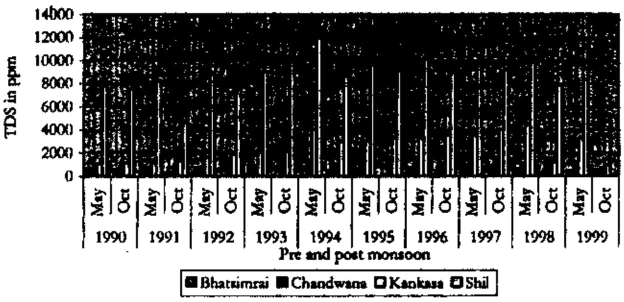

Fig. 1. *Spatial TDS variation in Netravati (1990-1999)*

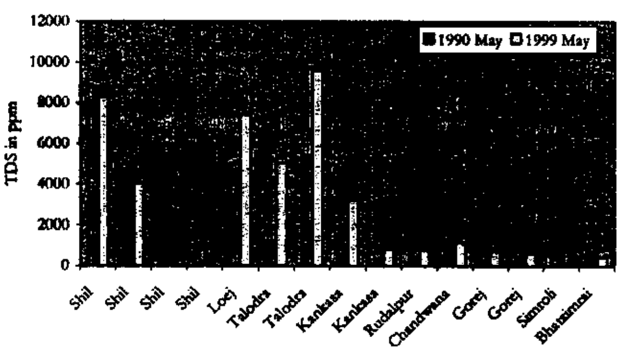

Fig. 2. *Temporal variation of TDS between 1990 and 1999*

Data collected from Kankasa during the study years (2002-2003) reflect that all shallow wells were located towards the sea, as reduced water level (RL) of these wells were above the mean sea level, and deep wells were located around 7 km away from the Shill coast as RL of these wells were below the mean sea level (Fig. 3). The fig. 3 also depicted that ground water TDS was higher in wells located within 7 km distance from the coast, pumping hours were higher for deep wells compared to shallow wells, and quality of groundwater was a major problem for shallow wells while availability of ground water was a major problem for deep wells.

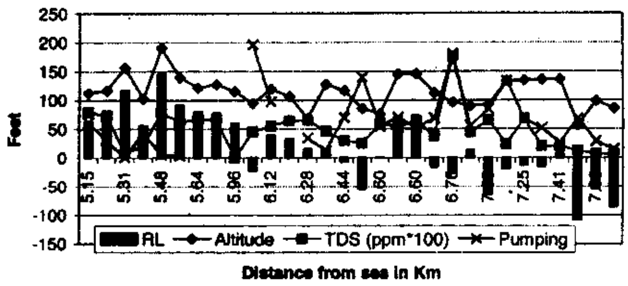

Fig. 3. *Distance Vs Rl, Altitude, TDS & Pumping hrs.*

Agriculture economy

Though Kankasa was affected by seawater intrusion; per hectare pumping hours, gross income and profit were higher than the other two study villages (Table 2). However, if the same amount of ground water draft is continued in coming years then the village will have to face severe problem of land and water productivity degradation and agriculture will be no more viable entity in the future because TDS and profit are negatively correlated (Fig. 4). Therefore, there is a need to restrict ground water overdraft and at the same time efforts are to be made to increase ground water recharge. Shift in cropping pattern and change in water management practices are the other possible measures to reduce the ground water overdraft.

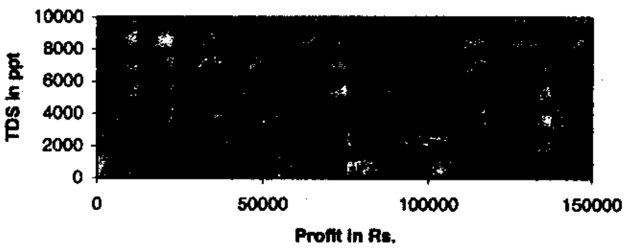

Fig. 4. *TDS Vs. Profit*

Possible technical and institutional measures to restrict seawater ingress

A simulation model (Table 3) suggests that if we restrict ground water pumping alone, it will reduce the TDS content in ground water by 50 percent over next 10 years, and hence water quality will be improved. Water card like ration card needs to be introduced to restrict the ground water overdraft. It is necessary to create village level institution to implement the water card system. Fixed number of pumping hours per hectare will be

Table 2. *Variation in economic parameters in three pilot sites N=90 (30 per village)*

Village	Average depth of well (m)	Average water level in wells from the bottom (m)	EC Value as on 15/1/03 (ms)	Average pumping hrs. per ha/year	Gross income per ha* (Rs.)	Total cost of production per ha* (Rs.)	Profit per ha* (Rs.)
Kankasa	32	8	9.44	16.12	69912	14152	55760
Chandavana	25	0.9	1.81	14.01	60578	24766	35905
Karmadi	24	1.2	2.05	21.44	36146	12553	23593

**Kharif* and *Rabi* 2003

Table 3. *Simulation model to maintain ground water quality in Kankasa*

Year	Rainfall (mm)	Recharge (ha-m)	Storage (ha-m)	Pumping (ha-m)	Balance (ha-m)	TDS (ppm)
			270	157	113	3150
2002	277	50	163	115	48	7415.6
2003	688	130.11	178.11	115	63.11	5640.2
2004	1221	232.29	280.3	115	165.3	2153.5
2005	54	8.58	173.9	115	58.9	6046.8
2006	627	118.42	177.3	115	62.3	5714.8
2007	928	176.12	238.4	115	123.4	2884.4
2008	463	86.98	210.4	115	95.4	3731.6
2009	1372	261.24	356.6	115	241.6	1473.2
2010	315	58.61	300.2	115	185.2	1921.6
2011	771	146.02	331.3	115	216.3	1645.9

Note: Rainfall pattern of last decade was used for simulation purpose, using SIPC (2002) data.

allocated to each water card holder. Any farmer who is having access to ground water may be entitled for the water card. Allocation of pumping hours will be based on annual rainfall, amount of ground water recharge, well discharge, specific yield of the geological formation, etc. A village committee has to be formed to strictly monitor the pumping hours of water card holders. In the context, periodical review of extent of pumping of water card holders is necessary. There should be strong socially acceptable binding norms to prevent violation of allocation rules. Water saving technologies such as microdrip and sprinkler may reduce the water requirement and may be able to maintain the current level productivity without adversely affecting the livelihood system of the village people. Similar type of simulation model can be developed for augmented storage capacity and increase in ground water recharge, as well as the cropping pattern change that may affect the ground water quality over a period of time.

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Impact of Paper Mill Effluent Irrigation on Soil Characteristics

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A study was conducted to assess the impact of paper mill effluent irrigation on soil resources in Pallipalayam, Nammakkal district of Tamilnadu. Soil samples at depth 0 – 30 cm, 30 – 60 cm and 60 – 90 cm from the fields put under different periods of irrigation viz., more than 25 years of effluent irrigation, 15 years, 12 years and 9 years of effluent irrigation, and field with well water irrigation were collected, analyzed for soil texture, porosity, water retention capacity and organic carbon. The study revealed that the effluent irrigation increased the bulk density, water holding capacity and organic carbon contents and decreased the porosity of the soil.

(***Key words*** : *Effluent, Paper mill, Reuse, Irrigation, Soil characteristics*)

Industrial growth has been attributed as the cause for environmental pollution in many places. The main challenge of the industries is to dispose the effluents. The problem is still more acute for industries, which consume large quantity of water, and in turn lets out huge volume of effluent. The land application of industrial effluents for irrigation is an appropriate solution in this context as it involves two main principles i.e., use of soil as a treatment system preventing pollution of the water bodies and use of wastewater as continuous or supplementary source of irrigation. Land application is defined as the controlled application of pre-treated wastewater onto the land surface to achieve a higher designed degree of treatment. Soil is a dynamic multicomponent natural system with various functions such as matter cycling and transformations, buffering, self purification, energy flow and bio diversity function. In other words, soil is physical filter (action sieve), chemical filter (adsorption and precipitation), and a biological filter (decomposition of organic matter). Thus, the soil can serve as a receiving medium and a final form of treatment by removing and decomposing various constituents in the effluents. In addition to that the colour removal from the paper mill effluent is best effected only through land application (Raghuveer and Sasthri, 1990). In tropical country where irrigation water is in short supply, utilisation of industrial wastewater for irrigation seems to be an appropriate technology. Though the concept seems to be promising, the utility of this effluent irrigation programme depends mainly on the long term sustainability. Moreover, overloading or continuous use can create soil sickness and other environmental problems and the very purpose of ultimate disposal with resource recovery can be defeated. Hence the study on impact assessment of soil characteristics of effluent irrigation was undertaken.

MATERIALS AND METHODS

In order to assess the impact of industrial effluent irrigation , paper mill effluent irrigation programme at Pallipalayam of Nammakkal district in Tamilnadu was selected. Profile samples at depth 0 - 30 cm, 30 - 60 cm and 60 - 90 cm from the fields put under different period of irrigation viz., more than 25 years of effluent irrigation, 15 years, 12 years and 9 years of effluent irrigation, and field with well water irrigation were collected and analyzed for soil texture, bulk density, porosity, water retention characteristics and organic carbon using standard methods (Piper, 1966, Jackson, 1976).

RESULTS AND DISCUSSION

The soil characteristics of the effluent irrigated field over different periods of time are given in Table 1.

Soil texture

From the Table 1 it could be observed that the soil texture of the effluent irrigated field as a whole was of sandy loam. The top surface soil contained more sand 68.0–74.3%, followed by silt 12.2 - 14.20%, and clay 14.8-17.80% in case of effluent irrigated fields, and 75.4% sand, 12.2% silt and 12.4% clay in control field. If the clay percentage is less than 10% then, the particular soil is not suitable for effluent irrigation since the potential of groundwater pollution is high. It could be observed

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Table 1. *Soil characteristics in effluent irrigated area*

Parameter	Period of effluent irrigation														
	More than 25 years			15 Years			12 Years			9 Years			Control		
Depth	0 - 30 cm	30 - 60 cm	60 - 90 cm	0 - 30 cm	30 - 60 cm	60 - 90 cm	0 - 30 cm	30 - 60 cm	60 - 90 cm	0 - 30 cm	30 - 60 cm	60 - 90 cm	0 - 30 cm	30 - 60 cm	60 - 90 cm
Soil Texture Sand (%)	68.00	65.00	62.40	69.30	69.00	64.30	72.10	70.00	65.70	74.30	72.00	66.20	75.40	75.40	69.10
Silt (%)	14.20	21.50	14.10	14.20	18.90	12.90	12.30	18.80	12.80	10.90	15.50	13.60	12.20	16.70	10.00
Clay (%)	17.80	13.50	23.50	16.50	12.10	22.80	15.60	11.20	21.50	14.80	12.50	20.20	12.40	10.70	19.90
Bulk density (g/cc)	1.38	1.35	1.33	1.28	1.30	1.26	1.30	1.30	1.25	1.30	1.30	1.18	1.20	1.20	
Prorosity (%)	38.50	34.70	32.40	41.50	40.40	35.00	43.10	40.20	36.00	43.10	42.00	36.00	48.40	45.00	40.20
Water holding capacity (%)	34.50	31.20	33.20	33.20	28.40	30.20	33.30	28.20	31.10	32.50	30.40	28.00	27.50	25.20	25.00
Organic carbon (%)	1.4	1.0	0.85	0.9	0.82	0.78	0.84	0.73	0.67	0.75	0.65	0.61	0.45	0.42	0.40

that in the study area the clay content ranged from 14.-17.8% and in subsurface layer it was more than 20% indicating that the soil was suitable for effluent irrigation.

Bulk density

The bulk density of the effluent irrigated field ranged from 1.25 - 1.38g cm^{-3} when compared to control field (1.2 g cm^{-3}). Though the change was not appreciable, the bulk density has increased slightly due to the continuous irrigation with effluents. Moreover, it was observed that the bulk density increased with soil depth. This could be due to illuviation of clay and other particles with the compaction of the soils as reported by Kumaresan (1979). The bulk density of the soil had influence on the water holding capacity of soil and its hydraulic conductivity. It is influenced by the structure, texture and compactness of the soil.

Porosity

The porosity of the effluent irrigated field ranged from 38.5 to 43.1%. in comparison with the control field (48.4%). From the data (Table 1) it may be observed that the porosity decreased appreciably with more number of years of effluent irrigation. This could be attributed to the clogging of the pores by the particles present in the effluent. This finding is in concurrence with the results of Cox *et al.* (1997). From the data it is also evident that the porosity decreased with the depth in all the profiles. The present study revealed that the continuous irrigation with effluent for over 25 years decreased the total porosity and this followed the general trend of inverse relationship between the bulk density and porosity.

Water retention capacity

One of the important effects of organic matter addition to the soil is that, it changes the retention characteristics of the soil water. In the present study, it could be seen that the water holding capacity increased in the soil due to continuous irrigation with the effluents i.e., it was about 34.50%, 33.20%, 33.30% and 32.50% in the effluent irrigated field for 25 years, 15 years, 12 years and 9 years, respectively. Whereas in control soil it was only about 27.50% which may be due to the slight increase in organic matter content and clay content in effluent irrigation soil. This is in line with the observations of Somashekar *et al.* (1984). From the above discussion, it could be concluded that the physical properties of the soil improved considerably due to effluent irrigation.

Organic matter content

The organic carbon content ranged from 0.40-0.45% in soils without effluent irrigation, and was 1.40, 0.90, 0.84, 0.75% in soils put under effluent irrigation for 25, 15, 12, 9 years, respectively. The organic carbon content increased significantly with the effluent irrigation. It was observed that the organic carbon content decreased with depth in all profiles. This is in agreement with the findings of Kannan and Oblisami (1990). The high organic carbon content in the surface soil is mainly due to the presence of organic matter in the effluent and it indicates the favourable soil condition for plant growth. Somashekar *et al.* (1984) and Juwarkar and Subramanyam (1987) have also reported that the soil organic matter content increased due to effluent irrigation. According to them, the presence of higher concentration of suspended and dissolved solids contributed to the build-up of organic matter. The organic matter also plays a role in improving soil aggregation, soil chemical reaction, nutrient availability to the plant and also serves as food for microorganisms. Thus, the organic matter improved the soil fertility of the field irrigated with the effluent.

CONCLUSIONS

Land application or reuse of treated wastewater in irrigation is a potential cost effective solution for the wastewater disposal problem. Irrigation with effluent for more than 25 years didn't have appreciable adverse impact on soil resources, rather the effluent irrigation increased the bulk density, water holding capacity and organic carbon content, and decreased the porosity of the soil. Better soil management practices like application of soil amendment, deep ploughing and other management practices may result in the long term sustainability of effluent irrigation programme.

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Effect of Methods of Irrigation and Amendments on Sapota in Coastal Saline Soil

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A field experiment was conducted (1996-2002) on coastal saline soil with three methods of irrigation as main plot and four types of amendments as subplots at the Fruit Research Station, G.A.U., Mangrol using sapota. The results revealed that methods of irrigation and amendments failed to produce significant effect on yield of sapota. Flood irrigation with amendments, either gypsum or FYM, however produced significantly higher yield, and was found economically viable. The ESP of soil decreased and was minimum significantly when crop was irrigated at 0.8 IW/CPE without amendment.

(***Key words:*** *Sapota, Methods of irrigation, Soil amendments, Saline soil)*

Sapota is largely cultivated and grown widely as a cash crop in Gujarat. The response of sapota to soil amendments under saline soil and irrigation water has not been fully explored. Therefore, the present investigation was undertaken.

MATERIALS AND METHODS

A field experiment was conducted (1996-2002) on coastal saline soils in SPD with three methods of irrigation (I_1: Drip 0.6 IW/CPE, I_2: Drip 0.8 IW/CPE, fraction and I_3: Flood irrigation) as main plots and four types of amendments (A_1: No amendment, A_2: FYM @ 10 t ha^{-1} every year, A_3: Gypsum @ 5 t ha^{-1} every alternate year, and A_4: Mulching with sapota leaves) as subplot treatments at the Fruit Research Station, G.A.U., Mangrol with sapota cv. Kalipatti as a test crop. The experimental soil had $EC_{2.5}$ 2.2 and 1.7 dSm^{-1}, $pH_{2.5}$ 8.2 and 8.3 and ESP 6.9 and 10.5 to 0-15 and 15-30 cm depths, respectively. The crop was planted on 23rd July 1990 at a spacing of 8.0 x 10.0 m with recommended dose of fertilizers. The irrigation and amendment treatments were imposed during 1996 to 2002. The saline irrigation water (Table 1) was applied as per the treatments. The analyses of experimental soil and irrigation water were carried out adopting standard procedures (Richards, 1954).

RESULTS AND DISCUSSION

Effect on yield and economics : The results revealed that irrigation method having drip with low amount of water produced the higher yield of sapota (Table 2) while with the flood irrigation having amendments, either gypsum or FYM, produced significantly higher yield. The observed interaction effect can be expected because of having their favourable effects on plant height, plant spread (E-W and N-S), trunk girth and number of fruits per tree per year. The present results are in agreement with the work of Singaravel *et al.* (2001). The data (Table 3) showed that application of gypsum @ 5 t ha^{-1} with flood irrigation proved most economical with net realization of Rs.37.85 per tree per year having ICBR of Rs.1: 2.47. Similar beneficial effect of gypsum were also reported by Polara *et al.* (2002).

Table 1. *Quality of irrigation water during the experimentation*

Quality parameter	Year						
	1996	1997	1998	1999	2000	2001	2002
EC(dSm^{-1})	12.00	10.0	12.0	12.5	13.5	14.0	13.0
pH	7.4	7.7	7.7	7.6	7.9	7.5	7.9
SAR	8.11	7.56	7.98	9.12	10.2	11.8	11.0

Table 2. *Interaction effect of methods of irrigation and different amendments on yield and yield attributes of sapota (1996-2000 pooled)*

Irrigation	Amendments							
	A_1	A_2	A_3	A_4	A_1	A_2	A_3	A_4
	Plant height (m)				Plant spread (E-W) m			
I_1	3.13	2.98	2.91	3.02	5.42	5.27	5,56	5.60
I_2	2.90	2.80	3.01	3.34	5.18	4.78	5.16	5.34
I_3	2.72	3.42	3.70	3.04	4.70	5.53	5.92	5.08
	SEm ± : 0.083 CD(P=0.05) : 0.232				SEm ± : 0.152 CD(P=0.05) : 0.427			
	Plant spread (N-S) m				Trunk girth (cm)			
I_1	5.63	5.22	5.20	5.25	44.86	34.95	36.17	46.45
I_2	5.13	4.67	5.41	5.16	39.52	30.33	40.56	39.01
I_3	4.95	5.45	5.99	5.11	31.33	38.01	40.62	40.07
	SEm ± : 0.148 CD(P=0.05): 0.416				SEm ± : 1.869 CD(P=0.05): 3.244			
	No. of fruits/tree/year				Yield kg/tree/year			
I_1	751.2	746.9	669.5	726.5	43.44	45.33	36.77	38.97
I_2	658.1	640.3	663.5	564.8	39.67	34.66	36.09	32.19
I_3	563.6	758.8	801.6	628.8	34.35	45.70	47.08	37.17
	SEm ± : 49.8 CD(P=0.05): 139.6				SEm ± : 2.73 CD(P=0.05): 7.83			

Table 3. *Influence of methods of irrigation with saline water and management with different amendment on gross realization and ICBR of sapota (1996-2002)*

Treatment	Yield kg/tree/ year (pooled)	Additional yield over control (kg/tree)	Additional income over control (Rs/tree)	Additional expenditure over control (Rs/tree)	Additional net return over control (Rs/tree)	ICBR
I_1A_1	43.44	9.09	45.45	33.90	11.55	1:1.34
I_1A_2	45.33	10.98	54.90	52.50	2.40	1:1.05
I_1A_3	36.77	2.42	-	-	-	-
I_1A_4	38.97	4.62	-	-	-	-
I_2A_1	39.67	5.32	-	-	-	-
I_2A_2	34.66	0.31	-	-	-	-
I_2A_3	36.09	1.74	-	-	-	-
I_2A_4	32.19	-2.16	-	-	-	-
I_3A_1	34.35	-	-	-	-	-
I_3A_2	45.70	11.35	56.75	38.60	18.15	1:1.47
I_3A_3	47.08	12.73	63.65	25.80	37.85	1:2.47
A_3A_4	37.17	2.82	-	-	-	-
CD(P=0.05)	7.83	-	-	-	-	-

Price of material considered : Sapota fruit : 5 Rs/kg, FYM: 200 Rs/tonne, Gypsum : 250 Rs/tonne, Drip system: 33.9 Rs/tree, Drip cost : 25000 Rs/ha + 10 % interest (Working life 10 years)

Application charge : FYM: 240 Rs/ha, Gypsum: 150 Rs/ha, Labor charge: 50 Rs/day

Effect on soil : The data (Table 4) revealed that the ESP of soil after monsoon decreased significantly after monsoon due to different methods of irrigation and due to amendments before monsoon. Irrigation water applied through drip with 0.8 IW/CPE recorded the lowest ESP value. The significantly lower ESP was found when crop was irrigated at 0.8 IW/CPE with no amendment followed by flood irrigation with FYM application @ 10 t ha^{-1} (Table 5).

From the above results, it can be concluded that application of gypsum @ 10 t ha^{-1} at alternate year or FYM @ 5 t ha^{-1} every year using flood method of irrigation with saline water produce maximum economic yield without any harmful effect on soil health.

Table 4. *Main effect of irrigation and management with different amendments on soil properties before (BM) and after monsoon (AM) under Sapota plantation*

Treatment Methods of irrigation	EC dS/m (1:2.5)		ESP	
	BM	AM	BM	AM
I_1 - Drip 0.6 IW/CPE fraction	3.56	3.62	10.4	6.20
I_2 - Drip 0.8 IW/CPE fraction	4.08	3.80	9.0	4.02
I_3 - Flooding	2.53	2.55	8.9	4.16
S Em ±	0.36	0.46	0.85	0.40
CD(P=0.05)	NS	NS	NS	1.56
Type of amendments				
A_1 - No amendments	2.79	3.89	11.9	4.58
A_2 - FYM 10 t/ha	3.80	3.53	7.8	6.02
A_3 - Gypsum 5 t/ha (alternate Yr)	3.72	2.74	9.0	3.97
A_4 - Mulching	3.02	3.13	9.0	4.61
S Em ±	0.43	0.47	0.83	0.57
CD(P=0.05)	NS	NS	2.46	NS

Table 5. *Interaction effect of methods of irrigation and amendment on ESP of soil after monsoon under sapota plantation*

Methods of irrigation	Amendment			
	A_1	A_2	A_3	A_4
I_1	5.31	11.30	3.68	4.48
I_2	3.05	3.39	4.03	5.64
I_3	5.40	3.35	4.20	3.70

S Em ± : 0.99, CD(P=0.05) : 2.96

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Performance Evaluation of *Abelmoschus esculentus* under Drip Irrigation System in Sundarbans Area

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For utilizing the limited water in the region in efficient way, an experiment was conducted during *rabi* season in the year 2002 at CSSRI, RRS, Canning Town, to evaluate the performance of *Abelmoschus esculentus* under drip irrigation system. There were six treatments with water of salinity 1.5 dS m^{-1} (S1) and 4 dS m^{-1} (S2). Irrigation was applied at CPE of 20mm. The crop under the drip irrigation system performed better than the conventional method of irrigation. The physiological parameters such as plant height, yield and dry weight were evaluated. The treatment with IW/CPE ratio 1 was the best in terms of crop and also showing minimum root zone salinity, when applied with water of lower salinity. The uniformity coefficient and the efficiency of the irrigation system were evaluated and found to be 86.2 and 86.6 percent, respectively.

(***Key words***: *Water scarcity, Saline soil, Limited water, Micro-irrigation, Uniformity coefficient, Irrigation system efficiency*)

Saline water can be used in drip irrigation system where salt is accumulated only at the surface of the periphery of wetting zone, and hence does not affect the growth of the crop. Rainfall is inadequate in Sundarbans (West Bengal) during the non-monsoon period. Good quality water scarcity prevails during *rabi*/summer season. For making efficient utilization of the limited amount of available water, irrigation experiment was conducted to compare drip and conventional irrigation with two water quality for each at CSSRI, Regional Station, Canning Town with the objectives (1) to evaluate the performance of *abelmoschus esculentus* and (2) to evaluate the system parameters for drip irrigation.

MATERIALS AND METHODS

The experiment was conducted at CSSRI, RRS, Canning Town during the year 2002. An 1 hp electric operated pump used for supplying water for drip. The system parameters such as Christiansen's uniformity coefficient (Cu) and efficiency of the irrigation system were evaluated after collecting and measuring the discharge in the individual drippers. *Abelmoschus esculentus* (lady's finger) was taken as the experimental crop with spacing of 1m. Two types of water with salinity 1.5 dS m^{-1} (S1) and 4 dS m^{-1} (S2) were used for irrigation. There were 6 treatments with three replications. The treatments were T1 (applying irrigation water with S1 when IW/CPE = 1), T2 (applying irrigation water through drip with S2 when IW/CPE = 1), T3 (applying irrigation water with S1 by the conventional method), T4 (applying irrigation water with S2 by the conventional method), T5 (applying irrigation water through drip with S1 when IW/CPE = 0.5) and T6 (applying irrigation water through drip with S2 when IW/CPE = 0.5). The irrigation was applied in each when the CPE was 20 mm. The soil salinity and the moisture distribution in the root zone were measured, and crop yield was recorded. The physiological parameters such as shoot length, root length, moisture content of the lady's finger fruits and plants were measured.

RESULTS AND DISCUSSION

The soil type was silty clay loam. The land was flat in topography with medium topography. Lady's finger was sown in the first week of February following harvest of rainfed rice in *kharif*.

The average discharge in the dripper in the drip irrigation system was 2.6 litre per hour measured *in situ*. There were total eight laterals numbering 1 to 8. There was valve control system for each lateral. The laterals 1 and 5 were for treatment T1, 2 and 6 for treatment T, 3 and 7 for treatment T5, and 4 and 8 for treatment T6. The uniformity coefficients Cu (1,5), Cu (1,3,5,7), Cu (2,6) and Cu (2,4,6,8) were evaluated after collecting the discharges from the concerned drippers and found to be 84.2, 85.86, 87.78 and 87.49 respectively. The uniformity coefficient (Cu) for the entire system was about 86.2. Uniformity coefficients of more than 80 percent indicated that water application was satisfactory by this drip irrigation system. The efficiency of the system was calculated based upon the water supplied through the irrigation system and the designed capacity. It was found to be 86.6 percent.

The crop period for ***Abelmoschus esculentus*** was 120 days. During this period, the air temp varied from 10.6° C to maximum 42.9° C, and the relative humidity ranged from 24 percent to 98 percent. The total amount of rainfall was 16 cm during the crop growth period. The standard dozes of fertilizers were applied to the crop. The total irrigation applied during the cropping period was 44 cm. The experiment had to be terminated prematurely due to incessant rain and water stagnation in the field after the 1st week of June.

The average number of nodes per plant with respect to the treatments were in the order : T1>T2>T4>T5>T3>T4. The shoot length varied from 36.45cm for T4 to 48.15cm for T1. The average root length also varied similarly from 18.5 cm to 25.2 cm. The crop yield was highest for the treatment T1 and it was 10 percent more than that for T2 (Fig.1). There was 36 percent higher yield in the plants with drip irrigation system than the conventional method. This might be due to better availability of moisture in the root zone of plants irrigated by drip irrigation system. The moisture content of the lady's finger plant and fruit were 80 percent and 90 percent, respectively.

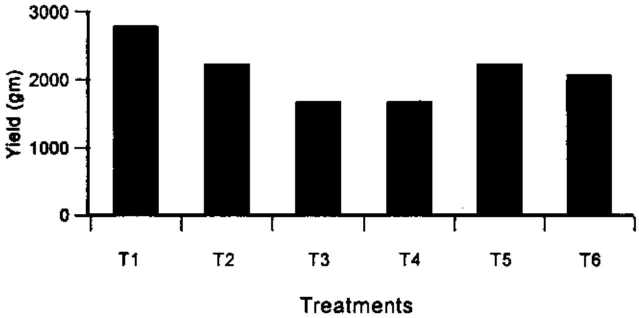

Fig. 1. *The yield of lady's finger per 30 plants under various treatments*

The average soil salinity (ECe) at 0-10 cm, 10-20 cm, 20-30 cm, 30-40 cm, 40-50 cm and 50-60 cm depths were 0.98, 0.88, 0.80, 0.74, 0.83 and 0.70 dS m^{-1}, respectively at the sowing time. The salinity in the root zone was higher for the treatments with S2 than with S1.

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Response of Different Genotypes of Groundnut to Saline Water irrigation in Saurashtra Region of Gujarat

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Controlled field study was conducted at NRCG, Junagadh to determine the tolerance of five genotypes of groundnut to varying salinity of irrigation water (0.5, 2, 4 and 6 dSm^{-1}) in clayey, moderately drained and shallow calcareous soils. Germination percent decreased with an increase in the salinity of the irrigation water but no significant difference was observed at ECiw of 2 dSm^{-1}. Percent decrease in pod yield using saline water irrigation of 2 dSm^{-1} was also not affected but at higher salinity of 4 and 6 dSm^{-1} the reduction in the yield over the control (0.5 dSm^{-1}) was significant. Other yield contributing characters such as, haulm yield, root weight per plant and shelling percent were also affected by the soil and water salinity. Oil content of different genotypes of groundnut was also affected adversely by the salinity stress. Soil salinity build-up in the root zone increased with an increase in salinity of the irrigation water ranging from 0.5 to 6 dSm^{-1} used during the dry spell of the crop growth period. Leaching of salt in the root zone was observed as a result of well distributed rainfall during the crop cycle from June to September, 2002. Decrease in ECe from 12.6 dSm^{-1} to 4.8 dSm^{-1} was noticed only due to rainfall of 24.6 cm in the month of June, 2002 because no saline water irrigation was given during this period. Hence rainfall plays an important role in managing saline soils using saline water irrigation for crop production. It is concluded that saline irrigation water having salinity of 2dSm^{-1} can be used safely in clayey, shallow, moderately drained calcareous soils for optimum groundnut yield in Saurashtra area of Gujarat.

***(Key words:** Groundnut, Genotypes, Saline water irrigation, Yield, Oil content, Growth characteristics)*

Soil degradation through salinisation has seriously affected the productivity of crops on over 1.2 m ha of land in Gujarat state. The problem of soil salinity is further complicated and more acute by the presence of poor quality ground waters that are frequently encountered in arid and semiarid regions and are often used for irrigation due to limited availability of good quality water and low rainfall. Groundnut being an important oilseed and food crop in Gujarat is going out of cultivation particularly in coastal belt where soil salinity and poor ground water quality is a serious problem. It is therefore important to generate the information on the management of soil and water salinity on groundnut production. Hence, a controlled field study was conducted to evaluate the tolerance of different genotypes of groundnut to saline water irrigation in saline soils representing Saurashtra regions of Gujarat.

MATERIALS AND METHODS

Controlled field experiment was conducted in *kharif* 2002 at NRCG Research Farm to evaluate the tolerance of different genotypes of groundnut to varying saline environment. These soils were shallow (25-50 cm depth), clayey in texture, moderately well drained, and calcareous in nature. Four levels of ECiw namely, 0.5 (control), 2, 4 and 6 dSm^{-1}, and five genotypes (Gangapuri, GG 2, ICGS 44, JL 24 and MH 2) were taken in a split plot design with three replications. Four sintex drums of 1000 litre capacity each were used for irrigating groundnut crop. Each salinity treated plot was separated from another plot by putting a 250 microne polycarbonate sheet upto 60 cm soil depth in different channels surrounding the various treated plots. *Bunds* of each plot were raised to the height of 30cm and width of 30 cm with the objective to absorb maximum rainfall in the plot. Recommended doses of fertilizer i.e., 12.5 kg N and 25 kg P_2O_5 were applied. The crop was sown on 2nd July, 20021, and was harvested on 8th October, 2002. Four saline water irrigations of different salinity were applied. Total amount of saline water irrigation applied during the dry spell of the crop growth period was 20 cm, besides the rainfall of 53.7 cm. Soil samples were taken from 0-15, 15-30 and 30-45cm soil depths periodically during the crop growth cycle and were analyzed for EC and pH. Yield and yield contributing characters were recorded at the harvest of the crop besides the germination count up to 15 days after sowing.

RESULTS AND DISCUSSION

Germination

Significant decrease in germination at ECiW 4 and 6 dSm^{-1} over the control (ECiW 0.5 dSm^{-1}) was observed whereas, at ECiW 2 dSm^{-1}, the difference in germination was non-significant. Further, the germination at 6 days after sowing (DAS) was 73 percent in case of control and same germination was observed at 8 and 12 DAS at ECiW of 4 and 6 dSm^{-1}, which indicate that increasing soil and water salinity delayed the germination (Table 1). Further, there was a difference in germination among different genotypes in the beginning, but at 8-15 DAS there was practically no difference.

Yield and yield contributing characters

Significant decrease in pod yield with an increase in ECiW from 2 to 6 dSm^{-1} over the control (0.5 dSm^{-1}) was observed (Table 2). ECe of the soil also varied from 1.7 to 4.8 dSm^{-1} as a result of saline water irrigation in shallow, calcareous, moderately drained clayey soil. The pod yield obtained at ECiW 0.5 (control) and 2 dSm^{-1} were 1309 and 1046 kg ha^{-1}, respectively which were significantly different. Almost similar trend was noticed in haulm yield but the absolute haulm yield was greater than pod yield in all the salinity treatments. Further, the percent reduction in haulm yield was lower than in pod yield which indicates that pod yield was more adversely affected by soil and water salinity. Decrease in pod/haulm ratio with an increase in salinity further confirms the above findings. Root weight per plant was unaffected up to ECiW 4 dSm^{-1}, but was significantly affected at 6 dSm^{-1} over the control. Shelling percentage was also adversely affected by increasing soil and water salinity. Padole *et al.* (1993) also reported that kernal, pod dry matter yields, protein content and oil content of groundnut (JL 24) decreased with saline conditions. Effect of soil and water salinity on pod yield was greater in case of MH2, GG 2 and Gangapuri than in ICGS 44 and JL 24 (Fig. 1) which indicates that the later genotypes were more tolerant to salinity. Almost similar response of different genotypes were observed in case of haulm yield and shelling percentage (Table 2).

Table 1. *Periodic germination (%) of groundnut as affected by soil and water salinity*

ECiw (dSm^{-1})	ECe (dSm^{-1})	Days to Germination						
		6	7	8	10	12	14	15
0.5	0.9	73	83	87	88	88	87	88
2	3.3	64	76	79	82	83	82	82
4	3.6	48	64	73	79	81	81	83
6	4.8	18	45	51	70	73	78	83
CD (P=0.05)		9.5	9.1	8.2	7.0	6.3	6.2	NS

Table 2. ***Effect of soil and water salinity on yield and yield contributing characters of groundnut***

ECiw[1] (dSm^{-1})	ECe[2] (dSm^{-1})	Pod yield (kg/ha)	Decrease in pod yield over control (%)	Haulm yield (kg/ha)	Decrease in haulm yield over control (%)	Pod/haulm ratio	Root weight per plant (g)	Shelling percent
0.5	0.8	1309	0	1632	0	0.80	0.56	72
2	1.7	1046	20	1475	10	0.71	0.53	69
4	3.3	787	40	1172	28	0.67	0.53	68
6	4.8	420	68	967	41	0.43	0.33	60
CD (P=0.05)		189.6		207.6			0.16	3

[1] Electrical conductivity of irrigation water

[2] Electrical conductivity of soil salination extract

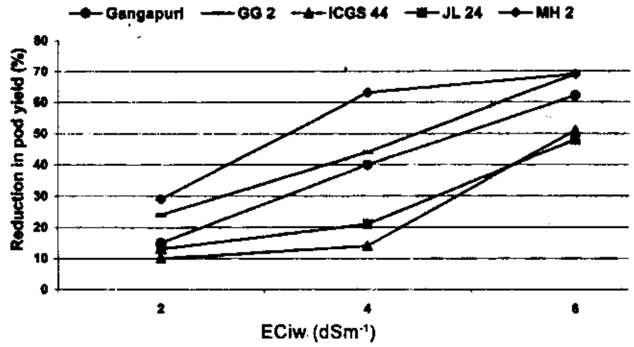

Fig. 1. *Percent reduction in pod yield in different genotypes of* kharif *groundnut by saline water irrigation*

Oil content

The oil content of different cultivars of groundnut grown in saline environment was found to be adversely affected. Mean oil content decreased significantly from 49.1 to 44.5 % with an increase in the ECiw from 0.5 to 6 dSm^{-1}. Arjunan and Gopal Krishnan (1980) and Aljibury and Talabany (1982) also reported similar findings. Percent decrease in oil content as a result of increased salinity was low in MH 2 in comparison to other genotypes (Fig. 2). The absolute oil content was also found to be low in relation to other genotypes. However, the effect of soil and water salinity on oil content of groundnut needs further investigation and also to find out what are the possible reasons for such significant decrease in oil content under salinity stress conditions.

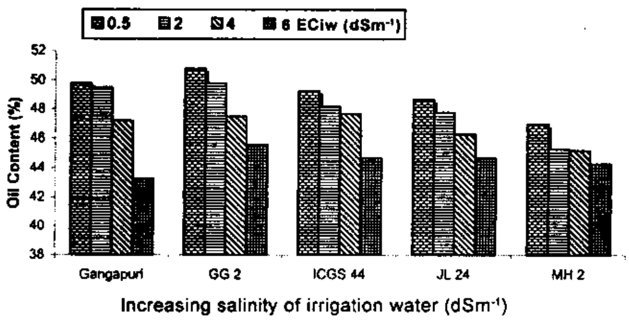

Fig. 2. *Effect of saline water irrigation on oil content of different cultivar of* Kharif *groundnut*

Root zone salinity and soil pH

The initial soil salinity in 45 cm root zone ranged from 1.4 to 12.6 dSm^{-1} well before sowing of the *kharif* 2002 groundnut. These salinity levels developed as a result of saline water irrigation to previous summer groundnut crop. The initial salinity range was reduced to 0.9 to 4.8 dSm^{-1} (Fig. 3) at the time of sowing of *kharif* Groundnut (3rd July, 2002). This reduction in highest salinity of 12.6 to 4.8 dSm^{-1} was mainly as a result of leaching of salt due to sufficient rain between the two sampling date i.e. 3.6.02 and 3.7.02. Soil samples at the 0-45 cm root zone was also taken on 31st July and 8th October, 2002 in the subsequent crop growth period, and saline water irrigation given to the crop during the dry spell period. During the crop growth period the soil salinity varied from 0.8 to 4.9 dSm^{-1} as a result of saline water irrigation ranging from 0.5 to 6 dSm^{-1} (Fig.3) and well distributed rainfall received during June to September 2002. Soil salinity build-up during the crop growth period was ranging from 1.7 to 3.3 dSm^{-1} as a result of irrigation with saline water having ECiw of 2 dSm^{-1}, which did not affect the pod yield in clayey, shallow and moderate drained soils. Hence, the critical limit of EC of saline irrigation water for optimum yield of *kharif* groundnut crop was 2 dSm^{-1}. This threshold limit of saline water irrigation may vary depending upon the texture of the soil and climate of the area. Ayers and Westcot (1989) reported similar findings, whereas Yadav (1984) reported that use of saline water of 4 dSm^{-1} caused 50 % reduction in the groundnut yield in sandy loam soil at Bapatla Centre. The mean soil pH (0-45 cm depth) increased with increase in the salinity of the irrigation water. pH also increased from 8.0 (3rd June, 2002) to 8.3 (8th October, 2002) as a result of saline water irrigation. Decrease in pH with soil depth was also observed during the crop growth period.

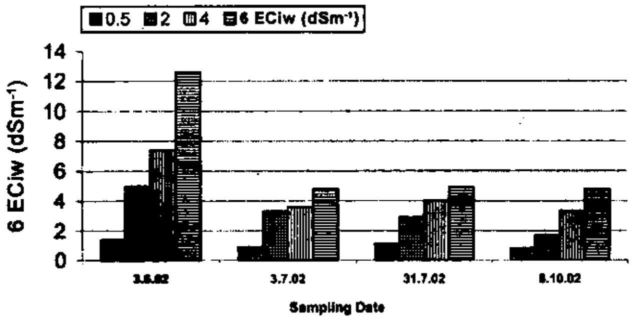

Fig. 3. *Effect of saline water irrigation on root zone salinity during the crop growth period*

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Role of Water Conservation Techniques and Pressurized Irrigation System in Alleviating Water Scarcity

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In view of water scarcity for irrigation combination of small scale water harvesting methods with efficient irrigation practices can provide excellent opportunities to ease out the problem in future.The paper discusses and reviews various water harvesting techniques and water and energy efficient irrigation systems for providing better opportunities in on-farm water management.

(***Key words:*** *Water harvesting, Pressurised irrigation system, Energy efficient irrigation system, On-farm water management*)

As the available water resources taken from streams, rivers and ground water will not be sufficient in most dry areas of the world to cover the needs of agriculture and urban areas, we have to reassess the value of certain traditional technologies coupled with modern irrigation methods to find out their value to ease future water scarcity. Since ancient times, farmers and herders have widely attempted to 'harvest' water to secure or increase agricultural production, which gives a wide range of indigenous irrigation techniques in practice. Technical means and distinct government policy favouring 'modern' water supply and distribution techniques in lifting ground water or establishing large canal systems even with inter-basin water transfer brought about a decline in the traditional techniques. Modern irrigation systems such as, drip, micro-sprinklers, sprinklers, etc. can be easily coupled with these water harvesting techniques, which may further provide an opportunity to enhance the water productivity.

Adoptions of modern irrigation methods have shown various constraints such as high initial investment, need of a certain degree of technical expertise and improper dissemination of know-how of these technologies amongst its users. Inspite of this, considering the average basin width in the country of 6 to 8 m the adoption of modern irrigation methods becomes impractical in many cases. Hence, there is need to look at the development and promotional aspects of these methods.

Water conservation and harvesting methods

Water conservation in agriculture can be achieved by adopting efficient rainfall, ground water, canal water, and on-farm water management practices. Water available through these sources needs combination of various management strategies in addition to creating certain structures. These aspects are discussed below.

Rainwater management

Conventional irrigation methods use rainfall after it has infiltrated into the ground, using underground water or the water of permanent streams stored in tanks and rivers. Rainfall availability duration is mostly confined in monsoon periods and 70% of the annual rainfall occurs between July to October. Hence, inspite of storing the water in storage tanks various management practices in the field can also help in utilization such as, storage of rainfall in rice fields and imposition of cultural practices concerned with water management, which helps in controlling the declining water table. *Bund* height of rice fields be so planned that it stores maximum rainfall in the field to avoid moisture deficiency during dry spells and minimize irrigation water requirement without affecting the crop yield. This will allow following benefits:

- Rainwater is captured in the fields during monsoon. It allows rice crop to utilize maximum rainwater and reduces irrigation requirement through other source of irrigation.
- Minimizing the runoff arrests soil and nutrients loss in the fields. This practice does not allow soil deposition in drains, which results in increase in the bed level of drain and thus more water spillage and spread in the area.
- *Bunds* help in storing the rainwater on the land surface and replenish the ground water below the land. This causes ground water to rise and it can be utilized for irrigation during non-monsoon period.

In addition to this, timely sowing of crops matching with the rainfall availability periods can be very effective practice in rainwater management.

Rainwater harvesting

It is estimated that even after development of full irrigation potential of 139.9 M ha as against the total cultivable land of 184 M ha about 44 M ha will be left as rainfed. Harvesting of rainwater and management strategies consisting of *in situ* and *ex situ* harvesting can be an alternative.

- **Microcatchment water harvesting** is a method of collecting surface runoff (sheet or rill flow) from a small catchment area and storing it in the root zone of an adjacent infiltration basin. The basin is planted with a single tree or bush or with annual crops.
- **Macrocatchment water harvesting** is also called "water harvesting from long slopes" or "harvesting from external catchment systems". In this case, the runoff from hillslope catchments is conveyed to the cropping area, which is located below the hill foot on flat terrain.
- ***In situ* rainwater harvesting** can be achieved by increasing infiltration rate with the help of deep ploughing, profile modification, vertical mulching and by keeping soil surface rough. The *in situ* rainwater harvesting techniques are location specific and depend on the rainfall intensity, slope and texture of the soil. On lands having slope up to 1 or 2 percent, field *bunding*, land leveling, contour ditching, and cultivation along contour could ensure water conservation. On lands having 2 or 6 percent slope, graded contour *bunds* can be constructed and on slopes ranging from 6 to 33 percent bench terraces can be made.
- ***Ex situ* rainwater harvesting** includes roof top collection, dug out ponds/ storage tanks, *nala bunding*, gully control structures/check dams/ *bandharas* (weirs), water harvesting dams, percolation tanks/ponds, subsurface dams/ barriers, etc. These technologies are highly location specific and practices evolved in a given region have a limited application in other regions. For example, roof top harvesting is recommended only in areas like, northeastern states, Andaman & Nicobar Islands, and southern parts of Kerala and Tamil Nadu.
- **Floodwater harvesting,** also called 'Large catchment water harvesting' or 'spate irrigation', comprises of two forms:

1. In case of "Floodwater harvesting within the stream bed" the water flow is dammed and, as a result, inundates the valley bottom of the flood plain. The water is forced to infiltrate and the wetted area can be used for agriculture or pasture improvement.
2. In case of "Floodwater diversion", the *wadi* water is forced to leave its natural course and conveyed to nearby cropping areas. These systems, the catchments being many square kilometers in size, require more complex structures of dams and distribution networks and a higher technical input than the other two water harvesting methods.

Pressurized irrigation systems

Pressurized Irrigation Systems require desirable operating pressure to fulfill the crop needs. It helps in controlled application of water, fertilizers and pesticides, with low and frequent irrigation to crops and high water application efficiency vis-à-vis surface methods. Various pressurized irrigation systems are:

- Drip System
- Sprinkler System
- Micro Sprinklers
- Mini Sprinklers
- Bi-wall
- Bubblers
- Perforated pipe systems
- Jet and Sprayers

The major benefit of this irrigation system is not only to save water (water saving in the range of 30 to 70%) but also to increase the yield and quality of agricultural produce. It also reduces the cost of overall requirement in agricultural process such as of fertilizer and pesticide (when applied through system) and labour cost, as it requires less manpower for irrigation even in larger areas. The adoption of this technology requires capital investment. The adoption of pressurized irrigation system due to cost factor is very poor in case of cereals or less valued crops. This does not mean that this system cannot be adopted. There is a need to look at the practical requirements and constraints in adoption of these technologies by small farm holders. In this series Sprinkler Irrigation Systems enjoy major advantage as it can be started at small scale. Ready access to equipment dealers and technical support is vital to achieve sustained efficiency. Micro and Drip Irrigation Systems, which have more numbers of parts, apply water to a small area with generally a fixed system, which becomes a costly option for small farmers. Its applicability remains limited for farmers with inadequate access to technical support, training services and equipment dealers. Centre pivots including LEPA system are generally designed to irrigate relatively large areas as the equipment requires skilled maintenance and are therefore not recommended for small farmer schemes. LEPA system is one of the best available options in view of energy and water saving aspects. LEPA irrigation system works even at pressure of 0.07 kg cm^{-2} with 98% of water application uniformity. At ICAR-RCER, Patna under the project Pressurized Irrigation Systems (Team of Excellence-NATP) LEWA (Low Energy Water Application device) has been developed, which is currently under field test, is one of the most promising attempts in the country in this direction. The LEWA device works satisfactory at 0.4 kg/cm^2 and can be used for *kharif* and *rabi* crops.

Promotional Aspects

In most of the cases, technologies are developed but face many problems when it is transferred. It happens because most of the developmental process overlook the practical aspects. This is due to lack of interaction between farmers and technical advisers. The cost of technology sometimes is unaffordable and this happens when a particular technology developed for large sized farms is downscaled. Claimed capacity of technology by manufactures many times varies or not achievable. Water and energy saving should be of prime importance though saving water or energy. The design aspects of technology should not limit the flexibility and decision making of farmers. Successful transfers of technologies are often based on farmers' experience with trial & error rather than on scientifically well established techniques.

CONCLUSIONS

As most farmers practising water harvesting are resource poor peasants or herders, some intervention of state authorities is needed, by way of financing the construction of small reservoirs or subsidizing for greenhouses or underground / drip irrigation installations. In some cases the available knowledge is sufficient to solve a specific problem, but the application or the promotion by state / local authorities alongwith support of extension services is often lacking.

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Impact of Different Sources of Irrigation on Agricultural Production in Mahanadi Delta

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Performance of agricultural production and productivity may vary under controlled and uncontrolled sources of irrigation as revealed by the case study. The surface irrigation system under the study with minor and major irrigation systems have contributed differently to the gross output, farm business income. Major canals in surface irrigation and private tubewell under ground water irrigation system varied considerably in terms output and net returns to farmer. Major canal in surface irrigation systems and private tubewells in ground water systems showed higher increase in net income from paddy cultivation in comparison to cultivation of paddy under minor canals, government tubewells under ground water system. With respect to overall impact on agriculture major canals in surface irrigation system and private tubewells in ground water irrigation system performed better. The higher yields under private tubewells show higher incremental income. The differential impact of different systems of irrigation was probably due to variation in timeliness and adequacy in irrigation supply and the confidence of farmer in the source of irrigation as the entrepreneurial attitude of farmer might vary with varying source of irrigation.

(***Key words:*** *Surface irrigation systems, Ground water irrigation, Agricultural production, Mahanadi delta*)

The state of Orissa has 65.59 lakh hectare of cultivable land of which 59.00 lakh hectare is irrigable from different sources. So far 39.73% of irrigable land has been brought under different sources of irrigation. The performance of irrigated agriculture in the eastern region is poor in general, and irrigation performance in Orissa remains far from satisfactory. Canal irrigation is the main source of irrigation where major and medium irrigation contributes more than 80% of irrigation potential created under flow irrigation. Ground water utilisation remains at abysmal level of 14% in the state. Lift irrigation that includes ground water development and river lift constitutes 13 % of irrigation potential created in the state (1998). The productivity impact of different sources of irrigation in the state is not well studied and compared critically. As the farmer is the ultimate user of irrigation water, availability or lack of it in time influences the output level, which is reflected in the income differential for farmers across the system. It is presumed that more the control of farmer on the source of irrigation, the more the inducement to manage inputs rationally, which assures a better yield to the farmer. As the risk associated with public irrigation system is more in terms of reliability and adequacy, the farmers do not venture into better application of inputs and its management under the system of unsure supply as generally happens for flow irrigation under, publicly supplied system. However, there cannot be a universal inference that the cost of cultivation and output under varying irrigation are necessarily different, as farmer entrepreneurship under different irrigation systems also becomes a major factor in overall management of inputs. So in terms of investment on different sources of irrigation, the farmer preferences of crops, water use efficiency, and the stake of beneficiary in the system are some of the influencing factors contributing to the success of the system. The present study aims at the investigation in to the above stated presumptions with case studies in Mahanadi delta irrigation system with the objectives (i) to find out extent of changes in cropping intensity, cropping pattern, productivity, cost-farm business income, on farm employment and structure of tenancy in command area of different sources of irrigation in Mahanadi delta system and (ii) to compare the differential impact of irrigation on crop yields, cropping intensity, cropping pattern, farm

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business income, on-farm employment and structure of tenancy across different system of irrigation.

MATERIALS AND METHODS

The present study follows the approach with system across the sources in the respective study villages in Mahanadi delta for the agricultural year 2002 *kharif* and post-*kharif* operation in the commands. Multi-stage stratified random sampling technique was followed for selection of blocks, village and farm house hold size classwise (Tables 1 & 2).

Selection of irrigation system

(1) Surface irrigation system

Major Canal system: Delta irrigation system under delta stage II of Mahanadi system was deliberately chosen for the study. Delta stage 1 covers 4.86 lakh ha certified ayacut with 5 doabs and Delta stage II covers 5.2 lakh ha certified ayacut with 8 *doabs*. Garedipanchan minor of Nimapar branch canal with a length of 38.92 km runs through Balipatna, Balianta, Nimapara and Gop blocks.

Minor Canal : Deras Minor canal system under Bhubaneswar block was purposively selected for the study. The system has *kharif* potential of 700 acres and rabi potential of 300 acres with left canal covering 5 vilages and right canal catering to the WTCER and state government farms.

(2) Ground water system

Government tubewell and private tubewell system under 42 Mouza of Cuttack Sadar block in district of Cuttack were chosen for the study.

Table 1. *Sampling across the sources*

Sources of Irrigation	No of villages	No of sample households	% Distribution of total households
1. **Surface Irrigation**			
a. Major canal	4	40	30.53
b. Minor Canal	2	41	11.30
2. **Ground water Irrigation**			
a. Government tubewell	18	45	34.35
b. Private tubewell	1	5	3.82

Table 2. *Distribution of sampled households on the basis of their operational holding across the system and size classwise*

Sources of irrigation	Size classes (ha)				
	0 – 1	1 – 2	2 – 4	>4	All class
1. **Major canal**					
HH (NO)	12	5	16	7	40
NSA (ha)	7.08	7	35.68	37.8	87.56
HS (ha)	0.59	1.4	2.29	5.4	2.42
2. **Minor canal**					
HH (NO)	36	4	0	1	41
NSA (ha)	21.27	5.6	0	5.4	32.27
HS (ha)	0.59	1.4	0	5.4	2.46
3. **Government tubewell**					
HH (NO)	44	1	0	0	45
NSA (ha)	18.68	1.09	0	0	19.77
HS (ha)	0.42	1.09	0	0	0.64

RESULTS AND DISCUSSION

The irrigation performance in terms of output, comparative picture (Tables 3-9) of sourcewise returns to farmers in terms of yields, returns to farmers under different systems for HYV and local paddy reflects the importance of the source of irrigation water in farm production under Mahanadi delta irrigation system. From the data (Table 14) it is explicit that higher gross returns were accrued under privately managed tubewells followed by major canals and minor canals and government tubewells. The returns to farmers varied on the basis of different sources of irrigation that was attributed to adequacy, reliability and control on the sources by the farmers. Maximum yield was obtained from private tubewells followed by major canal, minor canal and government tubewells. The material input use was higher under tubewells reflecting intensive input use under assured irrigation availability. Under government tubewells and private tubewells, the contributions of hired labour wage were more in comparison to other sources of irrigation where family labour component was more.

Table 3. *Impact of different sources of irrigation on crop yields (kg/ha)*

Sources of Irrigation	*Kharif* Paddy	*Kharif* non paddy	*Rabi* paddy	*Rabi* non-paddy
Major Canal	3.57	5.75	4.52	0.55
Minor Canal	3.48	0	4.30	0.51
Government tubewell	3.27	7.25	4.09	0.53
Private tubewell	3.63	7.75	4.46	0.58

Table 4. *Use of yield raising inputs during kharif for paddy cultivation across the system of irrigation*

Sources of irrigation	Yield (t/ha)	Rank	Fertilizer consumptions (kg/ha)	Rank	HYV (% of total area)	Rank
Major canal	3.57	2	174	3	41.44	3
Minor canal	3.48	3	156	4	64.5	1
Government tubewell	3.27	4	189	2	35.85	4
Private tubewell	3.63	1	205	1	42.23	2

Table 5. *Yield of paddy (kg/ha) at different reaches of canal irrigation system*

Reach	Major Canal	Minor canal
Head	3.48	3.19
Middle	3.20	0
Tail	2.72	2.18

Table 6. *Yield of* kharif *paddy size classwise across the system of irrigation (kg/ha)*

Size class (ha)	Surface irrigation		Ground water irrigation	
	Major	Minor	Government tubewell	Private tubewell
0 - 1	3.32	3.095	3.15	0
1 - 2	3.56	3.38	3.4	3.50
2 - 4	3.79	3.67	0	3.86
>4	3.63	3.79	0	3.53
All size (average)	3.57	3.48	3.27	3.63

Table 7. Yield of HYV paddy across the system of irrigation size classwise (kg/ha)

Size class (ha)	Surface irrigation		Ground water irrigation	
	Major	Minor	Government tubewell	Private tubewell
0 - 1	4.21	3.84	3.92	0
1 - 2	4.5	4.23	4.27	4.41
2 - 4	4.65	4.5	0	4.75
>4	4.72	4.66	0	4.22
All size (average)	4.52	4.30	4.09	4.46

Table 8. Yield of local paddy across the system of irrigation size class wise (kg/ha)

Size class (ha)	Surface irrigation		Ground water irrigation	
	Major	Minor	Government tubewell	Private tubewell
0 - 1	2.43	2.35	2.38	0
1 - 2	2.62	2.53	2.52	2.59
2 - 4	2.92	2.84	0	2.98
>4	2.53	2.92	0	2.85
All size (average)	2.6	2.66	2.45	2.80

Table 9. Yield raising inputs during rabi across the system of irrigation

Sources of irrigation	Yield (t/ha)	Rank	Fertilizer consumptions (N+P+K) (kg/ha)	Rank	HYV (% of total area)	% Allocation of area to paddy
Major canal	4.84	2	155	3	100	77.14
Minor Canal	4.52	4	141	4	100	94.36
Govt. Tube well	4.58	3	184	2	100	41.12
Pvt. Tube well	4.98	1	203	1	100	88.68

Cropping intensity and cropping pattern

From the Tables 10 and 12 it is inferred that cropping intensity for all classes of farmers was maximum under private tubewells though sample size was very small under this source. It is expected that the factor of availability and adequacy contributes maximum to higher cropping intensity under private tubewells, followed by government tube wells, major canal and minor canal under surface irrigation system. With respect to cropping pattern maximum area was put under HYV paddy in all the systems except private tubewell. The less area under HYV paddy under private tubewell in *kharif* might have been due to individual performance for local paddy, type of land and market reasons (more price for local paddy). However, in general, HYV paddy predominated across the system of irrigations. Pulses, vegetable and oil seeds occupied very low percentage of area under all the systems except under major irrigation where pulses occupied 14.35% of area. The area under crop diversification might have been well drained (upland under commands) and independent water availability as *kharif* pulses were dependent on monsoon rain.

During *rabi*, the HYV covered 59% of area under private tubewells whereas, it was less than 30% for other sources except minor irrigation projects where it was 33.27%. Pulses occupied maximum area (41%) under minor canal system in *rabi* and under government tubewells it was lowest (3%). The distribution of area under different crops across the system in *rabi* were influenced by assured irrigation supply, market factors, size of farms and farmer entrepreneurship ability.

Table 10. *Size classwise cropping intensity (CI) in % under different sources of irrigation*

System of irrigation	Size class distribution				
	0-1	1—2	2—4	>4	All class (%)
Major	244.06	228.5	97.5	54.2	113
Minor	126.32	100	0	100	108
Government tubewell	162.16	99.63	0	0	131
Private tubewell	0	192	134	167	164

Table 11. *Cropping pattern according different system of irrigation (% of area under particular crop) in kharif*

System of irrigation	Local paddy	HYV Paddy	All paddy	Pulses	Oil seeds	Vegetables	Others
Major	26.64	41.44	67.78	14.35	0	17.86	0
Minor	30.7	64.5	95.2	4.75	0	0	0
Government tubewell	28.29	36.53	64.78	1.657	1.287	31.71	0.5
Private tubewell	57.76	42.23	88.68	0	0	0	0

Table 12. *Cropping pattern according to different system of irrigation (% of area under particular crop) in* rabi

System of irrigation	HYV Paddy	Pulses	Oil seeds	Vegetables	Others
Major	29.37	33.02	0	37.59	0
Minor	33.27	41.5	0	25.1	0
Govt. Tube well	26.47	2.9	0	70.58	0
Pvt. Tube well	51.72	5.74	0	42.52	0

Table 13. *Constraints in irrigated commands as perceived by sampled farmers across the system*

System of irrigation	%HH getting adequate water	% HH using field channel	%HH affected by water logging	% area affected by waterlogging	% HH having field drains
Major canal					
Head	33	Nil	Nil	Nil	30
Middle	27	Nil	Nil	Nil	Nil
Tail	22.5	Nil	Nil	Nil	Nil
Minor canal	87.8	Nil	Nil	Nil	Nil
Head	0	Nil	Nil	Nil	Nil
Tail	0	Nil	Nil	Nil	Nil
Government tubewell	66	Nil	Nil	Nil	54
Private tubewell	98	Nil	Nil	Nil	80

Table 14. Size classwise gross value of output across the system of irrigation (Rs/ha)

System of Irrigation	0-1	1-2	2-4	>4	All Class
Major	10956	11748	12491	11963	11789
Minor	10214	11154	12111	12507	11496
Government tubewell	10395	11220	0	0	10808
Private tubewell	0	11550	12738	11649	11979

Size classwise distribution of cropping intensity was maximum for the class 1-2 ha (small farmers) as entrepreneurial ability of this class was higher under private tubewells, and for all other sources the size class 0-1 ha (marginal farmer) score over other classes across all the systems of irrigation. The inference that the smaller the better was to some extent found true in the case studies across the systems of irrigation other than private tubewells.

Constraints in water management across the systems of irrigation

The households who expressed satisfaction in terms of adequacy of water availability (Table 13) were higher (88%) under head reach of minor canal in comparison to major canals in all the reaches under surface irrigation system and for private tubewells almost all the farmers were satisfied with respect to adequacy norm. Only 54% respondents under government tubewells expressed having field drainage system and 80% under private tubewells used field drainage for disposal of excess water. It signifies that more the control over the system the better is the water management practices by farmers. Use of field channels (instead of field-to-field irrigation) was found to be absent for all the systems of irrigation indicating a matter of concern from water management point of view.

Policy Inference

From the study it is evident that more the control of farmer on the source of irrigation, the more the inducement to manage inputs rationally which assures a better yield to the farmer. As the risk associated with public irrigation system is more in terms of reliability and adequacy, the farmers do not venture into better application of inputs and its management under major canal system. However; there cannot be a universal inference that the cost of cultivation and output under varying irrigation are necessarily different, as farmer entrepreneurship under different irrigation system also becomes a major factor in overall management of inputs. So in terms of investment on different sources of irrigation, the farmer preferences must be given due importance along with cost and availability of water.

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Feasibility of Exploiting Ground Water In Coastal Tract Of Orissa

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The study was conducted in a coastal district of Orissa to find out the feasible status of developing ground water through proper well designing. One of the effective ways of determining ground water characteristics is to conduct and analyze pumping test results. In this study, pumping test was conducted in Manitri village of Cuttack District of Orissa in order to find out the aquifer characteristics of that area. A mathematical model SATEM was calibrated by using these pumping test results. The aquifer test results as well as the well log data of that area showed that good aquifer in this region fell within the depth of 40-50m depth below the surface. Hence there was good chance to develop ground water in these tract which could mitigate few of the water scarcity problems. It was found that the transmissiivity and storativity values were ranging between 188 to 710 m^2 day^{-1} and 1.5´10^{-4} to 9.8´10^{-3}, respectively. The specific yield was calculated as 0.92 m^3 hr^{-1} per sq m of the area under unit depression head. SATEM programme was calibrated by using the pumping test data and transmissivity values were found as 360-680 m^2 day^{-1} with respect to different thickness of the aquifer.

(***Key words:*** *Well log, Pumping test, Groundwater characteristics*)

Most of the areas of Orissa fall under the coastal tract of the state. There is ample amount of water resources in this state but the problem of waterlogging/flood during the monsoon season and water scarcity/ drought during the summer remain the same as usual. Shallow water tables and associated salinity problems in few patches of coastal tract of Orissa have become dominant features in these areas. Canal irrigation system has created unequal distribution of water throughout the command area. Management plans that have been developed to address this problem often focus on engineering means such as ground water pumping or horizontal subsurface drainage (Heuperman, 2000). It has been observed that the ground water development in Orissa is only 14.9 % (Anon., 2003) leaving vast water resources for future use. Use of shallow tubewells and open wells have been stricted to only domestic uses in this area. This paper emphasizes the feasibility of exploiting ground water in a sustainable way with the analysis of well log data, resistivity survey and pumping test, which can be useful while designing a well in this area.

MATERIALS AND METHODS

The project site was selected at Manitri village of Mahanga Block at Cuttack district. It falls in the middle end of Pattamundai Canal distributary No.5 (Mahanadi Delta I). From the preliminary survey conducted in the project site, it was found that there was presence of four numbers of open wells, which were constructed for irrigation purposes, but none of these was being used for the same. This area also faced water scarcity problem during summer. Two observation wells to a depth of 3-m were installed near the selected open wells, and subsurface water table depth was measured periodically alongwith the water table in the open wells. Pumping test was conducted in the open wells in order to determine the aquifer characteristics. A mathematical model SATEM (Boonstra, 1994) was also calibrated by using the pumping test data and both the results were analyzed to find out the aquifer constants. Resistivity survey was conducted in 7 locations of the project sites to find out the aquifer zones in these regions.

RESULTS AND DISCUSSION

The well log data (Table 1) collected from the exploratory well at Mahanga showed that the aquifer of the area lies in the granular zone and there is presence of alternate layer of sand and clay up to a depth of 95 m below the ground surface.

Table1. *Well log data of Mahanga Block (GWS&I)*

Depth below surface, m	Aquifer type
0 -9.14	Clay with Sand
9.14-18.29	Clay with laterite
18.29 to 42.68	Laterite
42.68 to 45.73	Clay
45.73 to 51.82	Laterite clay
51.82 to 60.97	Clay with sand
60.97m to 73.15	Sand
73.15m to 80.79	Black clay
80.79 to 94.51	Sand

Shallow (< 5m) hand dug wells are common in many areas of coastal Orissa. These wells offer hydrogeologists an opportunity to characterize the permeability of the shallow aquifers for ground water resource evaluation and environmental studies. However, hand dug well deserve special attention when testing because of their large diameters which create a substantial well bore storage effect. Hand dug wells have large diameter to facilitate construction and to store water. Standard techniques for interpreting pumping tests assume that well storage is negligible. In large diameter wells (well diameter >1 m), well storage effects cannot be neglected. The static water table depth in the open wells was 2.56 m and 1.75 m, respectively at the time of pumping test. The calculated and model results followed the same trend for both the wells.

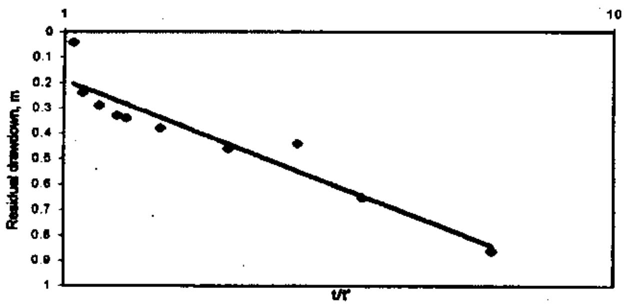

Fig. 1. *Residual drawdown plotted against t/t' for well no. 1.*

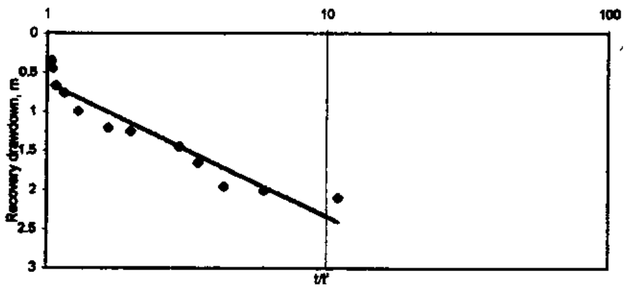

Fig. 2. *Recovery drawdown plotted against t/t' for well no. 2*

The average pumping rate was 0.575 $m^3 min^{-1}$ and 1.6 $m^3 min^{-1}$ for both the wells. Again, the recovery drawdown was monitored with small time interval. Transmissivity and Storage Coefficient values were calculated by using the Theis Equation. Time since pimping started to time since pumping stopped i.e., (t/t') was plotted against the recovery drawdown to calculate the Transmissivity values in case of both the open wells (Figs.1 and 2). Aquifer constants obtained from the analysis (Table 2) showed that the Transmissivity values were ranging from 188 and 244 $m^2 day^{-1}$. SATEM result showed that the values were ranging from 360-680 $m^2 day^{-1}$ depending upon the thickness of the aquifer. Storativity values were varying from 1.5 x 10^{-4} to 9.8 x 10^{-3} and the specific yield was calculated as 0.92 $m^3 hr^{-1}$ per sqm of the area under unit depression head (Table 3).

Table 2. *Aquifer constants obtained from the analysis*

Transmissivity (T) m^2/day	Yield, m^3/hr	Specific yield, m^3/hr per sqm of area	Hydraulic conductivity, (K) m/day
188	60-80	0.92	5-10
244	70-90	0.89	6-10

Table 3. *Aquifer constants obtained from SATEM*

Transmissivity (T) m^2/day	Storativity (S)	Yield, m^3/hr	Hydraulic conductivity (K) m/day
360-710	1.5×10^{-4}	62-72	6-15
395-680	1.4×10^{-3} to 9.8×10^{-3}	65-70	5-20

The results obtained from the pumping test analysis showed that the upper unit is more porous and high yielding type. Results with the well log and resistivity survey analysis showed that the good aquifer exists under the depth of 40-50m below the soil surface. Hence shallow tube wells upto this extent can be useful for irrigation purposes.

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Studies on the Development and Utility Status of the Shallow Tubewells in the Sundarbans Area

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The scarcity of good quality water in Sundarbans region is the greatest limitation for growing crops in the *rabi*/summer season. So, the ground water has been exploited by the farmers through shallow tubewells since a few years back. Present study was undertaken to evaluate the development and utility status of the shallow tubewells in this area. For this, a survey was conducted during the year 2000.The data on year of installation, materials, depth, strainer, pump, etc. were collected from the farmers tubewells. The depth of the tubewells varied from 67 m to 128 m. Almost all the farmers have been using them for *rabi* cultivation of paddy and other crops. The diesel pumps were used for lifting the water. The average cropped area per shallow tubewell was 6.3 acre. The cost of installation per tubewell was Rs 26,793/-(average). Quality of water in most of the tubewells was found to be suitable for irrigation. Farmers felt that there was decrease in discharge towards the later part of the cropping season. Initially, the number of tubewells increased alarmingly but later slowed down because of rise in diesel price and reduction in market price of the agroproducts.

(***Key words:*** *Shallow tubewells, Irrigation, Agricultural production*)

In Sundarbans region, 90 % of population are involved in agriculture. But more than 80% area is monocropped under rainfed *kharif* rice. The constraint for multicropping is the scarcity of good quality water during *rabi*/summer seasons. That is the main reason for economic backwardness of the people (Ambast *et al.*, 1998). To meet the growing demand of food and intensifying agriculture, exploitation of ground water was the major option left to the farmers. The farmers in this region have been exploiting the ground water through shallow tubewells since a few years back. There has been little information in this regard. Therefore, the present study was undertaken to generate information regarding the development of the shallow tubewells in this region and their present utility status.

MATERIALS AND METHODS

A survey was conducted during 2000 in 13 villages viz., Nikarighata, Dumki, Hinchakhali, Tengrakhali, Korakati, Belekhali, Dabu, Jairamkhali, Banibada Belekhali, No. 2 Dighirpar, Uttar Redokhali, Kunarshah and Uttar Rangad Beria of the South 24-Parganas district on the development and utility status of the shallow tubewells. A questionnaire was prepared for collecting the data about materials of construction, year of installation, depth, type and length of strainer, cost of installation, power utilized, crop cultivated, season and cropped area, methods of irrigation, mode of water distribution, and farmers perception about this technology. Total 95 farmers/shallow tubewell owners were interviewed. The data were also collected from the local artisans about the method of installation followed. The water quality of the tubewells was analyzed and classified as per standard guidelines for irrigation water (Minhas and Tyagi, 1998).

RESULTS AND DISCUSSION

The shallow tubewells have been installed in low, medium and uplands as per the owners' will. Two types of shallow tubewells were found such as (i) single and (ii) double. Some farmers installed the second one, just near to the first when the discharge was inadequate in the first one. That was for tapping water from the aquifers available at different depths. Both the tubewells were interlinked and only one pump was used for lifting the water. The direct circular rotary drilling method was followed for installing the shallow tubewells manually. The materials of the shallow tubewells were PVC pipe of diameter 7.62 cm, strainer, hand pump and diesel pump. The principle of operation of the shallow tubewells was priming the suction pipe through the hand pump and starting the diesel pump.

The range of depth of the shallow tubewells was 67m to 128 m with average of 84m. The depth of tubewell has been decided by the artisans involved in the installation process and by the owners. The tubewell development procedure was not followed and pumping test was also not conducted to find out the best suitable pump. The development of shallow tubewells at the study area was surveyed (Fig. 1) and it was found that a few tubewells were installed in the year 1996. The number of installation increased 10 times in the year 1999. Then, there was about 50 % reduction in the year 2000. This reduction was due to rise in diesel price and low market price of the harvested products.

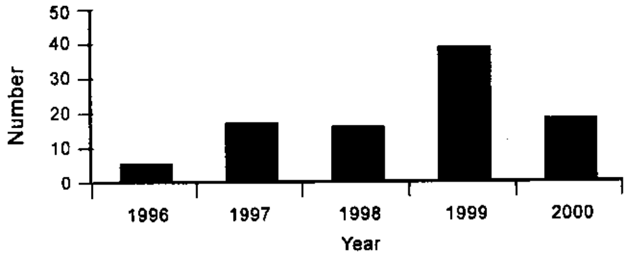

Fig. 1. *The installation of shallow tubewells in different years*

The strainers were of 3 types such as (i) Bamboo (ii) PVC and (iii) Metallic. PVC type strainers have been mostly used. The number of metallic type was least (Fig. 2). The length of strainer varied from 9.1m to 18.3m, the average being 14.2m. The cost of the tubewell was based on method of installation, materials, depth and the pump. It varied from Rs.18000/- to Rs.50000/- with average being Rs 26793/-. Here, all the pumps were diesel operated centrifugal pumps of capacity 3 to 5 hp.

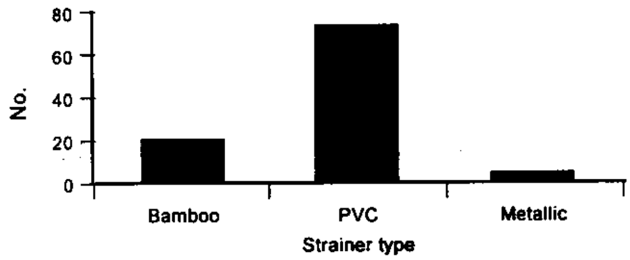

Fig. 2. *The different types of strainers in the shallow tubewells*

The principal crop cultivated through the shallow tubewells in *rabi* season was paddy. Some farmers also cultivated vegetables but the cropped area was little. The cropped area per tubewell varied from 1 to 16.67acre with average being 6.3 acre. The variation was based upon yield of the tubewell and demand by the farmers. All the farmers practised the flood type of irrigation. The mode of distribution of water from the tubewell to the farmers' fields was in rent basis. The farmer had to pay specific amount to the tubewell owner other than the fuel charge. The amount varied from Rs.900/- to Rs.2100/- per acre with average of Rs 427.50. The water quality in most of the shallow tubewells were found suitable (EC<2dS/m and SAR<10) for irrigating the crops in *rabi*/summer. The salinity of water was found increasing towards the later part of the *rabi*/summer season but that was within the permissible limit. Almost all the farmers felt that there was decrease in discharge towards the later part during this period.

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Effect of Protective Saline Water Irrigation with and without FYM and Gypsum on Yield of Groundnut

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A field experiment was conducted (1991 to 1997) to study the effect of protective saline water irrigation with and without FYM and gypsum on yield of groundnut at Agricultural Research Station, G.A.U., Khapat (Dist. Porbandar). The results revealed that protective irrigation with saline water during individual years significantly increased the pod and haulm yield of groundnut compared to no irrigation. Application of FYM @ 25 t ha^{-1} at 2nd year of application alongwith protective irrigation produced significantly higher pod yield during three out of four years, except during 1994. Almost similar trend was recorded in case of haulm yield. Additional pod and haulm yields of 547 and 678 kg ha^{-1}, respectively can be obtained with net return of Rs.8341 per hectare having net ICBR of Rs.1: 20.85 with protective irrigation.

(Key words: Protective irrigation, FYM, Gypsum, Groundnut yield, Coastal soil)

Groundnut is predominantly a rainfed crop in Western India. Use of soil amendments alongwith the protective irrigation with saline water may offer some clue to sustain the groundnut production n the saline arid tract. With this in mind present experiment was conducted.

MATERIALS AND METHODS

A field experiment on groundnut cv. GG-2 was conducted (*kharif*, 1991 to 1997) in RBD at Agricultural Research Station, G.A.U., Khapat (Dist. Porbandar). The treatments were T_1: Rainfed groundnut (control), T_2: Groundnut with protective irrigation (GWPI), T_3: T_2 + gypsum @ 50 % of GR once in three years - 1st year of application, T_4: T_2 + 50 % GR 2nd year of application, T_5: T_2 + 50 % GR 3rd year of application, T_6: T_2 + 25 t FYM ha^{-1}, once in three years - 1st year of application, T_7: T_2 + 25t FYM ha^{-1} from 2nd year of application, T_8: T_2 + 25 t FYM ha^{-1} from 3rd year of application, T_9: T_2 + T_3+ T_6, T_{10}: T_2 + T_4+ T_7, T_{11}: T_2+ T_5+ T_8, and T_{12}: Fallow. The experimental soil has texture silty loam, $EC_{2.5}$ 0.21 dSm^{-1}, $pH_{2.5}$ 8.4, $CaCO_3$ 36 g kg^{-1}, ESP 3.3, which were estimated by adopting standard procedures (Jackson, 1973). The RD of 12.5 kg N and 50 kg P_2O_5 ha^{-1} were applied as basal in the form of urea and DAP respectively. Due to unavailability of water for irrigation during the year 1993 the crop could not be saved.

RESULTS AND DISCUSSION

Effect on crop yield: The data (Table 1) showed that protective life saving irrigation significantly increased the pod and haulm yield compared to no irrigation. Similarly, the pod and haulm yields having FYM and gypsum treatments were also considerably higher with protective irrigation compared to no irrigation. The data after three years (1994 to 1997) were utilized for statistical analysis (pooled results). The data 1994 onward and pooled data show that pod and haulm yields were significantly affected by the different treatment, except pod yield during 1994 and in pooled results and haulm yield during 1997. Protective irrigation and FYM application @ 25 t ha^{-1} at second year (T_7) produced significantly higher pod yield during three (1995, 1996 and 1997) out of four years, and the highest pod yield in pooled result. Almost similar trend was recorded incase of haulm yield.

Economic evaluation: Protective life saving irrigation produced an additional pod yield of 547 and haulm yield of 678 kg ha^{-1} with net return of Rs. 8341 per hectare having net ICBR viz., Rs.1: 20.85 (Table 2).

Application of FYM @ 25 t ha^{-1} at second year with protective irrigation produced additional 434 kg pod and 547 kg haulm yield ha^{-1} accounting net return of Rs.5603 per hectare with net ICBR of Rs. 1: 4.18.

Table 1. *Effect of different treatments on yield (kg ha⁻¹) of* kharif *groundnut*

Treatment	1991	1992	1994	1995	1996	1997	Pooled
				Pod yield			
T_1 Control	290	635	1690	1954	1782	2754	2045(960)
T_2 Control	700	1528	1829	2292	1528	2778	2106(1507)
T_3 G(50)	653	1528	1991	2181	1296	2917	2016
T_4 G(50)	616	1524	2148	2087	1412	2962	2152
T_5 G(50)	596	1417	1921	2639	1490	3009	2265
T_6 F(25)	933	1829	1968	2504	1760	3085	2329
T_7 F(25)	600	1343	1921	2685	2106	3449	2540
T_8 F(25)	759	1601	1921	2171	1296	2476	1966
T_9 ($F_{25}G_{50}$)	800	1579	1968	2065	1597	2951	2145
T_{10}($F_{25}G_{50}$)	484	1379	1690	2208	1421	2800	2030
T_{11}($F_{25}G_{50}$)	759	1504	1852	2010	1412	2765	2010
T_{12} Fallow	-	-	-	-	-	-	-
SEm(±)	86	111	163	99	71	115	58
C.D.(P=0.05)	254	331	NS	291	208	339	NS
				Haulm yield			
T_1 Control	882	1604	2338	2500	3019	3127	2746(1662)
T_2 Control	1050	2878	2523	3093	2648	3218	2870(2244)
T_3 G(50)	1274	2597	3310	3051	2361	3310	3008
T_4 G(50)	1310	2572	3449	2941	2435	3240	3019
T_5 G(50)	1202	2674	3241	3356	2491	3449	3134
T_6 F(25)	1497	2851	3310	3009	3639	3449	3352
T_7 F(25)	1023	2801	3125	3542	3102	3889	3415
T_8 F(25)	1137	2699	2940	2995	2278	3147	2840
T_9 ($F_{25}G_{50}$)	1396	2625	3310	2870	2787	3472	3109
T_{10}($F_{25}G_{50}$)	1131	2444	2778	3164	2527	3449	2979
T_{11}($F_{25}G_{50}$)	1220	2725	3056	2917	2347	3286	2901
T_{12} Fallow	-	-	-	-	-	-	-
S.Em.±	87	153	209	76	99	141	70
C.D.(P=0.05)	258	465	619	224	294	NS	NS

Table 2. *Economics of different treatments for* kharif *groundnut*

Treatments	Pooled yield (kg ha⁻¹)		Additional yield over control (kg ha⁻¹)		Additional income over control (Rs/ha)	Additional expenditure over control (Rs/ha)	Additional net return over control (Rs/ha)	Net ICBR
	Pod	Haulm	Pod	Haulm				
T_1 Control	2045 (960)	2746 (1662)	-	-	-	-	-	-
T_2 Control	2106 (1507)	2870 (2244)	61 (547)	124 (678)	1072 (8741)	300 (400)	772 (8341)	1:2.57 (1:20.85)
T_3 G(50)	2096	3008	-10	138	141	560	-460	-
T_4 G(50)	2152	3019	46	149	919	280	639	1:2.28
T_5 G(50)	2265	3134	159	264	2675	187	2488	1:13.30
T_6 F(25)	2329	3352	223	482	3975	2680	1295	1:0.48
T_7 F(25)	2540	3415	434	545	6943	1340	5603	1:4.18
T_8 F(25)	1966	2840	-140	-	-	-	-	-
T_9 ($F_{25}G_{50}$)	2145	3109	39	239	1005	3240	-2235	-
T_{10}($F_{25}G_{50}$)	2030	2979	-76	-	-	-	-	-
T_{11}($F_{25}G_{50}$)	2010	2901	-96	-	-	-	-	-
T_{12} Fallow	-	-	-	-	-	-	-	-

Price of materials considered
Pod: 13.5 Rs/kg Gypsum: 200 Rs/ton
Haulm: 2.0 Rs/ha FYM : 100 Rs/ton

Application charges of:
Gypsum: 60 Rs/ha
FYM : 180 Rs/ha

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Effect of Irrigation, Fertilizer and Mulches on Fruit Yield of Drip Irrigated Pointed Gourd (*Trichosanthes dioica Roxb.*)

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Drip irrigated pointed gourd @ 80% of pan evaporation(PE) produced equivalent fruit yield with 100% PE, saved 18.6% irrigation water and increased WUE by 16.3%. Fertigation with 75% of the recommended dose in combination with 80% PE produced maximum fruit yield of 5.46 t ha^{-1}. Thus application of fertilizer through drip (fertigation) in eight equal splits at monthly intervals from January to August saved 25 % fertilizer. Paddy straw mulch @15 t ha^{-1} produced 6. 45 % higher friut yield than 7.5 t ha^{-1} straw mulch. Lowest level of fertilizer in present experiment had maximum feriliser use efficiency, nitrogen use efficiency.

(***Key words:*** *Drip irrigation, Fertilizer, Mulch, Use efficiency, Pointed gourd)*

Pointed gourd is a tropical, perennial vegetable crop, being grown on bower system or spreading on soil surface. It is widely cultivated in coastal belt as well as in well drained sandy loam soil of Eastern part of India. Generally the root suckers are planted in winter season and the first flush of fruiting starts in the month of March which continues up to June. During this period frequent watering is essential to maintain proper moisture in crop root zone, which is quite feasible through drip system. Under this system, application of desired amount of fertilizer is also feasible to make effective utilization of applied fertilizer to the crop unlike surface irrigation in which it is applied in 3-4 splits. Eastern India is rice dominated, and in the month of November-December, most of the farmers usually have paddy straw in surplus lying unutilized. When it is used, it conserves more moisture for longer period during high evaporative demand in summer and under prolonged dry spell in rainy season which regulates adequate moisture for crop growth (Mahrer *et al.*, 1984, Bennett *et al.*,1966). Considering these problems, the experiment was conducted with three irrigation schedules, 3 fertilizer levels and 2 mulch levels at the Research Farm of WTCER, Bhubaneswar.

MATERIALS AND METHODS

The field experiment was conducted at the research farm of Water Technology Center for Eastern Region Bhubaneswar during 2001-2002. The experimental soil was sandy loam to clay loam texture. On 24.11.2001 root suckers of pointed gourd was planted in crop geometry of 1.5-x 1.0 m in plot size of 6 - x 6 m. FYM @ 10 t ha^{-1} (3.6 kg plot^{-1}) was thoroughly mixed with excavated soil and again it was put into same pits before planting root suckers. The treatment comprised three irrigation levels i.e., 100, 80 and 60% of pan evaporation (PE), three fertilizer levels, i.e., 100, 75 and 50% of the recommendable dose (RD) of fertilizer (180:90:90 kg NPK ha^{-1}), and two levels of mulch i.e., 7.5 and 15 t ha^{-1}. Nitrogen was applied at monthly interval from January 2002 to August 2002, however, phosphorus and potassium were applied as per doses manually after application of urea solution through drip. The irrigation water through drip was applied at two day intervals till 10.06.2002 i.e., onset of rain. After receiving good amount of rainfall irrigation was stopped. Total evaporation from planting (24.11.2001) to onset of monsoon i.e., up to 10.6.2002 was 90.02 cm and rainfall was 18.64 cm. However during crop growth period i.e., 24.11.2001 to 30.9.2002, total evaporation and rainfall were 133.57 and 149 cm, respectively.

RESULTS AND DISCUSSION

Fruit yield

Application of irrigation water @100% PE through drip at two day intervals produced 7.1 and 25.2 % higher fruit yield over 80 and 60% PE in which the fruit yield was 4.92 and 4.21 t ha^{-1} respectively. Irrigations at 100% PE required 22.97% and 58.58% more water during dry month period over 80 % (47.9 cm) and 60% PE (37.13 cm) respectively. Considering the importance of irrigation water during summer season, irrigation at 80% PE may be followed as the fruit yield was slightly less than 100% PE. This reduction in fruit yield could be compensated by irrigating more area with saved water. Manjunath *et al.* (2001) and Singandhupe and Brahmanand (2001) reported that pressurized irrigation system saves 50-60% water and produces 10-15% higher yields over traditional surface irrigation. In this experiment 100% RD in eight splits through drip at monthly interval produced 3.4 and 21.8% higher fruit yield than 75 and 50% RD, respectively. So under drip system, fertigation with 75% RD produced comparable fruit yield with 100 % RD and saved 25 % fertilizer dose. In this experiment, it has been observed that application of 75 % RD of fertilizer with 80 % PE irrigation schedule produced 5.6 % higher fruit yield than irrigations at 100% PE with same amount of fertilizer dose. Effect of differential quantity of paddy straw mulch did not respond significantly, however, application of 15 t ha^{-1} paddy straw mulch produced 6.45% higher fruit yield than 7.5 t ha^{-1} in which the fruit yield was only 4.65 t ha^{-1}. With regards to interactive effects of irrigation, fertilizers and mulch, the effect was non-significant.

Fertilizer use efficiency

During crop growth period, adequate amount of irrigation water within crop root zone under 100 and 80% PE irrigation schedule enhanced utilization of applied fertilizer by the plants and hence fertilizer use efficiency, nitrogen use efficiency and Phosphorus/Potassium use efficiency were very high. FUE in 100 and 80% PE irrigation schedule was 20.82 and 19.03 kg fruit kg^{-1} NPK. In case of nitrogen and phosphorus or potassium use efficiency, the effect was quite significant and the NUE in 100 and 80% PE irrigation schedule were 41.65 and 38.10 kg fruit kg^{-1} applied nitrogen, respectively and in the lowest level of irrigation water (60% PE), NUE was only 33.10 kg fruit kg^{-1} applied nitrogen. Similarly in case of phosphorus and potassium, the response on fruit yield was quite high in 100 and 80% PE, and it was 83.30 and 76.21 kg fruit kg^{-1} of applied of phosphorus/potassium, respectively.

Generally plant absorbs more nutrients under constraint of nutrients. Under lowest level of fertilizer dose i.e., 50% RD, the FUE, NUE and P/K use efficiency was maximum i.e., 23.62, 47.25, and 94.51 kg fruit kg^{-1} of applied fertilizer, respectively. However with increasing fertilizer level from 50% to 100%, the FUE, NUE and P/K use efficiency were reduced to 14.34, 28.68 and 57.37 kg fruit kg^{-1} of NPK, nitrogen and phosphorus or potassium, respectively. The effect of differential amount of mulch on FUE, NUE and P/K use efficiency was non-effective, and hence any quantity of mulch material (up to 15 t ha^{-1}) may be used to have 18.22 to 19.39 kg fruit kg^{-1} of applied NPK, 36.45 to 38.40 kg fruit kg^{-1} of nitrogen, and 72.90 to 77.60 kg fruit kg^{-1} of applied phosphorus/potassium.

Irrigation water use efficiency

Effect of higher amount of irrigation water in 100% PE did not produce proportionate yield of pointed gourd and hence irrigation water use efficiency in 100% PE was 88.41 kg per ha-cm applied water, but in 80 and 60 % PE, it was higher by 16.27 and 23.25%, respectively. In case of differential amount of fertilizer level, the irrigation water use efficiency was statistically non-significant between 100 and 75% RD, and was found to be 105.37 and 105.89 kg fruit per ha-cm of applied irrigation water, respectively. But in case of 50% RD the IWUE was drastically reduced by 15.6 % over 100 % RD. The effect of two levels of mulch on IWUE was not effective, however, application of 15 t ha^{-1} straw mulch had 8.6 % more IWUE than 7.5 t ha^{-1} straw mulch.

Soil moisture status

Soil moisture content was recorded from four soil depths with TDR moisture meter during December, 2001 to June, 2002. The results showed that the moisture content in the December 2001 at source of emitter was higher in all irrigation levels but towards May, 2002 it was in declining trend. The soil moisture status increased with increasing soil depth and maximum moisture was observed in 60-80 cm depth. In the month of December 2001, the moisture content was 15.2 to 18.5% in 0- 20 cm soil depth and maximum of 22.0 to 25.3% in 60-80 cm soil depth in different irrigation level, but in the month of May, 2002, it was 13.4 to 17.3% and 19.0 to 21.7% in corresponding soil depths. During different observation periods, irrigations supplied with more quantity in 100% PE alongwith 100 % RD and 15 t ha^{-1} as mulch has more soil moisture and ranged from 13.4 to 18.9% (v/v) as compared to 60% PE with same amount fertilizer (100% RD) and mulch treatment (15 t ha^{-1}) in which the soil moisture was 12.8 to 17.9% (v/v). In case of 80% PE with 100% RD and 15 t ha^{-1} straw mulch treatment, the soil moisture was 14.2 to 18.5%.

Growth pattern

The pointed gourd is usually grown in a well drained soil and vines require training on some form of aerial support system to achieve maximum fruit yield. In this experiment, six vines were selected from each treatment level and were allowed to grow on trailing system. In another set, same number of vines were allowed to spread on ground and then the growth pattern were monitored at 2- 6 day intervals from 1.6.02 and ended on 13.8.02. The length of vine was maximum under highest level of treatment combination. In 100% PE, 100% RD and 15 t ha^{-1} mulch, the total length of vine was 286 cm under verical spread and 345 cm under horizontal spread. In case of lower level of irrigation (60% PE) with same amount of fertilizer and mulch, total lenght was 278 and 297cm under vertical and horizontal spread, respectively. The absolute growth rate was maximum of 7.0 to 18.6% under horizontal and 4.7 to 10.7% under vertical spread. More growth rate in horizontal spread of vines was due to 133.5 mm rainfall during 10 to 20, June, 2002, and later part of the growth period i.e., during July and August, which helped to extract more water through the root systems that were developed from nodes and penetrated through the soil profile as compared to the vines which were grown vertically and extracted water and other plant nutrient from only one place. Further, it has been observed that in 60% PE under horizontal spread, the growth rate was maximum in later age of plant as compared to 100% PE . This may be due to more availability of plant nutrients which were applied during planting to May, 2002 but not utilised fully due to lack of sufficient soil moisture. Subsequently receipt of sufficient rainfall i.e., 207.7, 294.76, and 37.5 mm during June, July and up to August 13, 2002, respectively benefited the crop growth effectively.

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Sustainable Yield Index of Mulberry as Influenced by Varieties, Levels of Irrigation and Soil Moisture Conservation Techniques

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Mulberry leaf production is often limited by the amount of available soil moisture and it can be substantially increased by supplemental irrigation. Of all the inputs in mulberry cultivation, irrigation is known to bear the highest correlation with leaf production. The response of two varieties of mulberry viz., K-2 and S-54 to four levels of irrigation i.e., control, irrigation at CPE (cumulative pan evaporation) 15 mm, CPE 30 mm and CPE 45 mm and four soil moisture conservation practices i.e., incorporation of coir pith, mulching with coconut husk, incorporation of silk worm litter, and no soil moisture conservation technique were studied for two years at the College of Horticulture, Vellanikkara. Total fresh leaf production (TFLP), benefit-cost ratio (BCR) and sustainable yield index (SYI) were worked out. The varietal reaction was significant and the variety S-54 was superior with respect to TFLP, BCR and SYI. Irrigation at CPE 30 mm and mulching with coconut husk recorded higher values for all the above parameters. The interaction effects were significant and maximum TFLP, BCR and SYI were recorded for the treatment combination S-54 x irrigation at CPE 30 mm x mulching with coconut husk.

(**Key words:** *Mulberry, Variety, Irrigation levels, Mulch, Sustainable yield index*)

Mulberry sericulture is an important agrobased labour intensive rural industry in India. Of all the inputs in mulberry cultivation, irrigation is known to bear the highest correlation with leaf production. Irrigation interacts remarkably with every other input (Rangaswamy and Jolly, 1993). Irrigation interval can be extended if appropriate soil moisture conservation measures are adopted. Various byproducts of crops can also be effectively used for soil moisture conservation. Incorporation of coir pith, mulching with coconut husk and application of silk worm litter are some of the measures that can be adopted for conserving soil moisture in the tropics. The present experiment was conducted to study the varietal response of mulberry to varying levels of irrigation and different soil moisture techniques.

MATERIALS AND METHODS

The experiment was conducted in split-plot design and the main plot treatments consisted of combinations of two varieties and four levels of irrigation. The four soil moisture conservation techniques constituted the subplot treatments. The treatments consisted of combinations of two varieties of mulberry viz., K-2 and S-54, four levels of irrigation i.e., control, irrigation at CPE (cumulative pan evaporation) 15 mm, CPE 30 mm and CPE 45 mm, and four soil moisture conservation practices i.e., incorporation of coir pith, mulching with coconut husk, incorporation of silk worm litter and no soil moisture conservation technique. The crop was irrigated from 15th November to 30th May during both the years. Pre-treatment irrigation was given to bring the soil to field capacity. The depth of irrigation was maintained at 3.3 cm. The details of irrigation given are furnished in Table 1.

The mulberry crop was harvested seven times i.e., six, nine, twelve, fifteen, eighteen, twenty-one and twenty-four months after planting during the course of the experiment. Sustainable yield index was worked out applying the formula suggested by Singh *et al.* (1990).

RESULTS AND DISCUSSION

Data on fresh leaf production, benefit-cost ratio and sustainable yield index are given in Tables 2 and 3.

The variety S-54 recorded maximum total fresh leaf production. S-54 is a high yielding mulberry variety and the high LAI of the crop might have been responsible for the higher production of mulberry. In general, all the three levels of irrigation influenced the productivity of mulberry when compared with the control. However, maximum production was observed when irrigation was managed at CPE 30 mm. This might be due to better growth of plants

Table 1. *Details of irrigation treatments*

Treatments	Total number of irrigation	Quantity of water (mm)	Effective rainfall (mm)	Total quantity of water (mm)
T1 -Control	10	330	265	628
T1 -CPE 15 mm	78	2574	82	2689
T1 -CPE 30 mm	39	1287	172	1492
T1 -CPE 45 mm	27	891	233	1157

Table 2. *Leaf yield, benefit-cost ratio and sustainable yield index of mulberry varieties as influenced by levels of irrigation and soil moisture conservation practices*

Treatments	Leaf yield (kg ha^{-1})	BCR	SYI
Varieties			
K-2	23861	1.47	0.26
S-54	35674	2.18	0.40
SEm±	300.01	0.01	-
CD (P=0.05)	910.05	0.05	-
Levels of irrigation			
Control	18754	1.26	0.21
CPE 15 mm	31835	1.82	0.36
CPE 30 mm	34483	2.09	0.39
CPE 45 mm	33998	2.13	0.39
SEm±	424.27	0.02	-
CD (P=0.05)	1287.00	0.07	-
Soil moisture conservation			
Coir pith	28170	1.69	0.32
Coconut husk	34298	2.05	0.38
Silk worm litter	28939	1.79	0.32
Control	27664	1.77	0.32
SEm±	379.97	0.02	-
CD (P=0.05)	1053.22	0.06	-

associated with favourable soil moisture regimes. The effect of mulching with coconut husk was consistent in increasing the production throughout the period of growth and considerable increase in productivity was observed over other moisture conservation techniques. The husk was spongy in nature and when buried in the soil it absorbed and retained moisture which became available to mulberry roots. A fully soaked husk was able to retain about six to eight times its weight of water (Thampan, 1982). The response of the variety S-54 was worth mentioning when it was given irrigation at CPE 30 mm and coconut husk used for soil moisture conservation.

The variety S-54 was found economical and it showed its superiority over K-2 in terms of BCR and SYI. Irrigation at CPE 45 mm and incorporation of coconut husk were also found favourable for increasing the above economic criteria.

The interaction effects assumed significance and the combination S-54 x irrigation at CPE 30 mm x mulching with coconut husk resulted in maximum BCR and SYI. Total fresh leaf production was the most important parameter deciding profit since there was not much variation in the cost of production of leaf. The minimum guaranteed yield with the treatment combination involving the high yielding variety S-54, irrigation at 30 mm of CPE

***Table 3.** Leaf yield, benefit-cost ratio and sustainable yield index of mulberry as influenced by the interaction effects of varieties, levels of irrigation and soil moisture conservation practices*

Treatment combinations	Leaf yield (kg ha^{-1})	BCR	SYI
K-2 x I0 x MCP	18459	1.20	0.22
K-2 x I0 x MCH	23171	1.51	0.27
K-2 x I0 x MCS	14976	1.01	0.15
K-2 x I0 x MC0	20834	1.45	0.23
K-2 x I15 x MCP	23021	1.29	0.26
K-2 x I15 x MCH	28085	1.58	0.30
K-2 x I15 x MCS	16504	0.95	0.17
K-2 x I15 x MC0	20487	1.21	0.24
K-2 x I30 x MCP	24120	1.43	0.26
K-2 x I30 x MCH	28741	1.70	0.32
K-2 x I30 x MCS	27670	1.69	0.30
K-2 x I30 x MC0	22786	1.43	0.28
K-2 x I45 x MCP	24886	1.52	0.26
K-2 x I45 x MCH	31840	1.95	0.34
K-2 x I45 x MCS	29645	1.87	0.33
K-2 x I45 x MC0	26436	1.72	0.28
S-54 x I0 x MCP	18066	1.17	0.21
S-54 x I0 x MCH	18255	1.19	0.22
S-54 x I0 x MCS	17903	1.20	0.18
S-54 x I0 x MC0	18379	1.28	0.20
S-54 x I15 x MCP	38182	2.14	0.43
S-54 x I15 x MCH	46709	2.61	0.52
S-54 x I15 x MCS	40734	2.40	0.47
S-54 x I15 x MC0	39855	2.36	0.45
S-54 x I30 x MCP	40636	2.47	0.47
S-54 x I30 x MCH	50678	3.01	0.55
S-54 x I30 x MCS	44463	2.72	0.49
S-54 x I30 x MC0	35775	2.26	0.42
S-54 x I45 x MCP	37030	2.26	0.42
S-54 x I45 x MCH	46804	2.86	0.52
S-54 x I45 x MCS	38567	2.43	0.46
S-54 x I45 x MC0	36760	2.39	0.45
Sem (±)	990.34	0.065	-
CD (P=0.05)	2750.39	0.180	-

I0 – control, I15 – CPE 15 mm, I30 – CPE 30 mm, I45 – CPE 45 mm, MCP – Coir pith, MCH – Coconut husk, MCS – Silk worm litter, and MC0 – No mulch and mulching with coconut husk was 55 % of the maximum observed yield indicating the sustainability of this treatment combination.

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Session

On

Management of plantation crops and its diversified uses alongwith home gardening

J. Indian Soc. Coastal agric. Res., 22(1&2), 137-141, 2004 **Invited paper**

Management of Home Gardens and their Economic Prospects under Coastal Agroecosystem

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A critical analysis of a typical home garden in the coastal region shows that farmers are giving adequate attention to utilize the available space both in the horizontal and vertical dimensions. Inclusion of different tuber crops (cassava, colocasia, amorphophallus, etc.), an array of vegetables and spice crops like ginger, turmeric, black pepper and vanilla has helped to enhance the bioresource diversity and farm resource diversity utilization in a homestead. Cultivation of different crops in the combination, in a multispecies cropping pattern model, consisting of distinct canopy stratification, helps to reduce soil temperature inside the microclimate thereby reducing evaporative losses of water and maintain humidity in the system. Recycling of agricultural waste biomass helps in build-up of soil nutrients in the long run and also helps to maintain the biodiversity of soil microflora. Farmers have started preparation of vermicompost in their home gardens for use in crop husbandry. Incorporation of components of animal husbandry will take care of the nutritional requirement of the farm family as well as earn extra income by way of sale of produce. Inspite of the manifold advantages of such a cropping/ farming system in the homesteads, there is a tendency not to make use of the land and other resources to their fullest extent by a few farmers probably because of labour shortage and economic conditions. As such they are to be motivated further for adoption of homestead farming programmes.

***(Key words:** Homestead farming, Intercropping, Labour utilization, System management, Economics)*

Among various farm models in the world, homestead cultivation claims uniqueness and the practice of home gardens being followed in Kerala from time immemorial has been receiving an outstanding recognition the world over. This highly intensified and welldeveloped indigenous system is often characterized by interactions between biotic and abiotic parameters including the farming community housed within these systems in conjunction with the agriculture and allied enterprises. However, the productivity and protective functions encountered in many of the home gardens are not well monitored, recorded and documented for use by the future generations of farmers.

Homestead farming, a typical land use system with multispecies cropping and multienterprises, utilizes maximum available resources of land and solar energy. It is believed that a myriad of sociocultural factors including food habits, consumer and market preferences have sustained this system since time immemorial. However, changes in domestic agriculture scenario thereby decline in economic sustainability and makes the farmers reluctant in adopting homestead farming.

Ruthenberg (1971) distinguished homestead cropping from arable cropping by the following features: 1) Cropping those plants for personal consumption that cannot be collected nor supplied by arable farming, 2) Small plots, 3) Proximity to house, 4) Fencing, 5) Mixed or dense planting of a great number of annual, semi-permanent, and perennial crops, 6) High density of land use, 7) Land cultivation several times a year, 8) Permanence of cultivation, and 9) Cultivation with hand implements.

Thus, a homestead can be defined as an operational farm unit in which a number of crops, including food and cash crops, vegetables and tree crops, are grown with livestock, poultry and/or fish production, mainly for the purpose of satisfying the farmer's basic needs. The components of a homestead /home garden are so intimately mixed in horizontal and vertical strata as well as in time, that a number of complex interactions exist among soil, plants, other components and environmental factors in the farmer's plot where he lives and manages the unit (Nair and Sreedharan, 1986).

Home gardens benefit family nutrition, increase household income, provide a buffer to food insecurity during lean season, provide habitat protection and soil and water conservation (Marsh, 1996).

In India, homestead is mostly popular in Kerala, as it enjoys an equatorial climate with an optimum for growing most of the crops, and where average land holding size is very low (0.5 ha as against 1.69 ha of national average). Kerala's homestead is unique, being more or less coconut based with an array of inter/mixed crops resulting in multistory cropping system, thereby efficiently harnessing solar radiation and using soil moisture and nutrients.

Main characteristics

Nair and Dagar (1991) has outlined the main characteristics and agroforestry emphasis of the major agroecological regions of India and the details pertaining to the tropical coastal and island regions are given below.

Characteristics	Tropical coastal and island region
Climate	Tropical humid, lowlands, rainfall 60 to 310 cm
Geographical spread	Coastal regions of West Bengal, Orissa, AP, TN, Kerala, Karnataka, Maharashtra and the Islands
Soils and vegetation	Entisols, Oxisols, Inceptisols, Alfisols, Evergreen, Semi evergreen, moist deciduous, littoral and mangrove forests
Main land use systems	Plantation crops and multistoreyed cropping, field crops, fish culture, forestry
Main land use and ecological problems	Deforestation and degradation of environment, coastal erosion, acid-soils and related soil problems, soil erosion along slopes, shortage of fodder
Major agroforestry emphasis	Afforestation of coastal regions with littoral and mangrove species, aquaculture with mangroves, multistoreyed cropping system; alley cropping

It can be noticed that with respect to main land use system, it is mostly plantation crop based which incorporates inter/mixed cropping/farming systems by inclusion of animal husbandry and related enterprises. Salam *et al.* (1992) have developed a coconut based homestead model consisting of 0.2 ha for the coastal uplands of South Kerala under irrigated agriculture. It includes various crop combinations apart from one unit each of cow, goat and poultry.

Interaction between components in homesteads

A typical homestead, with a combination of crops, presents a multitier canopy configuration. The canopy architecture of the components are arranged in such a way that they occupy different vertical layers with the tallest component having foliage tolerant to strong light and high evaporative demand and shorter components having foliage requiring or tolerating shade and high humidity. Usually the major portion of the upper canopy goes for coconut and it is followed by pepper trailed on coconut, tree spices and cocoa planted in between coconut rows. Often the lower layer of the system consists of banana, cassava and other tuber crops. At the ground level, pineapple, vegetables and other herbaceous crops including fodder grasses are cultivated. Wherever coconut is present as the major component of the system, the inter/mixed crops grown vary according to the age and canopy spread of palms. During the initial stage of growth, all sunloving crops can be grown and when the palms attain the age of bearing (7-8 years), as the light available inside the plantation is reduced due to canopy growth, shade-loving crops such as yams, ginger, turmeric etc can be grown. After the age of 25 years, tree spices such as clove, nutmeg, cinnamon can be grown as mixed crops.

Labour utilization

At present the farmer, his family members and a few labourers provide the necessary work force. In small holdings, planting, cultural operations and harvesting of different crops occurring throughout the year are attended by the farm family. Most of the crops, except coconut, in the home garden are labour intensive. As compared to monocropping, the home gardens involve high labour utilization. For example, the average requirement of labour for one-hectare home garden with an intensive crop combination with livestock (mixed farming) is about 600 man days per year (Gopalasundaram *et al.*, 1993) as compared to 120-144 man days for coconut mono cropping (Das, 1990). Introduction of vanilla, which requires frequent coiling of vines and hand pollination after flowering, as mixed crop with coconut or arecanut also makes the system more labour intensive. Recently, because of the high price being realized for fresh beans, many farmers have taken up vanilla cultivation.

System management

Most of the farmers are aware of the ill effects of crop cultivation by use of deadly pesticides and hence there is a purposeful shift to ecofriendly farming by eliminating the use of chemicals for providing nutrition and protection of plants against pest and diseases. However, this necessitates creating facilities for appropriate organic inputs in and around the farm units. The intense multispecies cropping pattern also needs rearrangement for optimum light use efficiency so that continuous harvesting of crops and the use of soil nutrients at different levels and time can be managed and the land could be put to the best use.

Analysis and development of homesteads

Taking into account the need for collection of basic data and restructuring some of the identified homesteads in Kerala and the Andaman and Nicobar Islands, the Agro-Ecosystem Coastal Directorate (NATP) is implementing a project "Analysis and development of homestead farms of Kerala- A farmer participatory Approach" form last two years. The major objectives include: creation of data base of homesteads of Kerala and Andaman and Nicobar Islands; formulation of strategic interventions in the existing homesteads to develop farm models for resource use efficiency and income maximization; development of location specific homesteads models for different agroclimatic zones by modification of the existing system through planned interventions in input, technology and management; awareness creation among farmers and scientists.

Methodology

The Central Plantation Crops Research Institute, Kasaragod, one among the five centres, is implementing this project in the four northern districts of Kerala viz., Kasaragod, Kannur, Kozhikode and Malappuram. In order to create the database, 25 percent of *panchayaths* of these four districts have been identified (Table 1). Out of the 83 *panchayaths* identified, ten homesteads from each *panchayath* have been randomly selected to represent various locations in consultation with the concerned agricultural officers. Detailed survey was conducted during the first half of 2002 based on a questionnaire containing aspects like family details, cropping history, yield level, marketing strategy followed and present socio-economic status of farm families. Soil samples were also collected from these homesteads and were analyzed from the district soil testing laboratory.

Table 1. *Details of districts and number of* panchayaths *selected*

Name of district	No. of panchayaths	
	Total	Selected
Kasaragod	39	19
Kannur	87	21
Malappuram	79	19
Kozhikkode	99	24
Total	304	83

Basic data from the 815 homesteads of the four districts surveyed were collected. Based on the resources (land, water and capital) availability as well as willingness of farmers for restructuring their homesteads through their participation as well as inputs supplied from CPCRI through the NAT Project, five homesteads in each district have been shortlisted in different agroclimatic subzones for further analysis and implementation of interventions. A multi disciplinary team consisting of experts from crop production, crop protection and social science divisions has been constituted and they visited these homesteads during August/ September, 2002 to identify and suggest suitable interventions for restructuring of such homesteads. The details of interventions proposed in the selected homesteads are listed in Table 2.

Table 2. *Interventions suggested by the multidisciplinary expert team*

Sl. No.	Types of interventions suggested/implemented
1	Planting pepper rooted cuttings (Sreekara) 2 Planting tissue culture banana (G9)
3	Raising Vanilla as a mixed crop
4	Planting of hybrid cocoanut (WCTx COD)
5	Mixed cropping tree spices (Nutmeg and Clove)
6	Planting hybrid mango grafts (H 87) and sapotta grafts.
7	Raising vegetable crops
8	Planting Vetiver grass on raised bunds
9	Balanced fertilizer management for cocoanut palms
10	Introduction of pine apple
11	Construction of Vermicompost unit
12	Raising / strengthening of bunds for soil conservation
13	Introduction of Gramalakshmi chicks

Observations

The basic data collected regarding homesteads of the four states indicate that most of the farmers, in general, are cultivating a number of crops in their homesteads and adopt manuring, plant protection operations and other cultural practices. About 26 percent and 32 percent of the farmers in Kozhikkode and Malappuram districts, respectively carry out their cultivation utilizing family labour. This was more or less the same case with Kasaragod (32%) and Kannur district (26%). While majority of the farmers (56 percent) in Kozhikkode district sell their farm produces by direct marketing, it was only 26 percent in Malappuram. The cases with Kasaragod and Kannur were also more or less the same as in the case of Malappuram. More than 60 percent of farmers in these three districts resort to the marketing through intermediaries, thereby earning only low economic returns. More than 60 percent of the homesteads surveyed in all the districts are undertaking livestock rearing by maintaining one cow or the other enterprise to meet the domestic demand.

Inputs (planting materials, fertilizers earthworms, poultry chicks, etc.) for various interventions were supplied to each participating farmer, and plantings and operations were carried out. Regular monitoring of the whole programme is being undertaken. Data on growth of inter/mixed crops such as vanilla, banana and pepper are being recorded. Though most of the farmers are already growing pepper in their homesteads, it was noticed that they were cultivated without any scientific approach. Hence, new improved high yielding variety of pepper viz., Sreekara, a Karimunda selection, which can tolerate more shade, was supplied. The tissue culture plants of banana (cv. G-9) supplied to farmers start yielding and the farmers are happy with the performance. Farmers also started production of vermicompost by utilizing agrowaste biomass and they are applying the same to various crops being cultivated. The expected outcome of different interventions is as follows (Table 3).

CONCLUSIONS

A critical analysis of a typical home garden in the coastal region shows that farmers are taking adequate attention to utilize the available space both in the horizontal and vertical dimensions. Inclusion of different tuber crops (cassava, colocasia, amorphophallus, etc.), an array of vegetables and spice crops like ginger, turmeric, black pepper and vanilla has helped to enhance the bio-resource diversity and on farm resource diversity utilization in a homestead. Cultivation of different crops in the combination, in a multispecies cropping pattern model, consisting of distinct canopy stratification, helps to reduce soil temperature inside the microclimate thereby reducing evaporative losses of water and maintain humidity in the system. Recycling of agricultural waste biomass helps in build-up of soil nutrients in the long run and also help to maintain the biodiversity of soil microflora. Farmers have started preparation of vermicompost in their home gardens for use in crop husbandry. Incorporation of components of animal husbandry will take care of the nutritional requirement of the farm family as well as earn extra income by way of

Table 3. *Expected outcome of interventions in different homesteads*

Sl. No.	Interventions undertaken	Duration	Expected improvements
1	Better crop husbandry	Short term	Improves productivity
2	Better planting techniques, adequate spacing	Short/long term	Improves growth environment, scope for intercropping
3	Introduction of improved varieties	Long duration	Increased yield, Increased economic returns
4	Inter/mixed cropping/mixed farming	Long duration	Better employment generation, resource utilization, reduces risk, more income generation
5	Integrated nutrient management	Long term	Prevents soil degradation, improves soil fertility
6	Integrate multipurpose tree species (fruits, timber, cash crops etc.)	Long term	Improves economy over a period of time

sale of produce. Inspite of the manifold advantages of such a cropping/farming system in the homestead, there is a tendency not to make use of the land and other resources to their fullest extent by a few farmers probably because of labour shortage and economic conditions. As such they are to be motivated further for adoption of homestead farming programmes.

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Diversified Uses of Coconut

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Traditionally coconut is dried to produce copra which is then milled or solvent extracted to get the oil. The fresh kernel of ripe cocoanut constitutes an essential ingredient in the recipes of diverse food preparations in the households as well as in food industries of different countries. Cocoanut chips, desiccated coconut, virgin coconut oil, partially defatted coconut gratings, coconut cream, coconut milk powder are some of the edible products prepared from fresh kernel. Coconut water which is a byproduct in the *copra* industry, can be converted to vinegar and nata de coco and even used for biogas production. Technologies are available now to pack tendernut water in cans and pouches and preserve as cool drinks. Under non – edible products from coconut, shell is most important. Shell powder is used in plastic industries and in bakelite manufacturing as a filler material and is used in mosquito coils. Shell carbon and activated carbon are having industrial importance in that it is mainly utilised in purification of water, oil, etc. Coconut wastes such as petioles and bunch wastes are used as a substrate for mushroom cultivation and also be used for vermicomposting. Thus every part of the palm is beneficial to mankind and hence it is aptly described as "Kalpa Vriksha.

(**Key words** : *Coconut, Diversified uses, Dessicated coconut products, Tender coconut products, Coconut water,* Copra *coconut milk, Non-edible products, Coconut wood)*

Coconut is the only tropical crop commercially cultivated extensively in about 93 countries with an area of 12.8 million hectares and production of 10.9 million MT (*copra* equivalent) in 2001. In India, Kerala stands first in both the area under cultivation and under production. The coconut based economy can expect a revival from the negative impact of liberalised imports only when the profitability of coconut farming is delinked from the price behaviour of coconut oil. This is possible to achieve through efficient utilisation of the land under coconut and also the products at the on-farm and community levels. India has not made tangible progress in product diversification and byproduct utilisation of coconut except for the traditional activities such as oil milling and coir processing. As a result coconut oil continues to be the only major coconut product having influence on the farm level price of coconut. This situation can be transformed only when coconut based products, both edible and non-edible, gets priority over coconut oil. In the same way we have not achieved noticeable progress in the utilisation of the multiple products of coconut palm for value addition both at the farm households and on community levels. As compared to the tardy growth recorded by the country in the processing sector, most of the coconut growing countries are profit making from the production and exports of diverse coconut products. Philipines export over 40 non-traditional products of which coco chemicals, coconut milk products, coconut water based products, and shell and coir products are of importance. From Sri Lanka shell based products, fresh coconuts, coir products, double distilled arrack and even leaf mid ribs are being exported. Likewise Fiji has started producing and exporting coconut cheese. Coconut is one of the export items from Indonesia and Thailand. Although possibilities are wide it is prudent for us to concentrate on selected products, which could compete pricewise and qualitywise, both in the domestic and export markets.

This paper deals with the various processes for the production of coconut based value added products.

Products derived from fresh kernel of matured coconut

Traditionally coconut is dried to produce *copra* which is then milled or solvent extracted to get the oil. Fresh coconut kernel contains about 4 to 4.5 percent protein. The major portion of the original protein passes on to the coconut cake which is the residual product after oil extraction. The oil has to be refined due to the development of free fatty acids produced during the drying stage which needs sophisticated equipments. The cake however is not considered suitable as a protein supplement because in the process of oil extraction the original protein gets discoloured and denatured due to the generation of very high temperature. Hence it is mainly used in ruminant feeding.

The fresh kernel of ripe coconut constitutes an essential ingredient in the recipes of diverse food preparations in the households as well as in food industries of different countries. In the household food preparation fresh kernel is used extensively in the grated, paste or milk form. The fresh kernel is of low acid nature, meaning extremely prone to microbial degradation, especially in tropical climate. The dairy industry with similar type of products has, by introducing hygienic processing of high standard, managed to control the quality of the end products. Therefore fresh kernel processing plants require the same level of hygiene as the dairies for safe and consistent production.

In the fresh kernel processing industries, shelling and removal of testa are the common labour intensive unit operation. As the existing machineries available are not satisfactory, further refinement is required.

Desiccated coconut

Desiccated coconut is the white kernel of the fruit, comminuted and desiccated to a moisture content of less than 3 percent. It is white in colour. It is a very important commercial product having demand all over the world in the confectionary and in other food industries, as one of the main subsidiary ingredients of fillings for chocolate, candies, etc. It is also used uncooked, as decoration for cakes, biscuits, ice cream and toasted for short eats.

Coconut chips

Coconut chips can be prepared by dehydrating the intermediate moisture coconut kernel. Intermediate moisture coconut kernel is the mature coconut kernel after removing the moisture content of the kernel partially by osmotic dehydration by using osmotic medium like sugar syrup. Coconut Chips is crispy and can be packaged and marketed in laminated aluminium pouches, which will have shelf life of 6 months. Since it is in ready-to-eat form, it could be used as snacks at any time. It could also be used just like fresh kernel after rehydration of the chips in hot water. Coconut chips with different flavour can be prepared by adding the required flavour essence in the osmotic medium. Instead of sweet, salted coconut chips and medicated coconut chips can also be prepared by suitable change in the osmotic medium.

Coconut milk and related products

Coconut milk is an emulsion of its oil in water into which some of the soluble components of the fresh kernel have already been passed. It is milk like liquid obtained from the gratings of the fresh kernel after they are mixed with some water, kneaded and pressed out. The milk is pleasant and sweet with an agreeable flavour. A comparison of the coconut milk with cow's milk has shown that coconut milk is richer in fat, poorer in protein and sugar content. Apart from household culinary uses, coconut milk is utilised as a substitute of dairy cream in beverage type milk, as evaporated and sweet condensed milk and in the preparation of white soft cheese, yoghurt and many other foodstuffs. Commercial production of these products has been promoted in the Philippines, Thailand, Indonesia, Western Samoa, Sri Lanka and Malaysia and to some extent in India.

Bottled coconut milk : The processing technology involves extraction of milk from coconut, straining the milk in a cheese cloth into an aluminium kettle with 0.1 percent benzoic acid before placing the kettle in an autoclave at 117°C for three minutes with steam injection. The temperature of the milk in the pot is then brought down to 80-85°C, by running tap water. The milk is then homogenised for about five minutes and bottled at 70°C to 80°C. The final product is as good as cow's milk and is highly nutritious.

Coconut cream : Coconut cream is a white, smooth, liquid cream with excellent coconut flavour and 20-30% fat, aseptically packed. The product is easily pourable and ready for direct serving or to be used in other food preparation. Coconut cream is essentially used as a fat source for the reconstitution of the skimmed dairy milk and as a component of infant milk powders.

Dehydrated coconut milk : This is produced on a commercial scale in the Philippines, Malaysia and India. In the Philippines, the fresh coconut milk is blended with small amounts of additives such as maltodextrin or casein and is spray dried. The final product is marketed in laminated foil bags. The powder easily dissolved in water to form a milky white liquid with the flavour and texture of coconut milk.

Virgin oil : Obviously, coconut oil has difficulty competing with other vegetable oils. However, by altering the manufacturing process, it is possible to produce a virgin oil of high quality with the following added values viz., coconut flavour, low free fatty acid (less 0.07% as lauric acid) without refining, maximum natural vitamin E content. No chemicals are added and it should be free from aflatoxin contamination. In this process, coconut milk is filtered and concentrated and then cream is separated by centrifugation. The cream is stirred vigorously to get the virgin coconut oil by a process called phase inversion. The oil thus obtained is very clear, nutritious and has got a longer shelf life.

Edible coconut flour : After expelling the milk, the protein rich residue is dried and powdered to obtain a product called coconut flour. The flour so obtained typically contains 7-8 percent protein, 3-5 percent moisture and 17 percent oil. It can be used as an ingredient in weight control foods because of its high fibre content. The protein contained in the flour is identical to that contained in the original fresh kernel. After blanching the residue has to dry. The dried coconut residue is passed through a special type of screw press under a specified expeller setting to reduce oil content of the residue without too much change in colour which will increase the shelf-life of the flour. The defated flakes are redried to reduce its moisture content to 2.5 to 3.0 percent which is finally ground to reduce particle size to a fine mesh.

Products of tender coconut

Tender coconut water has a great potential as a health drink both in Indian and international market. It has a caloric value of 17.4 per 100 g of water. Now technology is available to pack tender nut water in pouches and it can be stored safely for 3 months.

Snowball tender coconut : The soft tender kernel or solid endosperm of tender coconut is a delicious dessert. But the traditional method of its extraction is difficult, time consuming, and risky. Thus the kernel of the tender coconut is sometimes eaten or else thrown away. Coconut of 8 month maturity is more suitable for making snowball tender coconut. Before scooping out the globular tender kernel with water, a groove is made in the shell by using a machine. By inserting the scooping tool, specially made for this purpose, in between the tender kernel and shell and then by rotation of the nut, the snowball is scooped out from the shell. It is nutritive and is a drink and snacks at the same time. Since the snowball tender nut can be individually packed and refrigerated under hygienic conditions, the shelf-life of this product is prolonged and therefore this ready-to-serve product is found to become popular.

Canning of tender coconut : The tender coconut kernel obtained from 7 to 8 month matured coconut, usually available in tender coconut water packaging industries, canning can be done with covering syrup of 30 to 40 Brix. For canning, the pressure processing may be avoided by adding 0.3 percent to 0.4 percent citric acid in the cover syrup. Addition of ascorbic acid and antioxidants will have beneficial effect.

Products derived from coconut water of matured fruits

In most of the countries coconut water is now a waste product of the coconut industries. As the nut matures, the composition of the water, especially the sugar content, also undergoes significant changes. During the early stages of development, the quantity of invert sugar present in the water increases and reaches a maximum at 220 days. After this stage, sucrose appears in the water and the concentration of total sugars falls. Similarly the concentration of total solids also declines and subsequently disappears during germination.

Bottled coconut water : Bottling of coconut water for use as a soft drink is gaining popularity. Coconut water can be marketed as natural soft drink if preserved and packed. Non-carbonated beverage can be produced from the coconut water of mature nuts. The process involves collection of water, upgradation and pasteurisation, filtration and bottling. Coconut vinegar and nata de coco are prepared from coconut water which has got industrial demand.

Process for the production of *copra* and coconut oil

The dried coconut endosperm is called *copra*. The *copra* and the oil it contains are the principal products of coconut palm. With oil content of 65-70 percent, *copra* is the richest source of fat. The essential requirement of *copra* drying is to bring down the moisture content of the wet fresh kernel from 45-55 percent to 5-6 percent. There are two types of *copra* – edible *copra* and milling *copra*. Edible *copra* is available in two forms – ball *copra* and cup *copra*. The production of edible *copra* in India is around 50,000 tonne per annum and the produce is utilised for sweet snacks preparations in households and as an ingredient in the processed foods.

Milling copra : The conversion of fully matured coconuts into *copra* for milling purpose is the most common processing activity in the major coconut producing countries. Drying is an important post-harvest operation in the production of *copra* for the extraction of good quality oil. To obtain good quality white *copra*, particularly during rainy season, a suitable dryer using indirect heating is essential.

Coconut oil from copra : In most of the coconut producing countries, *copra* crushing has become a traditional industry. Power driven '*Chekkus*' or rotary mills, expellers and hydraulic presses are used for crushing on a commercial scale. The quality of *copra* is related to the quality of coconut oil. *Copra* is cut into small chips in a *copra* cutter. The chips are fed into steam jacketed kettles and cooked mildly at a temperature of 70°C for 30 minutes. After proper cooking, the cooked material is fed into the expeller continuously to extract oil. This oil is filtered by means of a filter press and stored in MS tanks. Bulk packaging is done in tin containers. HDPE containers and polymeric nylon barrier pouches are used for small consumer packing.

Similarly many nonfood products can also be prepared from coconut. Among the nonfood products of coconut, coir or coconut fibre, coconut pith and shell assume commercial importance. Other parts of the palm especially coconut wood and leaves are recently gaining attention.

Coir fibre : The coir fibre is extracted from coconut husk. The husk of an average coconut weighs about 0.4 kg of which 30 percent constitutes coir fibre and the balance 70 percent is pith, outer skin etc. There are two types of coir fibre: white fibre and brown fibre. The world production of coir fibre is estimated at 0.330 million tonnes per annum of which the contribution of India and Sri Lanka is about 65% and 32% respectively.

Structure and properties of coir fibre : The chemical constituents of pure coir are cellulose (32-43 percent), lignin (40-45 percent), hemicellulose (0.15-0.25 percent), and pectin which makes it more extensible compared to other natural fibres. The fibre is weather-resistant and also resistant to fungal and bacterial deomposition which are attributed to the high lignin content. Lignin is the main constituent responsible for the stiffness of the coir and also partly responsible for the natural colour of the fibre.

Coir pith : Coir pith constitutes as much as 70 percent of the husk and is now a waste product of the coir industry. Accumulation of this waste in industrial yards causes environmental pollution and fire hazard. Coir pith absorbs over eight times its weight of water and parts with it slowly. It is also excellent organic mulch in all kinds of soil. Pith in combination with cowdung is used for biogas production.

Coconut shell : Coconut shell, is another important commercial product. The major use is as a fuel. To a lesser extent, it is used as a raw material for the manufacture of *hookah* shells, various domestic utensils, curious, fancy items, etc. The commercial utilization of coconut shell for the production of shell charcoal, activated carbon, shell flour etc is now gaining importance in the producing countries with an expanding market demand.

Major shell products : Shell charcoal, activated carbon, and shell flour are the main commercial products obtained from the shell. Good charcoal is uniformly dark and produces a metallic sound when dropped on hard ground. The charcoal has a high adsorption capacity for gases and colouring matter and can, therefore, be used as a refining agent both as a deodoriser and as a decolouriser. The shell charcoal also finds way to laundries, smitheries, etc. The commercial value of shell charcoal lies in its use as the primary raw material for the production of activated carbon.

Activated carbon is a by-product extensively used as agents for purifying, refining and bleaching of volatile oils and chemical solutions. They are also in demand as an adsorbent of gases. Of late, a large number of plants based entirely on coconut shell charcoal have come up in the major coconut growing countries. In India, the use of coconut shells for the manufacture of activated carbon is covered by the Indian Patent No.109082.

Coconut shell flour is the pulverized form of shell known as 'Coconut shell flour'. This is manufactured from shells of fully matured nuts. Coconut shell flour gives a smooth and lustrous finish to moulded articles and also improves their resistance to moisture and heat. It is used in plastic industries as a filler material, and in the manufacture of bakelite and mosquito coils and agarbathis.

Coconut wood

Coconut wood is not naturally durable and it should be properly treated to protect it from wood destroying organisms like termites and decay fungi. The non-pressure methods, which involves brushing, spraying, dipping, steeping, dip diffusion, double diffusion and hot and cold bath appear to be promising. The preservatives used are either oil borne such as, creosote, pentachlorophenol and cuprinol, or waterborne salts like the standard chromated copper arsenate (CCA) under different trade names. The service life of treated wood is two to six times more than the untreated material. Coconut wood is also found useful in the manufacture of particle boards. Thus every part of the palm is beneficial to mankind and hence it is aptly described as "Kalpa Vriksha".

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Bioresource Management for Organic Farming in Coconut under Coastal Ecosystem

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The coconut palm is predominantly grown in nutrient poor soils under coastal ecosystem by the small holders with low use of external inputs. Biological strategies based on optimum use of locally available resources offer opportunities to achieve sustainability in production of the palm. The perennial nature of the palm, its growth habit, planting methods, production of large quantity of organic wastes throughout the year and association of rich diversity of beneficial microbes are the factors in favour of organic and biomanagement of the coconut palm. The low cost vermicomposting technology standardized at CPCRI enable bioconversion of lignocellulosic waste biomass from coconut palms into rich organic manure using local strain of epigeic earthworm belonging to the *Eudrilus* sp. Bioconversion of coir pith, a lignocellulosic waste biomass from coir processing industry to acceptable organic manure has become possible with the use of biopolymer degrading fungi. Basin management with efficient N_2 fixing leguminous cover crops such as *Pueraria phaseoloides, Mimosa invisa* and *Calopogonium mucunoides* enable generation of significant quantity of organic biomass and nitrogen at the site of need itself. Alley cropping of *Glyricidia* and incorporation of nitrogen rich organic biomass enabled the effective management of coconut gardens in littoral sandy soil. Biofertilizers of nitrogen fixing bacteria and P-mobilisers with the capabilities of production of plant growth promoting substances are valuable inputs for crop management.

*(**Key words** : Coconut, Bioresource management, Organic farming, Vermicomposting)*

The coconut palm *(Cocos nucifera* L.), a small holders plantation crop, is predominantly grown under coastal ecosystem in the western and eastern coast of the country. The perennial palm, which is known as "Kalpavriksha" or "tree of life", due to its multifarious uses, has an important role in the economy of the country as it sustains the livelihood of 10 million people in the coastal region, who are directly or indirectly involved in cultivation, processing and trade. The great majority of small holders manage their gardens with low use of external inputs, resulting in unsustainable productivity. Biological strategies based on optimum use of locally available resources offer opportunities to maximize soil productivity and minimize the cost of production.

The coconut palm, being perennial in nature, requires adequate nutrition throughout the growing period due to the continuous flowering and bearing habit. A holistic approach to resource oriented management practices is essential to achieve sustainability in production. Increasing realization of the detrimental effects of exclusive use of chemical fertilizers and consistently growing consumer demand and non-sustainable productivity have enabled to refocus attention on organic culture as a benign alternative. In organic farming, the nutrient requirement of the crops has to be met through organic and bioresources. The basic principle of organic farming is that if soil is fed properly with organic manures, it will in turn ensure good nutrition for plants. Only soils with high diversity of flora and fauna can continuously support the growth of healthy crops and are termed as living soils, which are considered as basis of organic farming.

Relevance of organic farming in coconut

The coconut palm, in general, is grown on coastal soils of low nutrient availability. The palm removes nutrients from limited volume of soil and replenishment of nutrients is highly essential to maintain the fertility of the soil. It is reported that 56 kg N, 12 kg P, 70 kg K, 34 kg Ca and 12.5 kg Mg are removed annually by the coconut palm from one hectare (Pillai and Davis, 1963). Hence, there is a continuous nutrient demand for the crop to replenish the nutrients removed by way of export to above ground parts. Low productivity of the crop in

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the vast majority of coconut gardens is primarily due to the inadequacy of nutrient inputs by resource poor farmers. In this context, low cost organic farming technologies assume particular significance in the cultivation of the crop to develop production systems that are agriculturally sustainable, economically viable and environmentally sound.

The palm is one of the highly amenable crops for organic cultivation. Being a perennial crop the palm produces huge quantities of organic wastes throughout the year. The availability of organic recyclable biomass from a hectare of well managed coconut garden was estimated to be about 14-16 tonnes annually in the form of leaves, spathe, bunch waste and husk (Biddappa *et al.*, 1996). Additional quantity of waste biomass is available from the inter and mixed crops which forms the components of the coconut based cropping and farming systems. The availability of recyclable biomass from a hectare of coconut based high density multispecies cropping system has been estimated to be 20-24 t ha"[1] annually (CPCRI, 2003). Recycling of these residues in the plantation itself will help to meet the major nutrient demand of the crops.

Vermicomposting for recycling of coconut plantation wastes

The coconut plantation wastes, which are lignocellulosic in nature with higher lignin content, could be effectively converted into rich vermicompost using an epigeic earthworm or compost worm belonging to the *Eudrilus* sp. obtained from decomposing coconut waste heaps (Prabhu *et al.*, 1998, Thomas *et al.*, 2001). A low cost technology has been standardized for converting the weathered coconut leaves to acceptable organic manure with a C:N ratio of 9.95 with 70% recovery. The composting can be done in cement tanks, basins, heaps or large pits taken in the interspace of four coconut palms. The organic manure has a nutrient composition of 1.2 - 1.8% N, 0.1-0.2% P and 0.2-0.4% K. The vermicompost obtained from coconut leaves had beneficial attributes such as higher population of beneficial microbes, presence of plant growth promoting substances and humic acids. *In situ* vermicomposting in coconut plantations by heap or trench method enabled production of quality manure at the site of need at a lower cost. Nucleus culture of the local *Eudrilus* sp. is capable of composting coconut plantation wastes being supplied from CPCRI to the farmers. These worms have fast multiplication rate in a 1:1 mixture of cowdung and decayed leaves. Experiments conducted on polybag raised coconut seedlings have shown that vermicompost at 20 percent level enhance the seedling growth and vigour. The results of the field experiments involving vermicompost application on adult coconut palms are indicative of the beneficial impact of vermicompost to enhance the productivity of palms.

Composting of lignin rich biomass using microbial cultures

Coir pith, a byproduct obtained after extraction of coir fibers from husk, accumulate as waste around the coir fiber extraction units causing environmental hazard. Coir pith, which is available at 7,5 million tonnes annually from different coir processing factories, is acidic in nature, and has low bulk density and high porosity. Though coir pith has many beneficial attributes such as high moisture holding capacity and plant nutrient content, the use of raw coir pith in crop production is not recommended as a manure due to the high C:N ratio of more than 100 :1. Research efforts on the utilization of this resource indicated that biopolymer degrading microorganisms can bring about decomposition of the lignocellulosic biomass to produce acceptable organic manure suitable for application as a nutrient source for crops. The technology utilizing basidiomycetous fungus, *Pleurotus so/or caju* with the amendment of 0.5% urea has been reported for production of organic manure (Nagarajan *et al.*, 1989).

Studies at CPCRI on biopolymer degrading microorganisms involved in the natural decomposition of coconut wastes under field conditions resulted in the isolation of a number of fungal strains with high degradative capabilities as evidenced by production of ligninolytic and cellulolytic enzymes on lignin rich biomass. Among them, *Lepista* sp., *Lentinus squarrosulus*, *Schizophyllum commune*, *Marasmiellus troyanus* and *Trichoderma* sp. showed high degradation potential. The technology developed at CPCRI using microbial inoculants with amendments of lime, rock phosphate and legume biomass resulted in the production of quality compost with a C:N ratio of 15 : 1 within a period of 40-50 days (Thomas *et al.*, 2001). Enrichment of compost was done with biofertilizers of asymbiotic diazotroph, *Beijerinckia indica* and phosphate solubilising bacteria. The composted coir pith can be used as manure in coconut plantations and can increase the capability of soils to store moisture and nutrients.

The services of earthworms can also be utilized for composting of lignin and polyphenol rich coir pith, and a local strain of *Eudrilus* sp. has been found to be highly useful for this purpose. A technology for large scale composting of coir pith has been standardized at CPCRI, Kasaragod using this local earthworm. A granular vermicompost with 1.2% nitrogen and a C:N ratio of 16.7:1 can be obtained in two months (Thomas *et.al.*, 2001).

Recycling of crop residues by mushroom cultivation

Utilization of lignocellulosic biomass for oyster mushroom cultivation and further conversion of the spent substrate to organic manure by composting or vermicomposting is a viable method for recycling of coconut palm wastes. A biological efficiency of conversion of 55-70% was obtained when coconut leaf stalk, bunch wastes or a combination of leaflets + bunch waste were used as substrates for oyster mushroom cultivation (Thomas *el al.*, 1998). Among the various species of *Pleurotus* tested, *P. sajor, caju, P. flabellatus* and *P. eous* were superior in sporophore production on coconut waste substrates. The spent substrate, when composted formed an acceptable organic manure with improved nutrient status and low C:N ratio. The composted, spent substrate had N content of 1.0 to 1.29%, P content of 0.08 to 0.13% compared to 0.45% N and 0.05% P in untreated substrate.

Basin management with leguminous cover crops

Leguminous cover crops, which are efficient in biological fixation of nitrogen, can contribute significant quantity of easily decomposable biomass and nutrients when grown as green manure crops in the basins and interspaces of coconut palm. The technique of basin management standardized at CPCRI involving cultivation of *Pueraria phaseoloides, Mimosa invisa* and *Calopogonium mucunoides* resulted in the generation of 15-28 kg of biomass and 102-175 g of nitrogen in the basin of a coconut palm during a growth period of 140-150 days (Thomas and Shantaram, 1984, 1993). These legumes have association with efficient strains of *Rhizobium* spp. and the nitrogen rich green matter is easily decomposable to release the bound nutrients for plant growth.

A field experiment conducted in a coconut plantation in an acidic laterite soil type revealed the feasibility of substituting upto 50% nitrogen with leguminous green manures (Thomas *et. al.*, 1999). The cultivation of leguminous cover crops improved the microbiological properties of soil and yield of coconut palm. Basin cultivation of leguminous crops was effective in the management of root (wilt) diseased palms showing improvement in the yield of the palm and marginal reduction in root (wilt) disease index. The cultivation of cowpea in the basins of coconut palms has also been shown to be a viable alternative crop that can be raised for green manures (Maheswarappa *et al.*, 2003). The cultivation and incorporation of green manure legumes can form an important component of the organic farming technology for sustainable agriculture.

Growing glyricidia as green manure crop under littoral sandy soil

The coconut growing coastal regions of the country have sandy soils which are characterized by poor physicochemical properties. Growing of perennial leguminous crop, *Glyricidia* has been found to be an effective method for the management of coconut gardens under littoral sandy soil. *Glyricidia sepium* when grown in three rows in between coconut palms at a spacing of 7.5 x 7.5 m yielded 7.9 t ha^{-1} yr^{-1} from three prunnings in February, June and October (Subramaniam *et al.*, 2000). Application of *Glyricidia* prunnings from interspace of one hectare of coconut garden could meet a major portion of nitrogen (90%), part of phosphorus (25%) and potassium (15%) requirement of coconut palm. Studies in Sri Lanka indicated that *Glyricidia* loppings when applied at the rate of 30 kg per palm could meet the total requirement of nitrogen and part of P and K and it can reduce the inorganic fertilizer inputs by 40% (Liyanage and Jayasundara, 1988).

Biofertilizers as low cost inputs

There is great potential for utilizing plant beneficial microorganisms as biofertilizers for sustainable coconut farming to increase the availability of nutrients and to enhance nutrient use efficiency. The coconut palm has association with unique diversity of diazotrophs in roots and root environment. The associative diazotrophs isolated from the roots of coconut palm include *Azospirillum amazonense, Azospirillum lipoferum, Azospirillum brasilense, Herbaspirillum frisingense, Burkholderia* sp., *Azoarcus* sp., *Arthrobacter* sp., *Xanthobacter* sp. (Prabhu *et al.*, 1998, Thomas and Prabhu, 2003). Acidophilic *Beijerinckia* spp. was the most conspicuous nitrogen fixer in coconut soils, occurring in higher numbers in coconut rhizosphere and rhizoplane indicating a closer association with the palm (Merilyn and Thomas, 1992). A number of efficient strains of phosphate mineralizing bacteria belonging to the genus *Bacillus, Pseudomonas* and *Micrococcus* were isolated from coconut soils (Thomas and Shantaram,1987). Plant growth promoting rhizobacteria (PGPR) belonging to the genus *Bacillus* spp. form endophytic association with coconut palm as the main component of the bacterial population inside the roots and in leaf tissues (Prabhu *et al.*, 2000). Mass multiplication techniques for these beneficial bacteria were developed and biofertilizer formulations have been prepared using low cost carrier materials.

Inoculation with efficient isolates of diazotrophs significantly enhanced number of main roots, and favoured the production of root branches in coconut seedlings. Preliminary results from field trials with nitrogen fixers and P-solubilisers also gave some indications that these bacteria can be effective to promote the growth and yield of coconut palm. Synergistic effects of various groups of microorganisms have also been brought out, resulting in better plant growth and crop yields. Soil amendments with organic materials favour the development and activity of plant beneficial microbes. It has been established that organic amendments such as coir pith, neem cake, green manures when combined with microbial inoculants resulted in the development of a high population of *Beijerinckia indica* in sandy soils.

Effect of organic resource management on soil biological activity

The coconut growing soils in the coastal belt are characterized by low organic matter content, poor physical properties and low native fertility. The major soil types are laterite, red and coastal sand and they are acidic in reaction (Khan *et al.*, 1978). The soils are light textured which under high rainfall conditions are subject to leaching of nutrients. The major portion of applied nitrogen is lost by leaching. Nutrient management strategies based on organic additions resulted in several beneficial attributes such as improved microbial activity, availability of plant nutrients, organic matter content and physicochemical properties of soil. The organic additions in the form of green manures, composts, crop residues and oil cakes had positive impact on soil fertility and productivity.

In situ cultivation and incorporation of green manure legumes viz., *Pueraria phaseoloides, Mimosa invisa* and *Calopogonium mucunoides* resulted in a high level of zymogenic response by different specific and non-specific group of plant beneficial microorganisms (Thomas and Shantaram, 1984). The green biomass of legumes provided easily decomposable source of energy and carbon source for the microbial groups. Population of function specific microorganisms such as N_2 fixers and phosphate solubilisers also increased considerably. Spore population and arbuscular mycorrhizal colonization were also augmented as a result of green biomass addition. Dehydrogenase, phosphatase and urease activities increased substantially due to the application of green manures. It has been suggested that the soil enzymatic activities could be considered as better indicators of soil fertility. Organic amendment with coir pith, green manures and neem cake when combined with microbial inoculation of *Beijerinckia indica* brought about significant improvement in nitrogen fixation and diazotroph population in coastal sandy loam soil.

Organic manures apart from supplying plant nutrients have profound influence on moisture retention, root growth and nutrient conservation. Organic additions in the form of forest leaves, coconut sheddings, cattle manure and coir pith in conjunction with inorganics, improved soil physical properties, water holding capacity and decreased the bulk density of soil when compared to the application of inorganics alone (Biddappa *et al.*, 1996). The available soil moisture increased to 1.94, 0.87 , 1.39 and 1.13% when coir dust, coconut sheddings, forest leaves and cattle manure, respectively were incorporated in littoral sandy soil. Organic manures also enhanced the growth and flowering of coconut seedlings. The establishment of coconut seedlings were better achieved in littoral sandy soils with organic amendments.

Beneficial effects of cropping /farming systems on soil fertility

Cropping/farming systems by raising compatible subsidiary crops and/or integrating with livestock enabled to increase the productivity and net returns from coconut gardens. Farm resources like land, labour, sunlight, water and nutrients were effectively utilized in the system and higher productivity was achieved as a result of synergistic interaction among the crop or crop-livestock components. The beneficial effects were reflected on enhanced soil fertility status, microbial activity and nutrient transformations which were conducive for sustainable crop productivity.

Mixed cropping of cocoa in coconut plantation significantly improved the activity and distribution of various microbial groups (Nair and Subba Rao, 1977). The beneficial flora comprising of bacteria, fungi and actinomycetes and function specific microorganisms such as, asymbiotic N_2-fixers, P-solubilisers and indole acetic acid producing (IAA) microorganisms were found to be increased in coconut root region under the mixed cropping of cocoa when compared to the monocrop gardens. The increased microbial activity has been attributed to the development of congenial conditions and higher organic matter content due to periodic shedding of leaves and prunings of cocoa. In the multistoreyed cropping system comprising of coconut, black pepper, cocoa and pineapple, the plant beneficial microflora were at an augmented level as a result of synergistic interaction of various crops (Bopaiah and Shetty, 1991a). The activities of soil enzymes, and mineralisation of carbon and nitrogen recorded at an increased level in the system indicated improved biological activities and nutrient transformations contributing to the higher productivity.

The mixed farming system which includes raising of fodder grasses in the interspaces of coconut, integration of animal enterprises including the maintenance of milch cows, and subsequent recycling of cattle shed wastes created highly congenial conditions for higher level of microbial and biological activity in the system (Potty and Jayasanker, 1976, Bopaiah and Shetty, 1991b). The soil fertility benefits recorded from the system include the augmented level of various microbial groups, microbial biomass content, soil enzymes and mineralisation of nutrients. A study on the association of *Azospirillum* in different coconut based cropping systems revealed highest level of root colonization of *Azospirillum* in coconut under mixed farming system in which guinea grass was the major component crop (Ghai and Thomas, 1989). Beneficial symbiotic association formed by arbuscular mycorrhizal fungi have positive influence on the uptake of immobile elements, biological suppression of root pathogens and absorption of water under stress conditions. The mycorrhizal association became more important in marginal soils under low levels of nutrient and water availability. Cropping system had a positive influence on arbuscular mycorrhizal association in coconut. Thomas (1988) reported that intercropping with hybrid napier improved the mycorrhizal status of root (wilt) diseased coconut palms when compared to the monocrop. Cropping system thus enabled better management of natural resources, improved the microbial activities and soil fertility which ultimately resulted in higher biological productivity.

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Strategies for Enhancing Production and Productivity in the Coastal Ecosystem of Lakshadweep Islands

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Coconut is the only crop of economic importance in the coastal ecosystem of Lakshadweep. Due to rapid subdivisions and fragmentation of holdings, they practiced very close planting which has resulted in overcrowding of palms. It has been estimated that on an average, 400-500 coconut palms of all ages are growing in one hectare of land as against 170-200 normally recommended for optimum yield in other coconut growing areas of the country. This has resulted in a very low nut yield. Experiments conducted at Minicoy have revealed that spacing has an impact on yield of coconut. Locally produced hybrid combinations involving Laccadive ordinary and Dwarf cultivars performed better than their parents. Orange Dwarf cultivar which resembled the Chowghat Orange Dwarf (COD) of the West Coast, is a potential tender nut variety that can be developed and established for increasing production and productivity of Lakshadweep islands in view of the heavy flow of tourists to the region.

Vermicomposting of coconut leaves which are available in plenty, but is being wasted, has been standardized using *Eudrilus* sp. of earthworms and has been found to be the easiest, cheapest and the most eco-friendly means of improving the soil fertility of the island ecosystem. Cultivation of the sunnhemp in the interspaces of coconut has been found to be efficient in substituting the chemical fertilizers.

Vegetable crops such as chilli, amaranthus, brinjal, snakegourd, pumpkin, cucumber and annual moringa were found to perform well under the island conditions. Tuber crops such as tapioca, sweet potato and elephant foot yam were found to be ideal for cultivation for increasing production and productivity of the island ecosystem. Recent experiments at Minicoy revealed that non-traditional crops such as cabbage, cauliflower and capsicum could be successfully cultivated under the island conditions. Mushroom culture has been standardized utilizing coconut waste materials available in the islands. Popularization and transfer of this technology have a great potential in increasing the productivity of coastal ecosystem of the Lakshadweep islands.

(**Key words** : *Lakshadweep Islands, Production strategy, Coconut, Vegetables, Mushroom culture, Vermicompost, Soil fertility through organic sources*)

The Lakshadweep, the smallest Union Territory of the Indian Union, spread over the area of 32 km with total 27 islands, of which 10 are inhabited, 12 are uninhabited, and 5 are attached. The average rainfall is 1600 mm, the temperature in between 29.3°C to 31.2°C and the land is about 3 to 4 m above sea level. Coconut is the only crop of economic importance in this group of islands. It is believed that the coconut cultivation started in the islands with early human settlement. The island farmers do not follow any definite pattern for planting the coconut seedlings as far as the spacing is concerned. Due to the rapid subdivisions and fragmentation of holdings, the islanders practised very close planting and strikingly planted more seedlings on the boundaries and corners to mark one's field. This has resulted in overcrowding of palms in the islands. It has been estimated that on an average 400 to 500 coconut trees of all ages are growing in one hectare of land as against 170 to 200 normally recommended for optimum yield in other coconut growing areas of the country. This has resulted in a very low nut yield even in the absences of any major diseases in the islands. (Jacob *et al.*, 2002). The total area under coconut cultivation is 2689 ha and the total number of yielding trees is about 6.5 lakhs. The average annual nut production is 3.6 crores. The mean per hectare production is 13730, the per palm annual yield being 58 nuts.

Strategies for increasing production and productivity

Since there is no scope for expanding the area for crop production, the future strategy depends on increasing the production and productivity of unit holdings. This can be achieved by (1) limiting palm population (spacing), (2) increasing soil fertility, (3) using quality planting materials, (4) adopting ecofriendly methods for the control of major pests of coconut, (5) through value addition and introduction of high value crops, (6) adopting post-harvest technology, (7) raising suitable horticultural crops, (8) adopting proper transfer of technology.

Limiting palm population (spacing)

Agronomic trials on coconut have clearly shown that density of planting has an impact on the yield of coconut. A spacing of 7.5 x 7.5 m has been proved to be ideal for optimum yield (Menon and Pandalai, 1958). High density of planting has been identified as the primary reason for low yield of coconut in Lakshadweep islands. In order to prove the impact of density of planting on yield of coconut under the Lakshadweep conditions, a spacing trial was laid out where 92 seedlings were planted at the recommended spacing. The yield was compared with the palms in double the density of planting, planted during the same period. The palms planted at the normal density of planting gave nearly 3.5 times more yield than from palms planted at double the density of planting (Muralidharan, 1999). The palms in the experiment were continued to be observed for yield. Accordingly the average per palm annual yield during the period from 1998 to 2002 in the normal spacing was 135 as against 40 in double the density of planting. This research finding is very useful and valuable and shall be adopted by the island farmers for increasing their yield per unit area. This can be achieved by thinning down the excess number of coconut palms in the existing gardens. The department of agriculture may start one demonstration unit in each island for convincing the farming community which will help them in adopting this technology there by increasing their income from the existing gardens.

Increasing soil fertility

Organic content of the soil in the islands is very low and the water and nutrient holding capacity is very poor. Further application of inorganic fertilizers may adversely affect the quality of drinking water. Production of organic/biofertilizers may have significant role in increasing production and productivity of the island ecosystem.

Vermicomposting of coconut wastes, especially the coconut leaves that are available in plenty in the islands is an easy technique that can be exploited for enrichment of soils in Lakshadweep. Trials conducted at CPCRI have revealed that the coconut leaves could be composed in 75-80 days by *Eudrillus* sp. of earthworm. Dried coconut leaves (without the petiole) made into pieces / dried leaflets separated from the leaf axes of the fallen coconut leaves were used for the purpose. One thousand earthworms were added to the compost pit and 100 kg of cowdung mixed with the leaves which were irrigated regularly to retain the moisture level. Ultimately 750-800 kg of vermicompost was obtained from this within a period of 75-80 days. Vermicomposting can be practised either in concrete tank or in pits of convenient size. Use of leaflets separated from leaf axes has been found to increase the efficiency and quality of the vermicompost. This technique is the cheapest, easiest and ecofriendly means of increasing soil fertility under the island conditions.

Chemical fertilizer substitution by sunnhemp (*Crotolaria juncea*) is another means of enriching the soil. Experiments carried out at Minicoy have revealed that 98% nitrogen and 28% each of potassium and phosphorus could be substituted by growing sunnhemp in the interspaces of the coconut. Cultivation of *Glyricidia maculata* as green manure crop is also another practical method for increasing the fertility status of soil in Lakshadweep islands.

Production of quality planting materials

The farmers in this region are generating their own planting material without following any scientific selection criteria. Selection of high yielding palms are farmost important to enhance the production. Hybrid combinations produced by crossing the locally available cultivars viz., Laccadive Ordinary (LO), Orange, Green and Yellow dwarfs, performed better in yield and early bearing in contrast to their parents/hybrids/varieties introduced from outside (Anon., 2001, 2002). Since there is no scope for expanding the area for coconut cultivation in the islands, the quality planting materials can be utilized for filling the gaps that may occur due to the filling of senile/old palms.

Ecofriendly methods for the control of major pests of coconut

Heavy crop loss due to the attack of Rhinoceros beetle had been reported from islands like Andrott and Minicoy. The attack was successfully brought down from 60% to 10% by the release of *baculovirus* (Mohan *et al.*, 1989). However, the attack began to increase slowly after a period of ten years. This highlights the need for periodic check and release of the virus to keep the attack under control. Extension of the programme to other islands will help in reducing the loss of nuts by the beetle attack and increasing the production.

Rats are the next major pest causing 25-50% of crop loss (Bhat and Sujatha, 1989). Sustained (continuous) trapping for a period of 5 days using commercially available single catch live traps could reduce the damage of nuts by rats to zero. It was observed that poison such as Phosphorus paste and zinc phosphide reduced rat damage 61.9% and 51.7%, respectively.

Eriophyid mite caused considerable damage ranging from 10% to 60% of the standing crop of coconut in most of the islands of Lakshadweep. Periodic and systematic spraying of the infested bunches/root feeding with neem oil based/azadirachtin containing formulations will not only help in arresting the spread of the pest but also minimize the loss to a greater extent.

Value addition and introduction of high value crops

Value addition is essential to increase the production and productivity of the coastal ecosystem of Lakshadweep. Production of a tender nut variety of coconut has great potential in enhancing the income of the island farming community in view of the boost given to the tourism. Orange Dwarf cultivar which resembles the Chowghat Orange Dwarf (COD) of the West Coast, is an ideal material to be developed and established for the production of tender nuts (Jacob and Krishnamoorthy, 1981). Application of Snow Ball Tender nut (SBT) machine developed at CPCRI Kasaragod may also help in increasing the income.

Production of palm jaggery from the neera is another area to be strengthened. Besides this, vinegar from neera/coconut water, charcoal from coconut shell, compost from coirpith and coir from coconut husk are other potential areas to be addressed properly.

Ball *copra* from Lakshadweep was highly priced and had good market in North India but its production has been on the decline in the recent years. Steps to identify a suitable variety and large scale production of ball *copra* and its marketing will lead to increase the production and productivity.

Mushroom culture has been standardized utilising the locally available waste materials in the islands. Adoption of the technology by the local entrepreneurs will help in increasing the production and productivity of the island ecosystem.

The vanilla crop was planted at Minicoy during 2001 using glyricidia as support plants. Its growth in the islands has so far been satisfactory and if found successful, it will generate more income and provide employment opportunities to the women and unemployed youth.

Adoption of post-harvest technology

Coconuts are harvested during the seven months in the non-monsoon period from October to April. There is no definite time schedule for harvest as in the case of mainland where the nuts are harvested once in forty-five days. One of the main reasons attributed for this irregular harvest is the non-availability of climbers in recent days. During the monsoon season, nuts are not harvested due to the lack of facilities for drying the *copra*. During the fair season 3-4 harvests are generally made and the nuts are made into *copra* by sundrying and taken to the mainland and disposed off . Installation of small oil extraction units and selling the oil within the islands will enhance income. By installing the *copra* drier designed by CPCRI, the *copra* can be dried during the monsoon season also and thereby the loss due to the non-harvest of nuts can be avoided.

Raising suitable horticultural crops

Vegetables and fruits were not the essential parts of the diet of the people of Lakshadweep till recently. Their consumption at present has been on the increase and are being brought from the mainland. Due to the continuous persuasion and the efforts by the Department of Agriculture and CPCRI, some farmers could be motivated to start the cultivation of these crops to some extent. Trials conducted at CPCRI Minicoy have revealed that vegetable crops such as tomato, chilli, snakegourd, bittergourd, cucumber, pumpkin, annual moringa, brijal and amaranthus could be raised successfully and profitably (Table 1).

Table 1. *Mean yield of vegetable crops tested*

Crop / Variety	Area in sq m	Yield/ plot (kg)	Yield/ha (kg)
Chilli Indam	30	72.0	24,000
Chilli (Jwala)	30	42.2	13,335
Chilli-Indam 9	30	67.0	22,335
Chilli-Indam 6	30	25	8,334
Chilli - local	30	20	6,667
Brinjal – Black long	30	101	33,667
Brinjal – Sourabha	30	83	27,667
Brinjal – Local	30	61	20,334
Snake gourd (Kerala local)	80	180	22,500
Pumpkin (Ambili)	16	44.5	23,300
Cucumber (Kerala local)	16	48.5	30,312
Amaranthus	16	8.1	5,062
Bitter gourd	68	20	2,941
Tomato	630	130	2,063

Banana varieties like Nendran, Kunnan and Robusta were also found to be suitable for the island conditions. Papaya and water melon have been found to perform well under the island conditions. Non-traditional crops like cabbage, cauliflower and capsicum were also tried under the Minicoy conditions during October season and were found to perform well. Cultivation of tuber crops like tapioca, sweet potato and elephant foot yam has also been found feasible in the islands (Jacob, 2003) (Tables 2 and 3). Intensification of the cultivation of these crops in the interspaces of coconut will certainly increase the production and productivity of coastal ecosystem of Lakshadweep.

Table 2. *Yield of fruit crops/tuber crops and other vegetable crops*

Crop	Variety	Yield
Banana	Nendran	12.5 kg/plant
Banana	Kunnan	12.0 "
Banana	Robusta	13.5 "
Papaya	Pusa Nanha	15.7 "
Water melon	MHW 285	120 kg/500 sq m area
Annual Moringa	TNAU	15 kg/plant
Elephant foot yam	Kerala local	2 kg/plant
Tapioca	M4	5 kg/plant
Sweet potato	Local	80 kg/500sq m area

Table 3. *Yield of new crops (Non-traditional) introduced*

Crop	Yield
Cabbage	800 g/plant
Cauliflower	350 g/plant
Capsicum	400 g/plant

Transfer of technology programmes

The impact of the technologies developed will be reflected, only if they are transferred to the farmers for their adoption. Hence concerted efforts may be made for the transfer of technology in all islands with the active cooperation of the department of the agriculture through kissan melas/interface programmes/farmers' training programmes at regular intervals.

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Storage Studies on Value Added Cashew Apple Products

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Cashew apple, a byproduct from cashew nut industry is wasted in large quantity due to lack of proper post-harvest technology. Value added products such as ready to serve beverages, syrup and jam were prepared from cashew apple and sensory evaluation of all these products were carried out. The products were filled in glass bottles, sterilized and stored under normal ambient condition to study the change in chemical parameters during storage. From the study it was observed that red coloured cashew apples were having more tannin than yellow coloured cashew apples. Cashew apple products without any artificial colour scored more and flavour of all the products were found satisfactory. The pH, ascorbic acid and total sugar content showed a decreasing trend in all the products during storage whereas, no significant change in total soluble solid and tannin content was observed.

*(**Key Words :** Cashew apple, Ready-to-serve beverage, Syrup, Jam, Storage study, Sensory evaluation)*

Cashew (*Anacardium occidentale L.*) is cultivated widely throughout the tropics for its kernel. It is native to northeast Brazil and in the 16th century Portuguese traders introduced it to coastal India (Morton, 1987). Now in India it is grown in West Coast, East Coast and a few *maidani* parts of Karnataka and Madhya Pradesh (Chada, 2001).

The true fruit of the tree is the cashew nut and its kernel is highly priced for table purpose. The pseudo fruit or cashew apple is a byproduct of cashew nut industry. This false fruit at its optimum reaches about 5-11 cm in length and weight of the mature fruit varies between 50-80 g. The fruit surface assumes a waxy and shining texture with yellow, red, or red-and-yellow skin. The pulp of this false fruit is spongy, fibrous, very juicy, astringent, acid to sub-acid and yellowish in colour (Morton, 1987).

There is a substantial production of cashew apple in the country and hardly 30 % of it is being commercially exploited presently for brewing cashew *feni* in Goa. In Orissa production of cashew apple is about 0.50 lakh metric tonne from an area of 1.14 lakh hectare (Chada, 2001). The apple and nut fall together when both are ripe and in commercial nut plantations, it is most practical to twist off the nut and leave the apple on the ground for grazing by cattle or pig (Morton, 1987).

The purpose of this research work was to find out the feasibility of preparing value added products from cashew apple available and wasted in the state of Orissa, and to carry out its storage and sensory evaluation studies.

MATERIALS AND METHODS

Cashew apple fruits both yellow and red type of the variety VRI 2 were collected at its optimum maturity stage from Orissa University of Agriculture & Technology Central farm in Bhubaneswar and they were brought to the food analysis laboratory with utmost care to avoid any bruises to the fruit. Both red and yellow types were analyzed for its chemical compositions separately.

Juice preparation

As the yellow fruits were found to have less tannin content (Table 1) these were selected for preparation of value added products. Good unblemished fruits were sorted out and washed with clean water. Tailing and topping of fruits were removed with stainless steel knives, because they believed to contain the maximum tannin content. Then fruits were cut into pieces and juice was extracted from the fruit by a juice extractor.

Tannin extraction

Polyvinyl Pyrolidone (PVP) 1.4 g was added to one litre of extracted juice and mixed properly with continuous stirring. Then it was left undisturbed for two hours. The clear juice on the top was decanted and the precipitate was discarded.

Preparation of cashew apple ready-to-serve (RTS) beverage

The RTS was made with the following recipe as per the method described by Lal and Siddappa (1967) with slight modifications, viz., clarified cashew apple juice: 1 litre, water: 1 litre, sugar: 750 g, potassium meta bisulphite: 0.3 g and citric acid: 2.5 g.

Table 1. Chemical composition of yellow and red coloured cashew apple

Components	Yellow cashew apple	Red cashew apple
Brix, °B	9.5	10
Total sugar, (g/100g)	8.39	8.57
Protein, (g/100g)	0.59	0.76
Fat, (g/100g)	0.02	0.02
Fibre, (g/100g)	1.93	1.56
Total ash, (g/100g)	1.28	1.17
Tannin, (g/100g)	0.32	0.39
pH	4.57	4.76
Moisture, %	87.13	87.22
Vit C (Ascorbic acid), (mg/100g)	328.32	309.37

Clarified cashew apple juice was added to the sugar syrup. The temperature of mixture was brought to 85-90°C and KMS was added as per the recipe. Two different coloured RTS were prepared by using fruit grade artificial colours such as Sunset Yellow and Ponceau 4R, and were compared with natural RTS (without artificial colour) for sensory evaluation studies. The RTS beverages thus prepared were bottled into 200 ml bottles with hot fillings and crown corking was done. Next the bottles were kept in boiling water for 15 minutes for sterilization.

Cashew apple syrup

The syrup was made with the following recipe as per the method described by Lal and Siddappa (1967) with slight modifications viz., clarified cashew apple juice: 1 litre, sugar: 2.5 kg, sodium benzoate: 0.75 g and citric acid: 5 g.

Cashew apple juice, sugar and citric acid were taken together and boiled. The temperature was brought to 85°C and sodium benzoate was added to it. The syrup was hot filled into 750 ml bottles. Two different coloured syrups and natural colour syrup without addition of any colour, were prepared and sterilized similarly as in case of RTS for sensory evaluation study.

Cashew apple jam

Cashew apple pieces after removal of topping and tailing were subjected to steam at 15 lb pressure for 5 minutes. Then pulp was prepared with the fruit pieces by a mixer grinder. One kilogram of sugar and 5 g of citric acid were added per kg of pulp. The whole content was mixed and boiled till it reached 65°B. Two different coloured jams were prepared similarly as in case of above products for sensory analysis. Jam thus prepared was put into wide mouth jar bottles with twist caps.

The cashew apple RTS, syrup, and jam were stored under normal ambient condition. The total soluble solids, acidity, pH, total sugar and tannin content of the products were analyzed at 15 days interval using standard biochemical methods (A.O.A.C., 1980).

RESULTS AND DISCUSSION

Chemical composition of yellow and red cashew apple

The chemical composition such as Brix (°B), total sugar, protein, fat, fibre, total ash, tannin, pH, moisture and vitamin C content of yellow and red coloured cashew apples are given in Table 1. Both varieties of cashew apples were rich in ascorbic acid (328.32 mg per 100g in yellow variety and 309.37 mg per 100g in red variety), total sugar i.e., 8.39 g% in yellow and 8.57 g% in red varieties, total ash (1.28 g% in yellow and 1.17 g% in red cashew apple). The cashew apples also contained very high amount of astringent, tannin (0.32g per 100g in yellow and 0.39 g per100 g in red variety) due to which it is not a popular dessert fruit. It was observed that tannin content was less in yellow cashew apple compared to the red one.

Sensory evaluation of value added products

Sensory evaluation tests using Composite Scoring Test was conducted for cashew apple syrup, cashew apple ready-to-serve beverage and cashew apple jam. Specific characteristics like colour, consistency, flavour and absence of defects were studied for this purpose. Flavour of this exotic fruit being the most important characteristics accounted for a larger part of the total score. Possible scores of colour, consistency and absence of defects were assigned 20 points each, whereas flavour was assigned 40 points. The panelists evaluated these dimensions of individual quality characteristics critically and inference was drawn with the use of weighed scale. The result of the sensory evaluation showed the natural colour of cashew apple syrup and cashew apple ready to serve beverage i.e., the panelist liked faint yellowish tint in transparent background and it scored more than those having added artificial colourants. Flavours of all the three products were found to be satisfactory and liked by the panelist.

Table 2. *Effect of storage on chemical parameters of cashew apple RTS*

Months of storage	0	1	2	3	4	5	6
pH	3.89	3.87	3.82	3.37	2.45	2.21	2.19
TSS, °B	14	14.5	14.5	15	16	16	16.5
Ascorbic acid, mg/100g	97.22	96.29	89.75	85.66	82.87	80.37	79.17
Total sugar, g/100g	21.32	20.97	19.87	18.73	17.79	16.93	16.29
Tannin, mg/100g	3.05	3.02	2.97	2.89	2.98	3.01	2.91

Table 3. *Effect of storage on chemical parameters of cashew apple syrup*

Months of storage	0	1	2	3	4	5	6
pH	3.97	3.89	3.71	3.54	3.38	3.32	3.21
TSS, °B	45	45	45.5	45	45.5	46	45.5
Ascorbic acid, mg/100g	137.17	136.73	129.37	126.28	125.23	122.89	118.19
Total sugar, g/100g	39.63	39.63	39.12	38.31	34.73	33.17	32.37
Tanin, mg/100g	5.93	5.91	5.86	5.93	5.81	5.87	5.79

Table 4. *Effect of storage on chemical parameters of cashew apple jam*

Months of storage	0	1	2	3	4	5	6
pH	3.53	3.55	3.49	3.33	3.21	3.17	3.11
TSS, °B	68	68	68	68	67.5	67.5	67.5
Ascorbic acid, mg/100g	161.36	160.83	158.14	153.27	148.37	144.92	143.39
Total sugar, g/100g	59.37	59.32	58.71	56.37	54.71	53.13	52.73
Tanin, mg/100g	12.37	12.18	12.17	12.08	11.99	11.96	11.96

Storage study of value added products

The pH and total sugar content showed a decreasing trend during storage of cashew apple RTS, whereas total soluble solid increased from 14 to 16.5 during 6 months of storage (Table 2). No significant change in tannin content was observed during storage.

From the storage study of cashew apple syrup, it was observed that the pH and total sugar content decreased from 3.97 to 3.21 and from 39.63 to 32.37 g per 100g respectively during 6 months of storage. The reduction in total sugar content might be due to degradation of the polysaccharides and oligosaccharides into different organic acids, which increased the acidity of the products. There was no significant change in TSS and tannin content of cashew apple syrup during storage (Table 3).

Similar trend was observed in case of cashew apple jam storage study. The pH was found to be decreased from 3.53 to 3.11 and total sugar content from 59.37 to 52.73 g per 100g. There was no significant change in total soluble solid whereas tannin content decreased slightly from 12.37 to 11.96 mg per 100g (Table 4).

The ascorbic acid content decreased from 97.22 to 79.17 (Table 2), 137.17 to 118.19 (Table 3) and 161.36 to 143.39 mg per 100g (Table 4) in case of cashew apple RTS, syrup and jam, respectively during storage. This might have been caused due to oxidation of ascorbic acid to dehydro ascorbic acid and other products.

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Suppression of Rhinoceros Beetle (*Oryctes rhinoceros*) by *Oryctes* Virus in Lakshadweep Islands : Current Status

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The microbial pathogen, *Oryctes* virus (earlier *Baculovirus oryctes*) was introduced into Minicoy and Androth Islands of Lakshadweep in 1983 and 1988, respectively for the biological suppression of rhinoceros beetle, *Oryctes rhinoceros*, one of the major pests of coconut palm. Subsequently, within two years of its introduction, the pathogen could significantly reduce the beetle population, bring down the damage to the palms and increase the virus incidence in the pest. To assess the current status, follow-up studies conducted in 1999 (11 years past introduction) in Androth and in 2001 (15 years past introduction) in Minicoy revealed that 25.2% of leaves, 0.86% of spathes and 26.9% of spindles of the coconut palms were damaged in Androth, whereas 45.9% of leaves, 36% spathes and 16.1% of the spindles were damaged in Minicoy Island. The natural virus incidence in *Oryctes* grubs was recorded to be 36% at Androth and 29.0% at Minicoy. On comparison, it was observed that barring the spindle damage in Androth and spathe damage at Minicoy, the other damage parameters were well below the status that was present before the introduction of the virus in these Islands. The viral disease incidence was also recorded to be quite high during the follow-up studies. This indicates that in Island condition, the virus is capable of exerting a long-term suppression of the pest.

(Key words: *Coconut, Rhinoceros bettle, Orycles virus, Microbial pathogen)*

The coconut palm is an important plantation crop of India, particularly in the Lakshadweep Islands where it serves as one of the main sources of income to the Island inhabitants, besides fishing. The coconut varieties commonly growing here are the Lakshadweep Tall, Lakshadweep Micro, Lakshadweep Mini Micro, etc. All these cultivars are highly susceptible to the attack by the ubiquitous insect pest, rhinoceros beetle (*Oryctes rhinoceros L*). The adult beetle inflicts the damage by chewing unopened soft fronds and boring holes into the spathes resulting in loss of photosynthetic area and low inflorescence setting. Management of this pest could be successfully accomplished using a microbial control agent, ***Baculovoirus oryctes*** isolated first in Malaysia (Huger, 1996). This virus was also found to be occurring naturally in the pest population in Kerala (Mohan *et al.*, 1983) but not in the rhinoceros beetles of the Lakshadweep Islands. The Baculovirus was then introduced into Minicoy and Androth Islands of Lakshadweep in 1983 and 1988, respectively. Within a period of 2 years after its release the pathogen significantly reduced the damage to the coconut palm caused by the pest in these Islands (Mohan *et al., 1989,* Anon., 1991).

In order to evaluate whether the pathogen had sustained the pest suppressive capacity or has there been increased pest activity, a follow-up study was taken in 1999 in Adroth and in 2001 in Minicoy Island to assess the damage caused by this pest and the percentage of them carrying the virus infection.

MATERIALS AND METHODS

Assessment of damages

The observations such as total number of leaves in a palm, number of leaves damaged by rhinoceros beetle evident by the 'V' shaped cuts on leaves, fresh spindle damage and spathe damage were taken from a total of 104 palms covering all the four villages of Androth *viz.*, Keecherry, Mecherry, Chemancherry and Jetty area. Similarly, 138 palms representing all the 8 major areas of Minicoy were observed in detail for the damage.

Site occupancy by the pest

The natural breeding sites of the pest i.e., farmyard yard manure pits, dead and fallen coconut trunks and coir waste dumps present in the representative parts of the Islands were scoured for the presence of the pests in single brood or multiple brood conditions.

Oryctes virus incidence

The *Oryctes* grubs and adults collected from Androth and Minicoy were observed for the presence of virus disease through exopathological symptoms by dissection for presence of white fluid in midgut and by 3% Giemsa staining of midgut fluid and midgut epithelial cells. (Zelazny, 1978, Mohan *et al.*, 1983).

RESULTS AND DISCUSSION

Assessment of damages

The extent of damage caused by the rhinoceros beetle to coconut palms in Androth Island is given in Table 1. It indicates that from the total of 104 palms observed, 25.2 % of leaves, 0.86% of spathes and fresh spindle were damaged to the tune of 26.9%. In Minicoy Island, the palms having beetle damage was around 45.9%. The leaf damage was recorded to be 36.0%, spathe damage 16.1% and fresh spindle damage 25% (Table 2).

Site occupancy by the pest

The percentage of sites occupied by the rhinoceros beetle and the brood conditions are given in Table 3. In Androth Island 32.2% breeding sites were found to be occupied as compared to 51% in Minicoy. The number of sites harboring multiple broods was also high in Minicoy.

Oryctes virus infection

From the Giemsa staining of the midgut epithelial cells the natural virus infection in *Oryctes* grubs was recorded to be 36.0% at Androth and 29.0% at Minicoy (Table 4).

The non-occluded virus *Baculovirus oryctes* was till recently considered as a part of the *Baculovirideae*, however from 1997 this pathogen has been removed from this group and put separately as *Oryctes* virus group (Evans and Shapiro, 1997). The *Oryctes* virus was introduced into Minicoy Island in 1983 and in Androth Island in 1988. Introduction of this pathogen had

Table 1. *Comprehensive areawise percent damage caused by rhinoceros beetle in Androth Island of Lakshadweep*

Area	No. of palms	Total leaves	Damaged leaves	Fresh spindle damage	Total spathes	Damaged spathes
Achada/ Ashigara	32	1106	328	12	273	4
Farm Store/ Mela site	42	1342	327	12	400	4
Saw mill	16	523	117	1	164	0
Kollikatt	14	433	86	3	98	0
Total	104	3404	858	38	935	8
% damage	-	-	25.2	26.9	-	0.86

Table 2. *Comprehensive areawise percent damage caused by rhinoceros beetle in Mincoy Island of Lakshadweep*

Area	No. of palms	Total leaves	Damaged leaves	Fresh spindle damage	Total spathes	Spathes damage
Central island	83	2638	1041	27	48	15
Light House	26	872	411	7	36	6
Kodi village	14	484	73	-	23	-
Kendiparty	7	260	33	-	12	1
Fallissery	1	34	2	-	2	-
Panchayat seedling farm	2	55	2	-	2	-
Met observatory	5	155	39	-	16	-
Total	138	4498	1601	34	138	22
% damage			36.00	25.00		16.00

Table 3. *Site occupied by rhinoceros beetle and the brooding details at Androth and Minicoy*

Island	Sites searched (no.)	Sites occupied by the pest (no.)	Site occupied %	Brood details	
				Single (%)	Multiple (%)
Androth	127	41	32.2	27 (66)	14 (34)
Minicoy	94	48	51.06	25 (52)	23 (48)

Table 4. *Percentage virus incidence in the pest in Androth and Minicoy Islands*

Islands	Grubs observed	Nos. with virus symptom (exo-pathological)	No. of grubs dissected	Details of microscopic examination	Grubs with confirmed viral infection	Percentage virus incidence
Androth	22	12	12	46 slide from 12 diseased grubs	8.00	36.00
Minicoy	90	32	32	127 slides from 32 diseased grubs	26.00	29.00

significantly reduced the damage caused by rhinoceros beetle and increased the viral incidence in the natural pest population in these two Islands in a matter of two years (Mohan *et al.*, 1989, Anon., 1991). It has been observed that the viral effect gets diluted due to many reasons (Gopal *et al.*, 2002) warranting frequent follow-up studies to monitor the pest/disease situation. The follow-up studies in Androth was taken up during 1999 and in Minicoy in the year 2001 after a gap of 11 and 16 years of last observations recorded, respectively. The current damage situation in Minicoy and Androth given in Tables 1 and 2 indicated that the rhinoceros beetle was active and was causing some damage to the coconut palms. A comparison of the damage/virus incidence before the introduction of the pathogen (situation 1), two years after the introduction (situation 2) and during the current follow-up studies (situation 3) is given in Tables 5 and 6 for both these places. The data denote that the damage to coconut was prevalent (situation 3), however barring the spindle damage in Androth and spathe damage at Minicoy the other parameters were well below the status than in situation 1. It could be surmised that the biocontrol agent has been effectively active in suppressing the population of the rhinoceros beetle and the damage caused by it to the coconut. Those beetles that contracted the disease became feeble and were unable to cause significant damage to palms. Their life span too decreases by 60% as compared to the healthy ones. The female beetles were generally rendered sterile and they laid non-viable eggs. The grubs died before molting into the pupa.

The main reason for this longterm effect could be attributed to the restricted land area of the Islands, which provided the diseased beetles, and its virus filled excreta with repeated chances to come in contact with healthy counterparts in the breeding and feeding sites resulting in higher virus perpetuation. Whereas, in mainland the opposite effect was seen i.e., dilution of viral inoculum occurred as there were vast areas with many breeding/feeding sites, where the possibility of contact of diseased rhinoceros beetle with healthy insects dwindled. Diseased beetles visiting some of these sites may find no healthy counterparts occupying these locations. Excretion of virus at such unoccupied sites rendered the pathogen non-viable. Moreover, the presence of another fungal pathogen *Metarhizium anisopliae* and occurrence of mycosis to all the stages of the pest in the mainland, especially during monsoon period suppressed the virus activity briefly (Hochberg and Waage, 1991, Gopal *et al.*, 2002). In recent years, an opportunistic bacterial pathogen *Pseudomonas alcaligenes* also has been recorded to undermine the production of virus inoculum in nature and limit the field perpetuation of this biocontrol agent (Gopal and Gupta, 2002). Absence of both the entomofungal pathogen, *M. anisopliae* and the opportunistic bacterial pathogen, in Lakshadweep Island also played a significant role in keeping the virus incidence high without drastic dilution, which had given the viral pathogen appropriate prevailing conditions for controlling the beetle population.

Table 5. *Comparison of the damage status in Androth since the release of the* Oryctes *virus*

Situation	Year of observations	Damage status (%)			Virus Disease incidence
		Leaf damage	Spathe damage	Spindle damage	
Situation 1* (pre-release)	April 1988	55.00	7.30	23.50	0.00
Situation 2* (post release)	Feb. 1992	7.69	0.32	0.00	85.19
Situation3 (follow-up study)	April 1999	25.2	0.86	26.9	36.00

*Data of situation 1 and situation 2 from Anon. (1991)

Table 6. *Comparison of the damage status in Minicoy since the release of the* Oryctes *virus*

Situation	Year of observations	Damage status (%)			Virus Disease incidence
		Leaf damage	Spathe damage	Spindle damage	
Situation 1* (pre-release)	April 1983	55.83	25.90	29.56	0.00
Situation 2* (post release)	Sept. 1985	12.89	1.61	2.90	68.91
Situation 3 (follow-up study)	Nov. 2001	36.0	22.0	34.0	29.00

*Data of situation 1 and situation 2 from Mohan *et al.* (1989)

However, when situation 3 is compared with situation 2 (Tables 5 and 6) the data showed that the damages have amplified while the viral disease incidence had come down to half. Fall in the virus incidence could be attributed to the increased availability of breeding sites because of cutting down of coconut palms and clearing of coconut gardens for construction works in the Islands. The dead fallen coconut logs were left as such in the fields that became the location of new breeding sites for the pest. Increase in large number of such breeding sites provided more chances for the diseased and healthy beetles not to come in contact with each other resulting in waste of the virus inoculum. For the obligate pathogenic virus to remain viable and effective it must enter the body of healthy beetles/ grubs within 24 to 48 h of its release in the environment by the diseased host, since with lapse of this time this could be rendered non-viable in nature (Zelazny, 1976). Non-maintenance of clean coconut gardens and its surroundings in these Islands particularly in central and southern areas of Minicoy resulted in increased rhinoceros beetle activity.

Site occupancy of the pest and the incidence of viral infection were interrelated (Zelazny and Alfiler, 1986). It is evident from the data given in Tables 3 and 4 that percentage of breeding sites occupied by the pest was less and the disease incidence was high in Androth and *vice-versa* in Minicoy. It has been reported that areas having high density of breeding sites were expected to have low incidence of disease due to the reduced chances of multiple visits by beetles to the same sites (Mohan *et al.*, 1989). Another reason could be the difference in the time elapsed since the introduction of the virus in both these Islands. It was natural that in the place where the virus was introduced more recently its suppressive effects on beetle population could still be higher than in the place where it was introduced much earlier as in the case of Minicoy. The presence of more multiple broods (site including more than one developmental stage of the pest) in Minicoy also pointed to increased beetle population when compared with Androth.

Overall, it revealed from the follow-up studies that the *Oryctes* virus was an efficient biocontrol agent for the management of rhinoceros beetle in the Islands. A long term effective suppression of the pest could be achieved due to the restricted land space, which provided opportunities for higher virus disease contraction in the insect population. However, dilution of viral inoculum with increase in beetle populations and damage to coconut palms were taking place over a period of time due to local factors that warrants augmentation of the pathogen.

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Extraction of Carotenoids from Crude Palm Oil

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Crude palm oil is reddish orange in colour immediate after the extraction from fresh fruit bunches. The pigments present in it are mainly carotenoids and among the different carotenoids, b-carotene constitutes the major part. Five different groups of pigments (mainly carotenoids) were observed according to their absorption maxima and elution pattern during column chromatography. Extraction of carotenoids for crude palm oil was carried out by saponification and adsorption method. By saponification, the complete carotenoids could be extracted and this process might be useful in the soap industry. Physical method of extraction of carotenoids was attempted to retain the edibility of palm oil with 20 different adsorbents and their different combinations comprising of 41 treatments. Montmorilonite and Fullers earth was found better, however, recovery was poor in case of Montmorilonite. Recovery was highest with Keiselghur earth followed by Fly ash. Twelve different solvents were studied as eluent to recover carotenoids from adsorbents and acetone was found best followed by Tetrahydrofuran and Methanol mixture. The recovered carotenoids from adsorbent as well as extracted carotenoids from saponified oil were concentrated in rotary flash evaporator under nitrogen.

(Key words: *Extraction, Carotenoids, Crude palm oil)*

Crude palm oil (CPO) is one of the main sources of carotenoids, and beta-carotene constitutes the major part of it. But the available palm oil (palmolein) in the market does not contain any carotenoids in it. During the process of refining, the carotenoids are destroyed alongwith other impurities. Attempts have been made to recover the carotenoids from CPO by different methods. Saponification is common procedure and carotenoids are recovered as a byproduct of the soap industry (Boekenoogen, 1968). Conversion of the oil to fatty acids methyl ester (FAME) is another process, in which, the FAME is used as fuel and the carotenoids are recovered under high vacuum or by molecular distillation (Ooi *et al.*, 1994). However, to keep the edible oil intact, physical method like adsorption of the carotenoids and the elution of the carotenoids by suitable solvent is better. Some reports are available on such physical methods for recovering carotenoids from CPO (Liew *et al.*, 1993, Desai and Dubas, 1994). In the present study, an attempt was made to categorize the major pigments present in the CPO and also a comparative study has been made among the different adsorbents and subsequent elution from them for the purpose of selecting the better adsorbent to recover carotenoids without affecting the edibility of the palm oil.

MATERIALS AND METHODS

Total carotenoids and beta-carotene present in the oil was estimated. Pigments from the CPO were extracted by saponification and TLC was conducted with the concentrated pigments sample to observe the major pigments present in the CPO. Silica gel plates with hexane: acetone (90:10) was used as running solvent. The pigment concentrate was passed through silica gel column and the absorption maxima of different fractions were recorded in a UV-VIS spectrophotometer.

Adsorption & recovery: Oil was treated with 0.5% (w/w) phosphoric acid (85%) and heated in a water bath at 85°C for 30 min for degumming. Equal volume of NaOH solution was mixed with the phosphoric acid treated oil. Amount of NaOH was derived from FFA (free fatty acid) content of the oil. Soap stock was separated from oil by centrifugation. Carotenoids were extracted from the soap stock. The oil was washed thoroughly with hot water. Different adsorbents and their combinations were added to the oil at different ratio and shaken it thoroughly at 50°C for half an hour in an incubator shaker. Oil from the adsorbent was separated by centrifugation and the adsorbents were washed with hexane to remove remaining oil. Extraction of carotenoids (recovery) from the adsorbents was carried out with different solvents. Carotenoids thus extracted from the adsorbent were passed through anhydrous sodium sulphate and concentrated by a rotary flash evaporator after flashing with nitrogen.

RESULTS AND DISCISSION

Pigments in CPO

Oil samples from different factories were analysed and total carotenoids ranged from 448.5 to 773.0 ppm. Major pigment was b-carotene, which varied considerably from sample to sample (Table 1). Carotenoids were extracted by petroleum ether from the saponified oil samples. However, still colour remained in the soap/methanol fraction, which could be extracted with diethyl ether and the l^{max} was recorded at 441nm.

Petroleum ether fraction of carotenoids showed four major pigments; when separated by TLC, Rf values of these pigments were 0.22, 0.27, 0.64 and 0.82. However, only one pigment spot was observed (Rf = 0.35) with diethyl ether fraction. When concentrated carotenoids sample was subjected to column chromatography with silica gel, and 50 fractions of 3 ml were collected, five groups of pigments were observed as per their absorption maxima (Table 2).

Separation of carotenoids

Complete extraction of the carotenoids was possible from saponified oil samples by shaking in an incubator shaker at 37°C at a speed of 100 rpm for 30 min. Carotenoids were extracted with petroleum ether and diethyl ether. This could be concentrated up to 160 times. In the soap industry, the carotenoids can be recovered, when the palm oil is used as raw material.

Physical method of extraction of carotenoids was important to retain the edibility of oil. Twenty different adsorbents were used separately and in combination, comprising of total 41 treatments. In this process, the FFA was neutralized with NaOH. The soap stock was treated as mentioned above and 5.3 % (S.D.= 1.5%) of carotenoids were extracted by petroleum ether.

Among the different adsorbents, 10-20% Montmorrilonite and Fullers earth showed almost total adsorption (Table 3) but the recovery was not good with Montmorrilonite. Hence, Montmorrilonite can be used as a bleaching agent, where recovery is not important. Low level of adsorption was observed with Fly ash and Carbon granules. Recovery was found best from Keiselghur earth (78.03%) followed by Fly ash ((61.02%).

For recovery from the adsorbent, acetone was found to the best solvent (Table 4) followed by Tetrahydrofuran and Methanol mixture (115.20). Tetrahydrofuran alone was able to recover 62.8µg g^{-1} of carotenoids; when it was mixed with Methanol, the recovery increased to 83.44%. Extracted carotenoids were concentrated in rotary vacuum flash evaporator after passing it through anhydrous sodium sulphate. The concentrated carotenoids were obtained as an oil suspension.

As per Desai and Dubas (1994), 76% of carotenoids could be recovered by using alumina gel and bentonite (1:4) mixture, but in the present study, the same could not be obtained and Fullers earth showed the best result. The concentrated carotenoids could be used as such in suspension of palm oil, but to further concentrate it, this can be again saponified and recovered.

Table 1. *Carotenoids and b-carotene content in CPO*

	Sample 1	Sample 2	Sample 3
Total carotenoids (ppm)	448.5	495.4	773.0
b-Carotene (ppm)	408.5	374.5	416.7
% b-Carotene	91.08	75.60	53.91

Table 2. *Pigments separated by column chromatography*

Fractions	01-07	08-20	21-36	37-41	42-50
l^{max}	443-444	423±2	443±2	418-420	443±2

Table 3. *Effect of different adsorbents on recovery of carotenoids from crude palm oil*

Adsorbent	% Adsorbent	Adsorption	From adsorbent	From CPO
FE	5	46	6.294	2.895
FE	10	94.19	24.220	22.813
FE	20	99	51.499	50.984
B	20	69.7	19.726	13.749
B	10	69.4	14.022	9.731
M	4	72	8.445	6.080
M	10	98	6.055	5.934
M	20	99	9.672	9.575
BA	10	49.7	17.607	8.751
BA	20	59.7	10.787	6.440
FA.at	5	17.03	39.516	6.730
FA.at	10	24.6	61.665	15.169
FA.	5	15.1	31.071	4.692
FA.	10	20	35.533	7.107
FA	20	25.68	61.027	15.672
AC	5	46.445	35.644	16.555
AC	10	54.97	41.890	23.027
AC	20	63.4	48.312	30.630
KA	5	22.72	34.895	7.928
KA	10	38.05	36.967	14.066
KA	20	44.71	47.165	21.087
KA.at	5	17.58	24.060	4.230
KA.at	10	33.58	24.538	8.240
KA.at	20	60.58	24.857	15.058
M + AG(1:1)	10	81.5	7.107	5.792
M + AG (1:1)	20	89.27	14.611	13.044
FE + AG (1:1)	10	55.32	12.190	6.743
FE + AG (1:1)	20	78.09	10.277	8.026
AG + BA (4:1)	10	9.64	40.281	3.883
AG + BA (4:1)	20	22.52	22.881	5.153
BA + FE (1:1)	10	77.43	15.583	12.066
BA+ FE (1:1)	20	87.46	16.508	14.438
B+M+AL+F (1:1:1:1)	4	68	14.675	9.979
B+AG (4:1)	5	62.2	11.425	7.106
BA+AG (4:1)	10	18	14.070	2.533
BA +AG (4:1)	20	34.4	25.956	8.929
KET	10	23.62469	68.557	16.196
KE	20	39.07414	78.034	30.491
CG	5	10.136826	29.238	2.964
CG	10	17.287801	49.043	8.478
CG	20	29.49388	61.983	18.281

FE: 43Fuller's earth; B: Bentonite; BA: Bentonite (acid treated); AG: Aluminum gel; M: Montmorrilonite; AC.: Activated charcoal; FA: Fly ash; KA: Kaolin; KA.at: Kaolin (acid treated); FA.at: Fly ash (acid treated); KE: Keiselghur earth, KET: Keiselghur earth for TLC, CG: Carbon granules, FE (A): Fullers earth-in acetone

Table 4. *Carotenoids recovery from adsorbent by different solvents*

Solvent	AC	CDS	CTC	CL	CH	DEE	H	IPA	PE	THF	THF+M	TL
20% Fullers earth												
Recovery µg/g	160.56	8.36	8.00	6.72	7.68	14.28	9.59	97.02	20.68	62.80	115.20	6.10

AC: Acetone; CDS: Carbon disulphide, CTC: Carbon tetrachloride; CL: Chloroform; CH: Cyclohexane; DEE: Diethyl ether; H: Hexane; IPA: Isopropyl alcohol; PE: Petroleum ether; THF: Tetrahydrofuran; TL: Toluene

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Integrated Pest Management of Rhinoceros Beetle, *Oryctes Rhinoceros* L. in the Oil Palm Plantations

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The oil palm, *Elaeis guineensis*, is an introduced crop in India and is one of the cheap and richest sources of vegetable oil. Rhinoceros beetle, *Oryctes rhinoceros* is the major pest of oil palm. Moreover, injury made by rhinoceros, beetle is a predisposing factor for infestation by red palm weevil , fungi and bacteria on the palms. Twenty hectare of oil palm plantation (replanted area) was selected as the operational area at the Oil Palm India Ltd., Seed Garden, Vettimattom, Idukki dist., Kerala (1994 planting). Integrated Pest Management Practices such as, setting of pheromone traps (Rhino lure) @ one trap per 2ha, re-release of *Oryctes virus* infected adult beetles, and application of *Metarhizium anisopliae* in the breeding sites (cowdung pits, decaying oil palm trunks) were executed in the operational area. As a result of the Integrated Pest Management practices executed substantial reduction in the pest incidence was noticed. Per palm damage on leaf, spindle, petiole and bunches came down, respectively, from 7.16, 6.96, 0.33 and 59.85 to 0.17, 0.02, 0.25 and nil. Management of rhinoceros beetle in the plantation abruptly reduced the secondary infestation by red palm weevil on the bunches.

(***Key words:*** *Rhinoceros beetle, Integrated pest management, Oryctes virus, Metarhizium*)

The red oil palm, *Elaeis guineensis* Jacq., a richest source of vegetable oil, is an introduced crop in India. At present oil palm is extensively cultivated in Kerala, Karnataka, Tamil Nadu, Goa, Maharashtra and Little Andaman. Rhinoceros beetle, *Oryctes rhinoceros* L. (Plate. 1) (*Coleoptera: Scarabaeidae*), is a major pest of oil palm in all the oil palm growing areas. Adult beetles bore into the palms at the base of the spear cluster to chew the tender tissues causing the spindle to break at the base and droop. The entry holes of the beetles can be recognized by the presence of chewed-up tissues. The damaged green leaves present a geometric cut pattern and the leaves, which emerge subsequently, become shortened, broken and distorted (Plate 1). In addition to this, adult beetles are found boring and chewing the female inflorescences even when they are inside the spathe. As a result, in most of the cases, the fruits in the upper portion of the bunches become undersized and dried (Plate 2). Moreover injury made by rhinoceros beetle is a predisposing factor for infestation by red palm weevil (Plate 3), fungi and bacteria on the palms (Ponnamma *et al.*, 2001). The peak period of visit to the palm crown by the beetle beetle is from June to August. The concept of Integrated Pest Management (IPM) has to play a vital role in modern agriculture. IPM schedule, incorporating sanitational, mechanical, prophylactic, curative, biological and attractant measures are required for the control of the beetle (Pillai *et al.*, 1993). The present studies (Feb., 2000 – Feb., 2003) deal with the integrated pest management of Rhinoceros beetle in a heavily infested oil palm plantation incorporating field sanitation, treatment of breeding places with the entomopathogen, *Metarhizium anisopliae*, trapping the floating population of beetles using the pheromone, rhinolure, and re-release of *Oryctes* virus infected adult beetles.

MATERIALS AND METHODS

Twenty hectare of oil palm plantation (replanted area) having 2250 oil palm seedlings (1994 planting) was selected at the operational area at Oil Palm India Ltd., (OPIL) Seed Garden, Vettimattom, Idukki dist., Kerala. Twenty percent of the palms (450) were selected (at random) as sample palms for assessing (pre-treatment and post-treatment) the extent of damage done on leaf, spindle, petiole, and inflorescence, and on bunch by rhinoceros beetle. Old oil palm logs and stumps and the cowdung pits in the farmers gardens adjacent to the plantation formed the breeding sites of rhinoceros beetle. After the collection of pre-treatment data, various IPM practices were executed in the operational area.

Metarhizium anisopliae

The fungus, *Metarhizium* (Plate 6) was mass multiplied in coconut water (Plate 7) adopting the method developed by Danger *et al.* (1991). Treatment of breeding sites was being done at quarterly intervals. The oil palm logs, in which different stages

Plate 1. Nature of Damage by Rhinoceros Beetleon Oil Plam

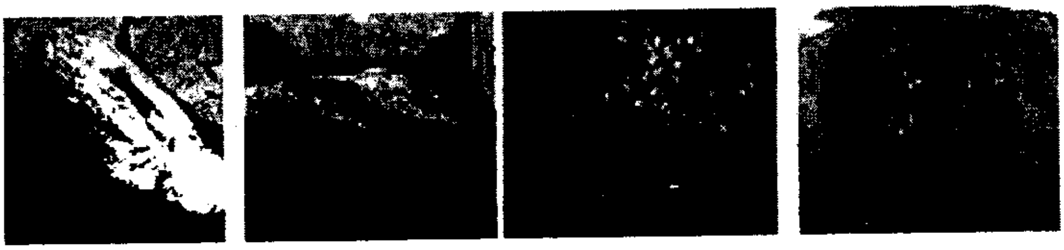

Plate 2. Infestation by Rhinoceros Beetle on Oil Palm Bunches

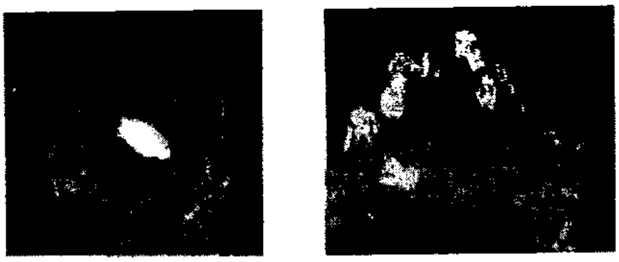

Plate 3. Infestation by Red Palm Weevil on Oil Palm Bunches

Plate 4. Pheromone Trap (Rhinolure)

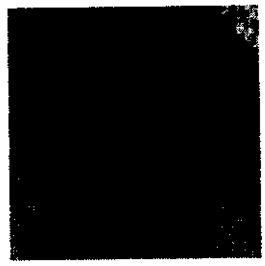

Plate 5. *Oryctes* Virus Infection

Plate 6. Grubs and Pupae Infested with *M. Anisopliae*

Plate 7. Culture

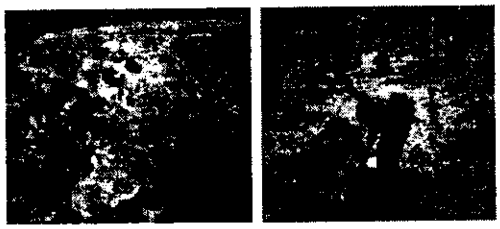

Plate 8. Treating Oil Palm Logs with *M. Anisoplia*

of the beetles were available, were cut open and were treated (Plate 8) with the fungal culture (after diluting to 20 percent). The fungal culture was also treated in cowdung pits surrounding the plantation. Persistence of the pathogen was assessed by site occupancy studies and causal organism was confirmed.

Pheromone

The present studies deal with the potential benefit of the aggregation pheromone (Rhinolure-980 mg) for integrated pest management of *O. rhinoceros* in oil palm plantations (Plate 4). Pheromone - PO 466 Sime RB Pheromone (I lure - ethyl-4-methvloctanoate – 980 mg) manufactured by Chem. Tica International, Costa Rica[1], was used. The traps were set @ one trap per two hectare (Total-10 traps). The beetles caught were collected and sexed at weekly intervals. The sachets were replaced when the liquid filled inside had evaporated fully.

Oryctes virus

Multiplication and maintenance of the culture were done using rhinoceros grubs maintained in steam sterilized oil palm mesocarp waste. Infected grubs (Plate 5) were dissected out and the midgut was macerated in phosphate buffer. The buffer having the virus was used for inoculating adult beetles. Beetles trapped in pheromone traps and beetles reared under laboratory conditions were used

[1] Name of manufacture does not suggest any preference in favour of the firm

for inoculation with *Oryctes* virus and released in the oil palm plantations. Release of inoculated beetles was done at frequent intervals @ 10 beetle per ha.

Post-treatment observations was taken at six monthly intervals. Data were compiled and statistically analyzed compared with the pre-treatment observations.

RESULTS AND DISCUSSION

A total of 60.9 m^2 of breeding material was treated with 60440 ml of the fungal culture. Persistence of *Metarhizium* was ascertained from site occupancy studies. During the progress of the experiment 100 percent mortality was noticed compared to 12.11 percent of the pre-treatment condition. Subsequently the *Metarhizium* infection was found to increase considerably subsiding the infection by *Oryctes* virus.

A total of 1665 beetles (1143 females and 522 males), were caught in pheromone traps within a period of 36 months, which resulted in a very high reduction in the floating population of beetles. The number of females caught per month ranged from 5 to 117 and males from 1 to 69. One thousand one hundred and forty three beetles, if they had remained in the field, would have caused heavy economic loss to the oil palm seedlings.One thousand three hundred and seventy five beetles (922 females and 453 males) inoculated with *Oryctes* virus were released in the operational area.

As a result of the Integrated Pest Management practices executed in the oil palm plantations of OPIL, Seed Garden, Vettimattom, substantial reduction in the pest incidence was noticed. At OPIL, Vettimattom the extent of damage (per palm) on leaf, spindle, petiole and bunches came down, respectively, from 7.16,. 6.96, 0.33 and 59.85 to 0.16, 0.06, 0.17 and nil. The analyzed data revealed that reduction obtained in the post treatment observations in the sample palms was very significant in leaf damage, spindle break and leaf cut (Table 1 and Fig. 1). Management of rhinoceros beetle in the plantation abruptly reduced the infestation by rhinoceros beetle and secondary infestation by red palm weevil on the bunches.

It was observed that the propagules of *Metarhizium anisopliae* established in the breeding medium well and could survive for a longer period and infected the grubs. The easy and rapid transmission of the virus disease could maintain the pest population at lower levels for a longer period. The pheromone is compatible with other control

***Table 1.** Pre- and post-treatment observation of sample palms*

	2000		2001		2002		2003
	1 Feb	2 Sept.	3 Feb	4 Sept.	5 Feb	6 Sept.	7 Feb.
			Leaf cut				
Mean	7.16	1.25	0.77	0.32	0.2	0.17	0.16
SD	4.32	1.64	0.96	0.73	0.5	0.444	0.37
t-value		27.13	30.62	33.12	33.12	34.13	34.24
		Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
			Petiole hole				
Mean	6.76	1.82	0.3	0.27	0.19	0.28	0.18
SD	4.15	2.08	0.54	0.58	0.48	0.59	0.45
t-value		22.55	32.68	32.83	33.32	32.78	33.38
		Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
			Spindle cut				
Mean	0.35	0.19	0.09	0.16	0.06	0.03	0.06
SD	0.83	0.43	0.29	0.43	0.25	0.17	0.24
t-value		3.68	6.17	4.34	7.09	8.03	7.11
		Sig.	Sig.	Sig.	Sig.	Sig.	Sig.

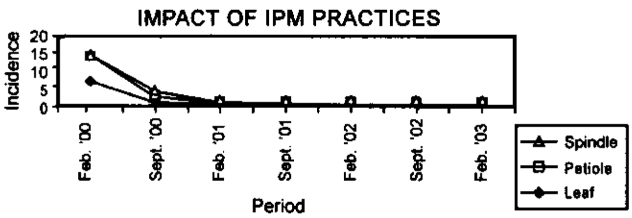

Fig. 1. *Impact of IPM Practices*

techniques without causing any harm to the natural enemy complex. To sum up, maintenance of field sanitation, mass multiplication and treatment of *M. anisopliae* in the breeding sites, re-releasse of *Oryctes* virus infected beetles, and collection of beetles using pheromone traps could all be used in a coordinated manner to form IPM methods which can be adopted for the efficient management of rhinoceros beetle in plantations as proved in the present experiment.

ACKNOWLEDGEMENT

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Session
On
Crop management and value addition of alternate uses vis-à-vis weather adversities

Advances in Coastal Agriculture and Value Addition in Goa

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The crops and cropping systems of coastal region and, in particular, Goa are unique. Among the field crops, rice, sugarcane, pulses like cowpea and oilseeds like groundnut are the prominent ones, while among the horticultural crops, cashew, coconut, arecanut, oil palm, fruit crops like mango, jackfruit, banana, few specific vegetables and spices like, black pepper are important in addition to the rich biodiversity of medicinal and aromatic plants. Increased cropping intensity with suitable cropping/farming systems in these crops with proper selection of species/agro-enterprises, keeping in view the market potential, will result in increased returns for the grower. There are tremendous prospects for income and employment generation in rural areas at on-farm and entrepreneur levels in crops like rice, groundnut, pulses, cashew, coconut, arecanut, mango, spices, etc., to conserve products and by-products against qualitative and quantitative damages and produce value added products for use in rural areas and market surpluses after value addition.

Animal husbandry and livestock production in coastal areas need to be further strengthened not only to meet the diverse requirements but also to bring in sustainability to the production. As the region is not self-sufficient in milk and milk products, improving the livestock and better cattle feed and fodder development programmes are the need of the hour. Further, there is ample scope for increasing the meat production through pig, goat and poultry rearing. Establishment of more hatcheries and broiler farms are essential to meet the growing demand of chicks and broiler meat. Opportunities exist for establishment of pork processing plants, slaughter house for small ruminants, cold storages and quality control facilities. This calls for sustained efforts of all concerned through involvement of people at large in livestock production.

Fishery is the major sector in coastal areas comprising both inland and marine fisheries. The common problems in marine fisheries production are over-fishing and extensive fishing in commercially important species, juvenile fishing, particularly in their breeding ground, and ingress point in estuary and mangroves, which affect the marine fisheries seriously. Production from the inland sector can be increased by bringing more areas into scientific and modern aquaculture with diversification from single species (tiger prawn) culture to other economically viable species such as other prawn species, fresh water prawn, oyster and mussel, crab, pearl spot, milk fish, etc., making available the essential seed requirements and introducing integrated farming and whole area development approaches. As the demand in fisheries sector is increasing for high value products like shrimps, processing infrastructure for value added products like cooked, ready to eat products, and canned food, have to be enhanced. Strategy for achieving this includes making available the latest processing technology, creating warehousing for frozen food and pooled marketing by the joint exporters.

*(**Key words** : Coastal agriculture, Value addition, Floriculture, Spices, Vegetables, Animal husbandry, Fishery, Goa State).*

The coastal zone of India is gifted with a wide range of topographical situations, soil types and is having a diverse and rich resource base comprising flora and fauna. Agricultural production in coastal region is often threatened by the natural calamities like floods, soil erosion, nutrient depletion, salinisation, emergence of new pest and diseases, extinction of precious wild and local germplasm, waterlogging, excessive exploitation of mangroves/ fishes, intrusion of seawater, pollution of various water bodies and increased cost of production. Hence emphasis needs to be given to improve the coastal agriculture on a sustainable basis through effective resource management. The rich productivity is getting fast eroded in coastal region because of deforestation, forest fire and human settlement. Coastal region has rich potential for rice based cropping system, horticultural plantation, and medicinal and aromatic plants of high export value. They are ideal for commercial aquaculture, dairy, piggery, duckery, poultry and agroforestry in association with agriculture. The coastal states have more than 13 cattle, 5 buffaloes, 9 sheep and 11 goat breeds. Large scale poultry and duck farming are concentrated in coastal regions of the country. Mangroves in this region serve in several ways, but are facing destruction. They need to be protected.

The coastal ecosystem, which is a dynamic junction of ocean, atmosphere and land, quickly undergoes changes in shape and location in response to natural forces and human activities. Coastal ecosystem is highly productive with high biodiversity and nursery habitat for many species. The coastal features such as mangroves, sand dunes, sea grasses, etc., forms the natural defence against storms, floods and erosion. Fishing of nearshore waters and farming of coastal lowlands are the major economic activities in the coast. The zone provides for marine transportation, recreation, tourism and salt production. The coastal zone is also affected by changes in sea level, temperature, rainfall, humidity, winds, besides changes in ground water, salinity, ocean circulation, sediment, flux, storms and erosion patterns.

Topographically, the region may be divided into (1) mountain and foot hills of Western Ghats, (2) middle strip of undulating terrain with river valleys, and (3) the coastal belts having saline lands, areas inundated with back seawaters, estuaries, sandy plains and sea coast. The region has a tropical humid coastal climate and receives heavy precipitation ranging from 2500 to 2880 mm. The annual temperature variation is between 17 and 35°C. Soils of the region are laterite, lateritic, alluvial, coastal saline, clay and sandy types. Laterites and lateritic soils constitute about 50 percent of the area whereas the forest cover is about 34 percent. The rich alluvial valleys, which are scattered throughout the region account for about 10 percent. The sandy soils adjoining the seacoast is rather limited in area. The saline lands are the next important ecosystem of the region with partial or full brackish water inundation.

Crops and cropping systems

The crops and cropping system of coastal zone are unique. The systems available in Goa, a typical coastal state in the West coast, are discussed here as an example of the coastal zone. The area under cultivation in Goa is only 39 percent of the gross cropped area and the majority of the area is rainfed. The sub-mountainous undulating terrain is mostly utilised for the cultivation of cashew. In the fertile valleys, a host of crops including plantations such as, coconut, arecanut, and spices such as, pepper, clove, ginger, turmeric, and fruit crops such as, banana, pine apple, etc. are grown.

Among the field crops, rice, sugarcane, pulses like, cowpea, and oilseeds like, groundnut are the prominent ones. In the saline lands where salinity and water inundation are the major problems, traditional salt tolerant rice is being cultivated as a predominant crop.

A. Rice

Rice (*Oryza sativa* L.) is cultivated in an area of about 49383 ha, the majority of which is in *kharif* (32746 ha). The total production of rice is about 1,26,523 tonnes, out of which two-third is from *kharif* (7,90711 t). Rice is cultivated in three distinct ecological zones during *kharif* viz., *Kher* lands (lowlying alluvial/sandy loams), *morod* lands (uplands) and *khazan* lands (coastal saline lands), while in *rabi* these are mostly under *Kher* lands. Although both direct seeding and transplanting are practised during *kharif*, the latter is more common in *rabi*. With the result, the productivity of rice is better in *rabi* (4085 kg ha^{-1}) than in *kharif* (3537 kg ha^{-1}). Higher cost of cultivation in the recent times is the major constraint in rice production.

It is estimated that out of the annual production of 2,12, 740 metric tonnes of paddy in the state, roughly 10-12 percent is lost due to faulty harvesting, threshing, transportation and storage. This can be avoided by using modern machinery like harvester, thresher and improving the storage infrastructure at the farmer's level. Lack of farm mechanisation which is yet to pick up due to the land fragmentation, and absence of cooperative efforts among the farmers of the locality in addition to the poor socioeconomic conditions, have resulted in traditional methods being employed in such post-harvest operations. The present infrastructure for post-harvest of these commodities and the existing marketing infrastructure in the state has remained a stumbling block so far as the area expansion of these crops are concerned. The lack of thrust on creating adequate processing infrastructure has limited the expansion of area of these crops specially fine grained, scented/ Basmati varieties. Although the state produces about 10,000 tonnes of pulses annually, there is no '*dhal*' mill and the local *alsando* is consumed as full grain. The constraint of processing and marketing has also led to a situation wherein major chunk of the fertile rice lands have been either kept fallow or have succumbed to the pressure of real estate lobby for land conversions. The local rice production is mostly done on a subsistence level rather than a profit making enterprise. Creating a sound and effective marketing system through the State marketing Federation/ Co-Operative Society, like the one existing for the horticultural produce, alongwith setting up of one modern rice mill in each of the districts, to start with, will infuse a sense of confidence in the farming community which may encourage them to venture not only into high value commodities but also for multiple cropping systems and related enterprises.

Rice based cropping systems

In contrast to rice production, majority of the pulse grown area is in *rabi*-summer season (8944 ha out of the total 9449 ha). About 95 percent of the pulse production is from *rabi*-summer season as the pulses are grown mostly under residual moisture situations (Anon., 2001). Cowpea (*Vigna unguiculata* Walp.) is the major pulse crop followed by green gram, black gram, etc. The productivity of the pulses is around 9.0 q ha^{-1}. Lack of high yielding varieties, maintenance of optimum plant population and stray cattle menace are some of the problems in pulse cultivation. The studies conducted at ICAR Research Complex for Goa on rice based cropping systems revealed the superiority of rice–cowpea (V-118) and rice- groundnut (cv. DH-3-30) systems in terms of biomass production, yield, gross returns and net returns, besides beneficial effects of leguminous crop rotation on the succeeding rice (Manjunath *et al.*, 1997).

B. Cowpea

The major pulse crop cowpea (*Alsando*), which is primarily a rice fallow crop, is taken up under residual moisture situations. This crop is dominantly cultivated in comparison to other pulses due to its high value and tolerance to major pest and disease incidence. The post-harvest includes sundrying the grains for further two to four days. Though the intensity of storage pest attack on *Alsando* is lower in comparison to other pulses, which the farmers attribute to rather thick seed coat, the indigenous storage practice involves firstly to thoroughly separate the damaged and infested grain manually from the lot and sundry it for two days. Thereafter, the grains are stored in air tight tin / plastic drums. In some cases the farmers add few leaves of neem or a commercial organic product. In some areas, castor oil is rubbed on the grain before storage. Efforts are on at ICAR Research Complex for Goa to collect the variability existing in the local germplasm and purify for further improvement.

C. Groundnut

Groundnut (*Arachis hypogea* L.) is the major oilseed crop in the region (1781ha), and like pulses, the crop cultivation is mostly restricted to *rabi*-summer season under residual moisture situations of rice fallows. The productivity of the crop is fairly good (15 q ha^{-1}) with most of the area covered by introduced varieties like DH-3-30, JL-24, etc. Availability of seed, maintenance of optimum plant population and earwig (pod borer) are some of the problems associated with groundnut cultivation. Retaining the seed for sowing in next season is also not possible due to the high humidity levels during monsoon. The produce is therefore disposed off to the local traders for oil extraction. The local oil mills (*Ghanis*) used for extracting coconut oil from *copra* do the extraction. However, the infrastructure is inadequate to achieve full recovery of oil and due to the absence of filtering unit in these local *ghanis*, lot of sedimentation is observed in the oil. The bye-product i.e., groundnut cake finds use as feed for cattle.

Thus, in order to sustain the production of the staple food commodities and groundnut, there is an urgent need to thrust on processing and marketing. Organised cooperative ventures in this connection can play a vital role. Incentive support by the Government and creation of awareness for value addition can bring in stability in prices and boost the production and productivity of these commodities in the state (Prabhu Desai *et al.*, 2001).

Horticultural crops

Of the total cropped area of 1,71,356 ha, an area of 99,672 ha i.e., 58 percent is under horticulture crops, thus playing a vital role in the economy of the state. Still there is an immense scope to plant horticultural crops especially cashew and other fruit crops in the cultivable wasteland. Trends in area and production of horticulture crops in the state indicate that during period of past five years, there is an increase in area under horticulture crops by 5,106 ha (5.53%) and production by 13,738 tonnes (6.19 %).

Among the horticultural crops, cashew stands first occupying an area of 54,060 ha with a total production of 22,976 tonnes. The productivity is very low (425 kg ha^{-1}). In Goa state, there is a well established network of marketing and processing of cashews. Agencies like Goa Bhagayatdar Society are involved in marketing sector regulating the prices in consultation with neighbouring national markets. Well established processing units with rawnut processing capacity, ranging from 100 kg to 16,000 kg per day, are the strong support to the cashew growers in the state. There are as many as 64 cashew processing units including small and large scale units alike (Adsule *et al.*, 2001).

From processing point of view, presently cashew apple juice is converted into alcoholic drink called "*Feni*". But of late, more emphasis is being given for using the apple juice for production of non-alcoholic beverages and other products. This opens a way to make use of the Vitamin C rich cashew apple into other forms like syrup, squash, candy, etc. for better utilization in the coming days. Further, after extraction of juice the apple residue is generally discarded as waste. However, studies have indicated that this apple waste could be incorporated in cattle feed at 10 percent level without any adverse effect on milk production (Sundaram, 1986).

Next to cashew, about 25,025 hectares are under coconut. The crop is mostly monocropped with uncared management. Adoption of improved cropping/farming systems with coconut through identification of compatible intercrops and integration with suitable allied enterprises enhances the return and employment potential to the growers. Coconut is largely consumed in fresh form in culinary preparation. Much effort is needed to promote processing and value addition of coconut to safeguard the interest of coconut growers in the state. Presently, a few oil expellers are established in the state for coconut oil extraction. Products such as desiccated coconut, desiccated coconut powder, coconut cream, coconut based handy crafts, shell powder, shell charcoal, and shell based activated carbon are some of the examples of value addition in coconut. Recently, snow ball tender nut (SBTN) technology has been developed at CPCRI, Kasaragod to scoop out tender kernel ball containing water for direct consumption. This technology may find place for easy adoption in Goa by targeting tourists visiting the state. Besides this, another technology to make coconut chips as value added products at home scale industry may also be suitable for Goa. In valley regions, arecanut is also cultivated in about 1,600 ha with annual production of 2500 tonnes.

Among the fruit crops, mango is most important one, but yet, there are no systematically planted commercial mango orchards. However, it is estimated that this crop covers about 4,140 ha with the total annual production of 17,228 tonnes and productivity of 4169 kg ha^{-1}. Presently, mango has been used to prepare products like leather, halva, etc. Alphonso, which is an ideal variety for pulping because of persistence of its colour and aroma even after processing, is available in Goa.

Jackfruit is in abundance in Goa. Consumers prefer firm fleshed fruits for dessert purpose. Other than this, the immature pulp and also the well matured but the unripe bulbs are used for culinary purposes. Regarding ripe fruits, soft-fleshed fruits are rarely consumed for table propose. Presently, the soft bulbed fruits are used for making *papads*, leather, etc. at home scale. Chips are also prepared out of firm flesh types. A sweet *idli* is also prepared by steaming a proportioned mixture of rava and jack pulp at home level, which is a delicacy for children.

Banana is cultivated in an area of 2,100 ha. The average yield is 7.37 tonnes per ha, while the total annual production is 15,482 tonnes. In Goa banana is consumed as table fruit as well as for culinary purposes. Very few processed products of banana like chips, papads, toffee, etc. are seen in the market and there is considerable demand for them.

A. Vegetable crops

Seasonal vegetable crops like okra, cucurbits, brinjal, chillies, cowpea, onion, amaranthus, radish, sweet potato, etc. are the common vegetables cultivated in the region mostly as rice based crops or as intercrops. The unique variants of brinjal, okra and chillies available in Goa region need to be conserved and exploited for commercial use.

B. Floriculture

Although coastal areas are low in flower production, Goa leads in consumption of cutflowers in India by virtue of common tendency of Goans to use the flowers in various social and religious ceremonies and booming tourism industry. Marigold, jasmin and crossandra are traditional flower crops grown in the state. Among these flower crops, local jasmin types are highly fragrant and are generally used for domestic purposes.

C. Spices

West coast of India, falling in hot humid per humid ecoregion of agroclimatic zone of the country is bestowed with favourable conditions for several spices and is therefore, rich in biodiversity as far as spice crops are concerned. Black pepper (*Piper nigrum*) occupies major area among the spices, mostly as mixed crop either in coconut or arecanut gardens. Kokum (*Garcinia indica*), nutmeg (*Myristica fragrans*) and cinnamon (*Cinnamomum zeylanicum*) are the important tree spices, of which the first one is spread abundantly with diverse types. Kokum finds place in culinary uses as a souring spice, in pharmaceutical industry as a source of hydroxyl citric acid, and also as herbal drink made of its syrup. Natural variability offers scope for selection of elite types. The latter two are the important spices suitable for incorporating in coconut based multistoried cropping systems. Tirphal (*Zanthoxylum *rhetsa*), a minor but widely used spice, is naturally available in abundance and worth documenting for further crop improvement programmes. Turmeric, ginger, chilies and onion are the other important spice crops for which there is scope for commercial cultivation. Local chilies (*Khola* types) are highly priced for their oleoresin quality. These also possess vast variability and need to be documented for further utilization. In general, identification and utilization of the potential genetic variability of these spice crops is the prerequisite while formulating the strategies for enhancing the spice production in the state. Further, there is scope for introducing other non-traditional spice crops like cardamom for higher elevations and vanilla in palm based cropping systems in the state.

Animal production

Animal husbandry and livestock production is gaining importance in the state of Goa, as elsewhere in the coastal zone. The state, however, has to go a long way to reach the national livestock productivity levels with the sustained efforts of the state Govt. through its development departments/co-operatives working in Animal Husbandry sector and involvement of people at large in livestock production.

There is a wide scope for development of livestock in coastal zone for the following reasons. 1) The demand for milk, meat and eggs is ever increasing due to uninterrupted and increasing population in these areas. 2) To achieve the recommended targets of milk consumption per day, production level of local animals needs to be increased. The growing demands for milk products like ice creams, butter, ghee, etc. at reasonable rates can be met only by increased milk production. 3) The meat industry can be enhanced by giving more stress on goat and pig development. The natural and social environment is very much conducive for the development of these species of livestock. 4) Considering the inherent capacity to generate self-employment, poultry industry (broiler meat egg) can widen its base in the area.

Fisheries

Coastal zone has ample unexploited deepsea resources and inland water resources, which should be taken advantage for production and export, while enterprises like ornamental fish rearing and fish and prawn seed production have potential for strong rural base, income generating and employment opportunity. Growing international demand for quality and value added and high products open up large opportunity of the trade. Diversification of new species like other prawn, crabs, oysters, mussels, etc., for which there is a good scope in Goa, gives a lot of employment and income generation. Brackishwater aquaculture, ornamental fish farming, production of seed for commercially important species, natural collection of unconventional export resources like live sea cucumber, integrated farming systems under coastal ecosystem of Goa are new opportunities which can transform the small state of Goa into strategic export centre.

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Diversified Cropping Systems and Socioeconomic Prospects in Coastal Saline Soils of Gujarat State

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The coastal areas are subjected to climatic vagaries resulting in low productivity and migration of people. The resource poor areas face many socioeconomic constraints and the region as whole needs holistic approach for its development and further upliftment of socioeconomic status of the people. In majority of the places, monocropping is followed and rice is grown in summer months. However, different farming systems with fruit species, vegetables, forages and on highly saline and degraded lands biosaline agriculture using halophytes is also followed in parts of coastal saline soils of Gujarat. In this paper, an attempt is made to look at the constraints, utilization of the coastal resources and strategies for its development with special reference to socioeconomic situation.

(*Key words:* *Cropping systems, Socioeconomic prospects, Coastal saline soils*)

The coastal zone may be defined as zone representing transition from terrestrial to marine influence and *vice versa*. It comprises not only the shoreline ecosystems but also upland watersheds draining into the coastal waters and the nearshore sublittoral ecosystems influenced by the land based activities. India has 8129 km long coastline, which is bounded by the Arabian Sea on the west, the Bay of Bengal on the east and Indian Ocean on its South. Coastal area has ecological disadvantages and possesses inherent infirmities, which make them sensitive to the development-induced stresses. Coastal areas are frequently subjected to serious conflicts in the utilisation of resources. The major driving forces of coastal area degradation are:

(a) high rate of growth in population;

(b) overfishing due to lack of alternative livelihoods;

(c) large commercial enterprises aiming at quick profit at the cost of sustainability and their insensitivity to the interests of local inhabitants;

(d) ignorance about management of resource sustainability among stakeholders and policy makers;

(e) lack of understanding of environmental significance and importance of coastal habitats; and

(f) inadequate enforcement of environmental rules and regulations.

Salinity problems in coastal Gujarat

Salinity problems in coastal areas occurred during the process of their formation under marine influences and subsequent periodical inundation with tidal water, and in case of lowlands having proximity to the sea, due to high watertable with high concentration of salts in it. The coastal soils exhibit a great deal of diversity in terms of climate, physiography and physical characteristics as well as in terms of rich stock of flora and fauna. The major problems encountered in these areas are:

- These lands are subjected to the influence of tidal waves and periodical inundation by tidal water;
- Shallow water table enriched with salt contributes to increase in soil salinity during winter and summer months;
- Heavy rainfall resulting in excess water during *kharif* season;
- Poor surface and subsurface drainage conditions;
- Lack of good quality irrigation water and acute salinity during rabi;
- Poor socioeconomic conditions of the farming community limiting introduction of high investment technologies.

The northwestern coast of India to the west of Gulf of Cambay is shaped like a begging bowl. The bottom of this bowl is Saurashtra while the west side rise of the bowl is Katchchh. Salinity in the coastal areas is both natural and man made. This coast has long been known as a very fertile and productive tract with orchards and vegetable gardens in addition to the intensive field crops. Good ground water has been in sufficient supply in the past and until two decades back, this was some kind of a paradise of Gujarat state. Many of India's environmental problems arise from attempts to meet the basic needs of its enormous population for food and energy. The agricultural scenario has become grimmer due to unabated depletion, pollution and degradation of land and water resources.

Continuous and unabated use of saline ground water affected the soil structure, salt balance and resulted in the disappearance of useful bacteria and plants essential for the stability of the soil system. Shortage of fresh water also has become a limiting factor for the growth of industries, especially the dairy industry, one of the largest in the world. In this paper, an attempt is made to look in to the diversified cropping systems followed in the coastal saline areas with special reference to Gujarat and strategies to improve the socioeconomic scenario in the region.

Agricultural scenario in coastal region

Cropping systems of coastal saline soils

The dismal declining trend of productivity of rice under monocropping can be altered through crop diversification depending upon the site specific conditions in order to have more efficient water and fertilizer use, less biotic and abiotic risks, and better environmental quality. The crop diversification in coastal systems depends largely on the salinity level and irrigation water availability. With proper water management it is possible to incorporate pulses, oilseeds and vegetables in rice-based cropping. Crops like barley, cotton, chilli, sunflower and a good number of vegetables are produced in large quantities in the rabi season in coastal areas.

Coastal ecosystem is recognized as low productive high potential area, therefore major thrust needs to be given for increasing the productivity through energy efficient highly productive cropping system. A number of arable crops have been identified suitable for growing in the dry season under the ricebased cropping system in coastal saline soils. Rice is the most dominant staple food crop. The extent of loss of some important crops due to soil degradation is given in Table 1.

Monocropping leads to largescale virulence of pests and diseases, loss of genetic diversity, marked reduction in yield and other ecological threats. In the predominantly monocropped coastal tracts the net sown area in the east coastal plains is 8.58 M ha with cropping intensity of 134% and that in the west coast is 2.77 M ha with 125% cropping intensity (Subba Rao, 1994). Mono or multiple rice cultivation by and large impairs soil fertility resulting in decline

Table 1. *Estimated impact of soil degradation on Indian agriculture*

Crop	Percent loss	Average value of loss (millions US$)
Paddy	2.7 - 4.7	190
Wheat	3.9 - 6.4	248
Barley	4.5 - 7.0	8
Groundnut	2.8 - 4.4	11
Gram	5.6 - 7.8	60
Rapeseed and mustard	5.8 - 8.5	155
Jowar	5.7 - 7.6	40
Bajra	6.8 - 8.4	25
Maize	3.2 - 4.9	25
Cotton	5.3 - 6.9	140
Sugarcane	4.5 - 7.9	200
All other crops	4.0 - 6.3	750
Total	4.0 - 6.3	1951

Source: The cost of inaction : Valuing the economy-wide cost of environmental degradation in India (World Bank): 1995

in productivity (Yadav, 1994). The yield of the rainfed crops ranges from 500 to 1000 kg ha^{-1}and that of straw from 1,000 to 2,000 kg ha^{-1}. The irrigated crops yield in the range of 1,000-1,600 kg ha^{-1}, and fodder up to 40 q ha^{-1}.

Because of soilwater constraints prevailing in the coastal region in Gujarat state, a change in cropping pattern has been noticed in the state over the last two decades. Fig. 1 shows the shifting has been towards non-food crops because of the commercial value as compared to cereals or food crops. Because of high salinity of the soil and ground water and non-availability of good quality water, salt sensitive crops do suffer. As the erratic monsoon also tapers down at the critical stages of crop growth resulting in crop losses, conservation of limited fresh water and its use in conjunction with saline ground water is a good proposition for raising tolerant and non-food crops.

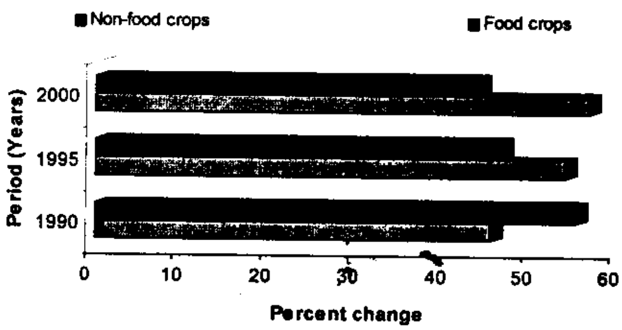

Fig. 1. *Percent change in food and non-food crops in coastal areas of Gujarat*

***Table 2.** Growth stage sensitivity of different for saline water irrigation on saline black soils with high ground water table*

Crop	Growth stages				
Mustard	Branching	>	Flower initiation	>	Pod formation
Safflower	Grain filling	>	Flower initiation	>	Branching
Dill	Vegetative	>	Flowering	>	Seed Formation

Source: Gururaja Rao *et al.*, 2001

Attempts made at our station indicated that crops like mustard, safflower and dill can be grown on saline black soils with high ground water table using limited fresh water in conjunction with fresh water in cyclic mode. Flowering and pod formation stages in mustard, vegetative and flowering stages in safflower and flowering and seed formation stages in dill are the most sensitive (Table 2) for saline water irrigation (Gururaja Rao *et al.*, 2001).

Horticultural and plantation crops

The coastal ecosystem offers a great scope not only for a wide variety of fruit and vegetable crops but also for the plantation crops, spices, medicinal plants (Yadav, 1994), forage species and halophytes (Gururaja Rao *et al.*, 1993, 1999). Plantation crops like coconut and spices like black ginger, turmeric, seed spices like cumin, fennel, coriander and fenugreek are high value commercial crops. Fruit crops like ber and pomegranate have been found ideal for saline black soils (Vertic Haplustepts) having salinity up to 4-6 dS m^{-1} (Gururaja Rao and Khandelwal, 2001).

Vegetable based cropping system

Cultivation of vegetables in a raised bed system during *kharif* season proved to be beneficial in coastal saline areas. The crops, on a flat bed system could not be grown due to water stagnation. Vegetables like gourds, lady's finger and dolichos can be grown in *kharif* season. In *rabi* season brinjal, chilli, tomato, cabbage and cauliflower cab be grown by this technique (Bhattacharya, 1999).

Halophyte based cropping system

In the coastal saline areas, fresh water is becoming scarce for agriculture as a result of increasing domestic and industrial use. The amount of farmland available for food production will also decline because of salinisation. It is against this backdrop that the potential has been highlighted for the reuse of saline soil for food production or other purposes by using salt tolerant plant species (halophytes) and crops. It would be worthwhile to identify the potential salt tolerant plants and halophytes for supply of food and meet other requirements (Glenn *et al.*, 1999). Reutilization of saline soil using salt tolerant crops (including halophytes) is a new challenge. The opportunities offered by saline environments (saline land and salt water) for bio-production and ecosystem development have already been put on the international agenda.

The coastal region and Bhal area in Gujarat with highly saline soils and saline ground water can be profitably utilized for saline agriculture. Research carried out at our station has shown that *Salvadora persica*, a facultative halophyte, which is a good source for C-12 and C-14 fatty acids with immense application in soap and detergent industry and pharmaceutical derivatives, has been found as a life support species (Gururaja Rao *et al.*, 2003, 2004). Cultivation of this species provides good economic returns to the farming community (Table 3) inhabiting in the coastal areas and also restores ecological stability of the region (Gururaja Rao *et al.*, 2004).

Dill (*Anethum graveolens)*, a seed spice crop has been found drought tolerant and grow well with residual moisture giving economic yield. It is also salt tolerant and can tolerate salinity up to 5 dS m^{-1} giving fair yield. The seed production can be increased by using the marginal and sub-marginal quality of ground water. The cost of cultivation and expected benefits of dill cultivation is given in Table 4.

Forage grasses

Other promising halophytes include *Cressa cretica* and halophytic grasses like *Aeluropus lagopoides* and *Eragrostis* species. Production of some important forage grasses grown on highly saline soils indicted *Dichanthium annulatum* as an ideal forage species for cultivation on saline black soils (Fig. 2) due to its better salt tolerance (Gururaja Rao *et al.*, 2001b). This species has been found to have a well defined salt compartmentation in that roots act as potential sinks for toxic ions like Na^+ and Cl^- making the shoots relatively salt free.

Table 3. *Cost of cultivation and cost/benefit ratio of Salvadora persica grown on highly saline black soil (Rates taken for one hectare at 4 m x 4 m spacing)*

Field operations (Input costs)*	Cost (Rs.)
Field preparation (by tractor)	500=00
Pitting (625 pits of 1' x 1' x 1')	625=00
Cost of saplings @ Rs. 0.90 per plant	565=00
Planting (3 labourers)	150=00
Irrigation during first year (saline water)	150=00
Digging of pit of 2.5 x 2.0 x 1m (for saline water)	200=00
Fertilizer (@ 50 g DAP/plant) & FYM	300=00
Plant basin making @ Rs. 0.35/plant	220=00
Miscellaneous (gap filling at 5%)	50=00
Total	2760=00

Returns (4m x 4m spacing)'

Parameter	1st year	2nd year	3rd year	4th year
Planting cost* Rs. ha^{-1}	2760/-			
Harvesting and Fertilizer cost, Rs. ha^{-1}	500/=	550/=	650/=	750/=
Gross yield, Mg ha^{-1}	0.725	0.978	1.580	1.838
Gross income (in rupees)	3625/=	4890/=	7900/=	9190/=
Net benefit (in rupees)	365/=**	4340/=	7250/=	8440/=
Cost/benefit ratio	10.03	0.126	0.090	0.088

* Total planting cost was taken as the cost during first year of bearing only

** [Rs. 3625-3260 (Planting costs 2760 + harvesting and fertilizer costs of Rs. 500/-]

After deducting the harvesting costs at the rate (Rs. ha^{-1}) of 500/-; 550/-; 650/- and 750/- during II, III, IV and V Year, respectively. Total planting cost based on the locally prevailing rates was taken as the cost during first year of bearing only.

' Under well managed conditions

Source: Gururaja Rao *et al.*, 2004.

Table 4. *Cost of cultivation on salt affected soils*

Items of Expenditure, ha^{-1}	Cost (Rs.)
Field preparation	1200=00
Seed	150=00
Seed treatment and sowing	300=00
Fertilizer	800=00
Interculture and weeding	200=00
Irrigation*	350=00
Harvesting and threshing	1500=00
Miscellaneous	1000=00
Total	500=00
Returns	6000=00
Yield of dill, 0.75 t ha^{-1}Gross Returns @ Rs. 30000/- t^{-1}	22500=00
Net return (Rs.)	16500=00

*Two saline water irrigations and one best available water

Source : Gururaja Rao et al., 2000

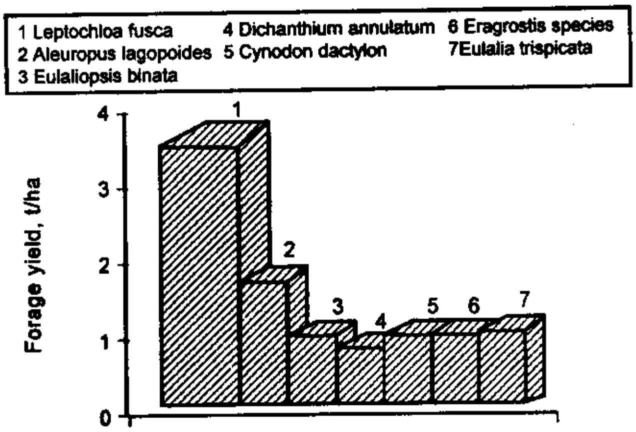

Fig. 2. *Forage yield of grasses grown on saline black soils (ECe, 14.6 dS/m)*

Source: Gururaja Rao *et al.* 2001c.

Integrated approach for enhancing the agricultural productivity

The smaller the farm, the greater is the need for marketable surplus to ensure cash income. Integrated farming system helps in stabilizing the productivity, providing steady income to the farmers, ensuring the buffer stock against risks due to crop loss or price fluctuations and generating the income during the gestation period. An integrated development approach, which takes care of different components of the economy will be more acceptable, should remove the technological, infrastructural and social and policy constraints responsible for the productivity gap, and in some cases, productivity decline. The important approaches are:

- Reducing the cost of production through eco-technologies and improving income through efficient production and post-harvest technologies will help to enhance opportunities for both skilled employment and farm income particularly in coastal saline areas;
- Cultivation of fruits and vegetable in association with cereals and the supply of much needed fodder and fuel wood;
- Employment generation through cottage industries like bee-keeping, cut-flower industries, etc. will prevent the out-migration of people to urban areas and create employment at door steps;
- Development of dairying in conjunction with other programmes; and
- Establishing village cooperative societies in multi-pronged development activities for utilization of common property resources like harvested water, fuel, fodder, fish. etc. for the rehabilitation of the coastal ecosystem.

Thus, the integrated approach can help to enhance income and yield per drop of water and per unit of land and time, which needs to be standardized, demonstrated and popularized speedily, if a reduction in the cost of production is to be achieved without reduction in yield.

Table 5. *Issues and strategies for the upliftment of socioeconomic status of people in coastal saline black soils*

Issues	Strategies
1. Research and development pogrammes have not been sustained by people in long term	Approaches that minimize dependence and maximize selfhelp by the farmers need be adopted.
2. Technologies have not adopted by resource-poor farmers	a. Analyse the range of needs that exist in a community (related to resource access; gender specific factors; farming system); b. Technology testing and demonstrations should include involvement of all and not only the few, often richer community members; c. Use more farmer managed experimentation and evolve effective feedback mechanism and facilities for learning and dialogue between scientists and farmers.
3. Landless people and other non-farmers do not support interventions	a. Identify and include all stakeholders in problem identification, planning and implementation; b. Encourage viable group formation to maintain and continue with new approaches.
4. Research programmes have not yet addressed the complexity of problems of costal saline areas	a. Identify and analyse farming system and community prioritized problems using participatory methods to ensure real problem is addressed; b. Agree the roles and responsibilities of farmers and scientists in developing appropriate means of addressing the identified problems.
5. Rapid resource degrada-tion in crop and non-crop lands and rapid decline in common property resources	Evolve economically viable technologies for diversification; location specific water harvesting and conservation technologies involving user groups; emphasize on agro-forestry, horticulture, regenerative agronomy, crop-livestock integration; methods on economical water use (micro-irrigation methods); rehabilitate common property resources, etc.

Socioeconomic constraints in the coastal saline soils

The development of coastal region faces a variety of constraints viz., environmental, economic, technological, social and institutional constraints as given below.

- In a large part of coastal areas low literacy and acute poverty coupled with small and fragmented nature of farm holdings inhibit investments for the agricultural development in these areas. Inadequate infrastructure for the supply of inputs and energy is another constraint.
- The illiteracy, particularly among women, makes them unaware of technologies. Cultivation preferences vary and at times do not match with the prevailing environment. Farmers, because of poor resource base, adapt subsistence cropping practices.
- Timely non-availability of high yielding and stress tolerant varieties as well as lacking timely availability of inputs make it near impossible for the farmers to adapt modern technologies;
- Private entrepreneurs and credit/financial institutions do not come forward mainly because of inadequate and uncertain demands from the farmers;

The farm technologies that will be developed and disseminated will help people improve their livelihoods and incomes, and thus, will prevent them from abandoning the area and migrating to other places. Studies at farm or household level is important for understanding farmers' response and strategies to cope with changes to his environment and for developing technologies to help farmers cope better with these changes. Research efforts need to develop an integrated knowledge base such that agricultural shifts can be analyzed at the interface between changes in the natural resource base and the socio-economic environment.

The issues prevailing and strategies for the upliftment of farming community in the coastal region are given in Table 5.

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J. Indian Soc. Coastal agric. Res., 22(1&2), 185-190, 2004 **Invited paper**

Problems and Prospects of Medicinal and Aromatic Plants Cultivation in the Coastal Ecosystems of India

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Coastal ecosystems (CES) with their various soil and climatic conditions have tremendous advantage for the production of a variety of medicinal and aromatic plants in India. Long coast line of about 7000 km in east and west coast and their soil types, climate and land use are considered here. High rainfall and moderate temperature and long growing periods in this region coupled with the availability of infrastructure facilities for transport, storage, value addition and industrial support may provide the required impetus for the wide scale cultivation of these crops in CES of India. The prospects of cultivation of medicinal and aromatic plants under diverse cropping systems, availability of improved cultivars, strategies for organic farming and constraints in the production and marketing are discussed. The future strategies for better utilization of our plant wealth and natural resources to lead the global herbal market and aroma trade are emphasized.

(**Key words** : *Medicinal & aromatic plants, Cropping system, Agro-technologies, Organic farming, Marketing constraints*)

Since ancient time, Medicinal and Aromatic Plants (MAP) are in use for relieving human sufferings by treating diseases and also for beautification and fragrance. The demand for herbal products including drugs and aromatic oils are growing rapidly worldwide during last two decades. India, with its rich herbal traditions, vast biodiversity, technological competence and cheap manpower resulting low cost of production, can reap rich dividends in medicinal and aromatic plants trade in international markets. The coastal ecosystems of India are having tremendous potential for the cultivation of selected medicinal and aromatic plants in view of its unique climatic conditions, high rainfall, diverse soil types and prevailing various cropping systems.

Agroclimate, soil and land use in coastal ecosystems

I. East Coast region

The coastal ecosystems of India comprise of southeastern coastal plain, extending from Kanyakumari to gangetic delta in the eastern coast. This region covers an area of 8.5 mha representing 2.6 percent of total geographical area of the country. The coastal parts from Thanjavur (TN) to West Godhavari (AP) receive 900-1100 mm rainfall of which 80 percent is during October-December. The annual water deficit is 800-1000 mm for this region. However, the remaining part towards north receives 1200-1600 mm mean annual rainfall of which 80 percent is during summer. The annual water deficit is 600-800 mm. The soil is isohyperthermic with mean annual soil temperature above 22°C. This bioclimate varies from semiarid to subhumid. The dominant soil types are Haplaquents, Halaquepts, Ustifluvents, Pellusterts and Ustropepts. The soil is slight to moderately sodic at places with poor drainage. Major cropping systems prevailing in this region are rice, coconut, various pulses and oil seeds.

II. West Coast region

The western coastal region comprises south Gujarat, western coastal plains of Maharashtra, Kerala, Karnataka states including Nilgiri hills of Tamil Nadu in the western coast. The total area under this region is 11.1 mha representing 3.6 percent of the total geographical area of the country. This region is characterized by hot and humid summer and warm winter with mean annual temperature varying between 25°C to 28°C. The mean annual rainfall exceeds 2000 mm in most areas with seasonal deficit of 300 – 400 mm. The soils of this region are Dystropepts, Eutropepts, Hapludults and Haplaquepts with localized Haplorthox. Major Crops are rice, coconut and spices.

Prospects of cultivation of medicinal and aromatic plants

The coastal regions are suitable for cultivation of wide range of medicinal and aromatic plants because of the diverse climatic and soil conditions. Medicinal and aromatic plants can be commercially successfully cultivated as sole crop at the same time these can be included in the various existing cropping systems as per demand. The need for cultivation of medicinal and aromatic plants in the coastal regions of India can best be described as below,

1. There is an increasing demand for high quality, homogenous herbal and aromatic raw materials, which are possible through systematic cultivation of these crops.
2. Several studies in various agroclimatic regions emphasized the need for increasing the land use efficiency, productivity and getting higher profits through intercropping, multicropping and relay cropping. Medicinal and aromatic plants are not only grown in the diverse climatic conditions but also these are of different habit patterns such as, annuals, perennials and trees, making them ideal for inclusion in various cropping systems.
3. Because of their suitability to be grown successfully in the marginal, saline, sodic, degraded and wastelands, these crops help to achieve higher farm income and rural employment. The soils of coastal regions are either affected by salinity and sodicity due to poor drainage, the cultivation of suitable medicinal plants would provide viable alternatives for sustainable farming in this region.
4. The recent developments in R & D on the isolation of active principles and value addition along with active involvement of industrial houses in infrastructure building for exploitation of medicinal herb and aroma chemical extraction, purification and product manufacturing make the cultivation of these crops profitable for both farmers and industry.

Medicinal and aromatic plants suitable for commercial cultivation in the coastal ecosystem are shown in the Table 1.

Fitting of medicinal and aromatic plants in existing cropping systems

For the past two decades, several attempts were made in the cropping system research to include the medicinal herbs, aromatic plants with the conventional food, commercial and plantation crops (Table 2). Intercropping medicinal and aromatic plants with other field and plantation crops not only increases the land use efficiency, productivity, but also the net returns from the particular piece of land. Mixed cropping, alley cropping, crop rotation and multitier cropping with these plants are proved to be successful with increased nutrient recycling having reduced pest and disease load on the crops. Successful intercrops of aromatic plants in other ecosystems in India are presented in the Table 2.

Agro-technologies for production of medicinal and aromatic Plants

The research works undertaken by various organizations like ICAR, CSIR institutes like CIMAP, Lucknow and RRLs, and state agricultural universities resulted in the development of agro-technologies for the production, processing and value addition in these crops. Improved varieties are available for various medicinal and aromatic plants (Table 3). The production technologies of various medicinal and aromatic crops are available (Maiti *et al.*, 2000) Improved varieties of medicinal plants are high yielding with more active principles which are adaptable to different agroclimatic regions of our country. The recent varieties of aromatic crops are producing superior quality essential oils with higher level of aroma principles.

Organic farming of medicinal and aromatic plants and their implications

Organic farming concepts are accepted as panacea towards the rampant and persistent degradation created by the modern agriculture. Organic farming offers scope for rejuvenating the soil and environment and helps in realizing the sustainable agriculture. The emphasis on organic agriculture in medicinal and aromatic plants is highly relevant because unlike conventional food and commercial crops, which are tailored to respond towards the added inorganic fertilizers and, more importantly, they thrive mainly on these synthetics for higher yields and to get rid of pest and diseases, these crops are least responsive to added fertilizers and preserve quality in the absence of synthetic agrochemicals. The ever-increasing demand for organically produced herbs and aroma chemicals will pave way for less dependence on agrochemicals.

Good agricultural practices for medicinal and aromatic plant

In recent years, importance of Good Agricultural Practices (GAP) and Good Field Collection Practices (GFCP) for medicinal plants is being recognized in assuring the quality of end products. However, quality control for the cultivation of medicinal plants as source material for herbal medicines is highly complicated. GAP guidelines have been developed so far by the European Union, China and Japan. It must be noted that the guidelines developed by the

Table 1. Medicinal and aromatic plants suitable for coastal ecosystem

Sl. No.	Scientific name	Common name	Parts used
1.	*Abelmoschus moshcatus*	Muskdana	Seed
2.	*Acorus calamus*	Vach	Rhizome
3.	Adhatoda vasica	Vasaka	Leaf
4.	*Aloe barbadensis*	Aloevera	Leaf
5.	*Alpinia galanga*	Alpinia	Rhizome
6.	*Andrographis paniculata*	Kalmegh	Herb
7.	*Asparagus racemosus*	Satavari	Fleshy root
8.	*Baccopa monieri*	Brahmi	Herb
9.	*Cassia angustifolia*	Senna	Leaf
10.	*Catharanthus roseus*	Periwinkle	Root and leaf
11.	*Centella asiatica*	Jalbrahmi	Leaf
12.	*Clitoria ternate*	Aparajita	Root
13.	*Coleus forskohli*	Coleus	Root
14.	*Curculigo orchiodes*	Kalimusli	Fleshy root
15.	*Curcuma longa, C.aromatica*	Turmeric group	Rhizome
16.	*Cymbopogon flexuosus*	Lemon grass	Leaf
17.	*Cymbopogon martinii*	Palmarosa	Inflorescene and leaf
18.	*Eclipta alba*	Bhringraj	Herb
19.	*Evolvulus alsinoides*	Vishunukranta	Whole plant
20.	*Gloriosa superba*	Glory lily	Rhizome
21.	*Gymnema sylvestre*	Madhunasini	Leaf
22.	*Indigofera tinctorea*	Neel	Whole plant
23	*Kaempferia galanga, K. rotunda*	Kacholam	Rhizome
24	*Mucuna pruriens*	Kauch	Seed
25.	*Pogostemon cablin*	Patchouli	Leaf
26.	*Phyllanthus amara*	Bhuiamla	Herb
27.	*Piper longum*	Long pepper	Fruit and root
28.	*Plumbago zeylanica*	Chitrak	Root
29.	*Sida cordifolia*	Bala	Root
30.	*Solanum nigrum*	Makoi	Whole plant
31.	*Solanum surattense*	Kateli	Root
32.	*Solanum viarum*	Khasi kateri	Fruit
33.	*Tinospora cordifolia*	Guduchi	Stem
34.	*Tribulus terrestris*	Gokhru	Seed
35.	*Zingiber officinale*	Ginger	Rhizome

countries cannot be universally applied as guidelines for other countries. Therefore, every country must frame their own guidelines. The following issues must be addressed while framing the GAP .

1. Identification and authentication of medicinal plant species
2. Seeds and other germplasm including vegetative propagules must be verified botanically to genus and species, and variety or cultivar or genotype.
3. The principles of good plants husbandry including right type of rotation of plants in a given environmental condition must be followed.
   a. Site selection must be appropriate according to the need of the crop.
   b. Ecological environment may be adhered to.
   c. Climatic conditions must be congenial for bioactive secondary metabolites formation.
   d. Soil must be ideally suited for the crop growth.
   e. Irrigation and drainage may be controlled according to the needs of the crop.
   f. Plant maintenance and protection should be in such a way that can improve quality and quantity of medicinal plants. Pesticide application must be as far as possible be avoided.
   g. Harvesting must be in proper season and time to ensure the best quality production.
   h. Farmers must have the knowledge of medicinal plants they are growing.

Constraints in production and marketing

Inspite of the remarkable upward surge in the use of herbals and natural products worldwide, there are constraints in the cultivation and trade of medicinal herbs aroma crops. The following are the major reasons for the apprehensions raised towards the cultivation of these crops.

a. Large scale collection of raw materials from forests and natural habitats resulting in the cheaper availability of these products
b. Lack of market awareness
c. Availability of seeds and propagation materials
d. Demand and supply fluctuation leading to loss in profit
e. Lack of minimum support price
f. Lack of decentralized infrastructure facilities in processing and value addition
g. Lack of knowledge of production technologies
h. Lack of quality control and testing facility for ensuring reasonable returns

Future Strategies

There is a strong and definite trend towards herbal medicine and natural products against the synthetics around the globe. The undesirable and often deleterious side effects arising out of allopathic medicines fuels the consumer drive towards the benevolent and cheaper alternatives like herbal healing and traditional system of medicines. India with its rich plant wealth and strong R &D facilities

Table 2. *Intercropping of aromatic crops*

Aromatic Crop	Intercrop	Reference
Lemongrass	Blackgram, Cowpea & Soyabean	Singh Sridhara (2000)
		Singh Shivaraj (1998)
	Lemon scented gum	Chand (1998)
	Eucalyptus	Chauhan *et al.* (1997)
Java Citronella	Eucalyptus	Chauhan *et al.* (1997)
Palmarosa	Eucalyptus	Chauhan *et al.* (1997)
	Pigeonpea	Maheshwari (1997)
	Blackgram & cowpea	Singh *et al.* (1997)
Kacholam	Coconut	Maheswarappa *et al.* (1998)
		Maheswarappa *et al.* (2000)
		Maheswarappa *et al.* (2001)
Patchouli	Papaya	Ram *et al.* (1999)
	Coconut	Viswanathan *et al.* (1992)

Table 3. *List of medicinal and aromatic crops and their varieties*

Sl. No.	Crops	Varieties
	Medicinal crops	
1	Jal Brahmi (*Bacopa monieri*)	Pragyashakti and Subodhak
2	Periwinkle (*Catharanthus roseus*)	Prabal, Nirmal, Dhawal
3	Coleus (*Coleus forskohlii*.)	Maimul, Garmai
4	Datura (*Datura metel*)	RRL-Purple, RRL-Green
5	Asiatic Yam (*Dioscorea floribunda*)	FB (C)-1, Arka Upakar,RRL-Green
6	Long pepper (*Piper longum*)	Vishwam, Gol thippali
7	Sarpagantha (*Rauvolfia serpentina*)	RS-1
8	Khasi-kateri (*Solanum viarum*)	Arka-sanjivani,Arkamahima, BARC, Glaxo
	Aromatic crops	
1	Lemon grass (*Cymbopogon flexuosus*)	NLG 84, Sugandi, OD 19, OD 440, Pragati, RRL 16, Praman, CKP 25
2	Palmarosa (*Cymbopogon martini*)	CI-80-68, RRL(B) 77, RRL(B) 77E, ODP-2, PRC-1, Trishna
3	Java Citronella (*Cymbopogon winterianus*)	Java Sel-2, Jorlab-2, Manjusha, Mandakini, Jal Pallavi
4	Patchouli (*Pogostemon cablin*)	Java, Singapore, Indonesia, IIHR-PP-1, IIHR-2, IIHR-PP-5, Malaysia, Johore

can play a key role in the medicinal plant sector and become a world leader in export of bulk and for formulations if we focus our efforts for cultivation, commercialization and marketing of herbs and aromatic plants. The government of India, having understood the needs for this sector, formulated a separate board for Medicinal Plants in the year 2002 and this will play as an apex body for the formulation of policies and implementation of policies related to various aspects medicinal plants such as cultivation, R & D, marketing, export & import, etc. in the country. The National Research Centre of Medicinal and Aromatic Plants under the auspices of ICAR is undertaking research on crop improvement, crop production, crop protection and post-harvest technologies of few selected medicinal and aromatic plants. As a catalyst to the movement towards harnessing our bio-resources, a medicinal plant botanical garden and field gene bank have been developed. This will serve as a repository of national germplasm collections and also a reference source to the industry for commercial exploitation of our plant wealth.

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Invited paper

Advances in Cropping Systems Research for Coastal Areas

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The advances made in cropping systems research during last decade (1990-91 to 2001-02) through on-station and on-farm centres of AICRP on Cropping Systems located in the states of Gujarat, Maharashtra and Kerala on west coast and Tamil Nadu and Orissa on east coast have been reviewed. The major achievements and lessons learnt are highlighted. Wide gap in productivity (up to 269%) between existing rice-rice system (2.6 to 4.0 t ha^{-1}) and diversified alternate cropping systems (8 to 48 t ha^{-1} year^{-1} as rice equivalent yield) exists under coastal zones which needs to be trapped in national perspective. Through long term studies, the integrated nutrient management approach using 50% recommended dose of nutrient through green manuring and 50% through chemical fertilizers during *kharif* with 100% recommended dose of nutrient through chemical fertilizers during *rabi* have been found suitable for improving systems productivity and sustaining the predominant rice-rice system in coastal areas. Moreover, the deficiency of micronutrients, specially zinc and sulphur, in east coast have been noticed as major constraints influencing systems productivity. Application of 25 kg sulphur per ha and 5 kg zinc per ha through zinc sulphate in Orissa, while 50 kg of sulphur per ha and 5 kg of zinc ha^{-1} in coastal A.P. and T.N. have been found advisable to improve system productivity. Making use of current level of technological advances made so far with special emphasis on regional constraints it is possible to increase the productivity and profitability by four times under rice-based systems in coastal areas.

(**Key Words:** *System based yield gaps and potentials, Zone wise technologies, Management options, Diversification opportunities*)

The Indian coastal ecosystem has coast line of 8219 km long, which is spread over east and west coast covering about 30 million ha of land with net sown area of 8.58 million ha and 2.77 million ha, respectively (Subba Rao *et al.*,1994). The major cropping systems in the coastal areas are rice-fallow and rice-rice. The coastal ecosystem is characterized as area of low productivity with high potential. The cropping intensity is comparatively high (134%) in east coast when compared to west coast (125%). Lot of advances have been made for improving the system productivity in the coastal ecosystem. However, the information remained scattered. Therefore, the present attempt was made to synthesize the scattered information for ready reference of scientists, planners and extension workers.

MATERIALS AND METHODS

The studies were conducted at on-station and on-farm centres of All India Co-ordinated Research Project on Cropping Systems located in coastal areas since inception of the project in 1989 to address different issues pertaining to both east and west coast areas. The experimental data as reported in annual reports of the project for the period up to 2001-02 forms the base of the synthesis of the present information. To drive valid conclusions in ready-to-use form, the available data were pooled over years and processed. The improved varieties as recommended for the areas alongwith standard package of practices were used. For calculation of yield potential in different cropping systems, the mean maximum yield as obtained during say, 1990-91 to 2001-02 was used and denoted as achievable yield potential in terms of rice equivalent yield. For easy comparison of the cropping systems, the yield of different crops was converted into rice equivalent yield using prevailing market rates of the year 2002 uniformly presuming that the inferences will be valid in the present day context. The potential alternate choice of crops for different cropping seasons and systems in various agro-ecozones was also judged based on comparative picture in terms of rice yield equivalents.

RESULTS AND DISCUSSION

Yield potential and gaps

In west coast at Navsari representing south Gujarat heavy rainfall zone, the potential yield of 10.9 t ha^{-1} as rice grain equivalent is achievable through diversified approach against the existing rice-wheat system showing a possible increase of 53.6 percent (Table 1). This increase is possible through introduction of summer crop of greengram

Table 1. *The average and potential yield of different cropping systems in different coast zones*

Cropping Systems	Rice yield equivalent (t/ha) Av.	Potential	Gap	Gap (%)	Possible increase over existing system (%)
West coast: South Gujarat heavy rainfall area (Navsari-Gujarat)					
Rice-wheat (E)	7.1	8.2	1.1	15.3	-
Rice-wheat-greengram	8.7	10.9	2.2	25.9	53.6
Rice-groundnut	7.2	8.4	1.2	16.6	17.7
Rice-sorghum (F)-groundnut	8.7	10.2	1.5	16.9	43.6
West coast: North Konkan coastal zone (Karjat-Maharastra)					
Rice-rice (E)	7.2	8.5	1.3	18.3	-
Rice-maize (cob)	23.9	26.4	2.5	10.4	268.5
Rice-groundnut	12.9	15.3	2.4	18.9	113.8
Rice-mustard-cowpea	10.2	13.8	3.6	35.3	92.5
Rice-sunflower-cowpea	8.6	12.3	3.7	43.6	72.1
Rice-dolichos bean-cowpea	10.3	13.1	2.8	27.4	83.3
Rice-watermelon-cowpea	10.5	15.7	5.2	49.7	118.9
East coast: East and South Eastern coastal zone (Bhubneshwar-Orissa)					
Rice-g.nut-cowpea (E)	14.1	17.8	3.7	26.1	-
Rice-potato-ladyfinger	15.8	20.9	5.1	32.2	47.7
Rice-cabbage-lady finger	13.5	34.9	3.4	10.9	147.1
Rice-tomato-cowpea	18.8	23.2	4.4	23.5	64.2
Rice-potato-sesamum	16.2	19.2	3.0	18.4	36.0
Rice-tomato-ladyfinger	30.0	36.4	6.4	21.4	157.9
Rice-mustard-ridgeguard	17.4	19.8	2.4	13.5	39.9
Rice-tomato-poi (leafy veg.)	41.2	48.8	7.6	18.5	245.9
East coast: Cauveri delta zone (Thanjavur-Tamil Nadu)					
Rice-rice (E)	9.9	11.7	1.8	18.3	-
Rice-rice-pigeonpea	12.5	14.7	2.2	17.8	48.8
Soybean-rice-sunhemp (S)	11.7	13.8	2.1	18.2	39.8
Maize-rice-soybean	10.2	13.7	3.6	35.3	39.2
Blackgram-rice-g.nut	11.3	14.3	3.0	26.6	44.7
Soybean-rice-g.nut	11.2	13.0	1.8	16.1	31.4
Rice-rice-soybean	13.1	16.0	3.0	22.8	62.3
G.nut-rice-blackgram	10.4	11.9	1.6	14.9	20.8

in rice-wheat system. Similarly, in north Konkan coastal zone of Maharashtra, a potential yield of 26.4 t ha^{-1} as rice grain equivalent is possible through adoption of rice-maize (cob) system resulting a very wide gap of 268.5% when compared to existing rice-rice system giving average yield of 7.2 t ha^{-1}. The potential possible increase through other diversified cropping systems ranged from 72.1 to 118% .

In east coast, at Bhubaneshwar representing east and south eastern coastal zone of Orissa, a very high potential yield up to 48.8 t ha^{-1} as rice grain equivalent is achievable through diversified cropping systems like rice-tomato-lady finger showing 246.0% gap between the existing and potential systems. Other diversified systems having potential for increase ranging from 36.0 to 157.9% are available for due adoption as per need (Table 1). The very high yield potential yield at Bhubneshwar was mainly due to inclusion of vegetable crops in the system which fetched good sale price. In Cauveri delta zone of Tamil Nadu, the studies at Thanjaur showed that diversified systems like rice-rice -

soybean can yield up to 16.0 t ha^{-1} year showed 62.3 % possible increase over existing ice-rice system (9.9 t ha^{-1} $year^{-1}$). The yield gap under this zone was low showing that the good yield about 10t/ha is already obtained with use of improved package of practices in rice-rice system of the zone.

Choice of efficient crops for diversification

To quantitatively differentiate the potential choice of a crop for diversifying the existing cropping system, the crops yield was converted in terms of rice equivalent yield (REY). The data given in Table 2 showed the most appropriate choice (s) for the different zones. In general, rice was still a most appropriate choice both in east and west coast areas during *kharif* with yield ranging from 4.2 to 5.5 t ha^{-1} due to climatic compulsions. However, at Thanjaur, representing Cauvery delta zone, groundnut was also an equally good choice giving rice equivalent yield of 4.7 t ha^{-1} with added advantage for soil fertility improvement. In *rabi* too, the rice was the good choice at Thanjaur (T.N) and Karmana (South zone of Kerela). But, at Navsari, representing high rainfall zone of Gujarat, sunflower and sorghum fodder were better while at Karjat representing north coastal Konkan zone of Maharashtra, watermelon and groundnut were identified to be the potential choice. Similarly, in east coast at Bhubneshwer, representing coastal zone of Orissa, vegetable crops like cabbage, tomato and potato were found to be distinctly better choices during *rabi* for diversification of existing systems. In summer, the greengram and maize fodder at Navsari, cowpea at Karjat; groundnut, cowpea and greengram at Karmana, lady's finger and cowpea at Bhuneshwar, and groundnut, soybean at Thanjvur, representing different zones of east and west coast, were identified to be the potential choices. The productivity of existing systems can be enhanced 3 to 4 times with adoption of diversified cropping systems involving crops identified (Table 2).

Table 2. *Efficient crops for diversification of existing rice-rice system in different zones*

South Gujarat heavy rainfall (Navasari, Gujarat)		
Kharif	*Rabi*	*Summer*
Rice (4.3)	Sunflower (2.0)	Greengram (2.2)
	Sorghum fodder (1.8)	Maize (F) (2.0)
North Konkan coastal zone of Maharashtra (Karjat)		
Rice (4.9)	Watermelon (8.0)	Cowpea (2.2)
	Groundnut (7.7)	
South zone of Kerela (Karmana)		
Rice (4.0)	Rice (2.8)	Groundnut (3.8)
		Cowpea (1.9)
		Greengram (1.8)
East and South Eastern coastal zone of Orissa (Bhubneshwar)		
Rice (4.2)	Cabbage (12.2)	Lady finger (5.8)
	Tomato (11.3)	Cowpea (5.1)
	Potato (8.2)	
Cauveri delta zone of T.N. (Thanjavur)		
Rice (5.5)	Rice (5.4)	Groundnut (4.1)
Groundnut (4.7)		Soybean (2.4)

Figure in parenthesis shows the rice equivalent yield of different crops

Promising cropping systems

The promising cropping systems as identified through experiments at farmers field in participatory mode are given in Table 3. In north eastern coastal zone of Orissa (Ranital) instead of rice-greengram sequence, rice-groundnut was found more remunerative giving net return of Rs. 54680 ha^{-1} $year^{-1}$ which was comparable to existing system with net return of only Rs. 31480 ha^{-1} $year^{-1}$. In south eastern high rainfall zone of Tamil Nadu (Tiruneveli), the rice-rice- lady's finger was advisable for large scale adoption instead of rice-rice system. Similarly, in north eastern zone of Tamil Nadu and South Konkan coastal zone of Maharashtra, the rice-groundnut system was more remunerative than the existing rice based systems. Some of the efficient cropping systems for coastal areas in India have also been reported elsewhere with supportive evidences (Gangwar *et al.*, 2003).

Nutrient Management

Effective nutrient management is essential to obtain and sustain the cropping systems yield over years. The long term studies conducted at four locations viz., Bhubaneshwar (Orissia), Maruteru (A.P.), Karjat (Maharashtra) and Karmana (Kerela), representing different zones, have clearly revealed that application of recommended doses through integrated nutrient management approach involving 50% through organic sources like green manuring and 50% through chemical fertilizers during *kharif* followed by use of recommended doses during *rabi* were better and advisable (Table 4). In fact, soil test based balanced use of nutrients is essential to obtain higher yield in coastal ecosystem. In addition to the

Table 3. Most promising cropping systems as identified in farmers participatory approach

Cropping Systems	Average yield (t/ha)			Net return (Rs./ha)
	Kh.	*Rabi*	*Su*	
North Eastern coastal zone of Orissa (Ranital)				
Rice-greengram (E)	4.71	0.63	-	31480
Rice-groundnut	4.81	2.31	-	54680
Southern& high rainfall of Tamil Nadu (Tiruneveli)				
Rice-rice (E)	4.78	4.66	-	40063
Rice-rice-lady finger	4.94	4.67	9.87	68316
North Eastern zone of Tamil Nadu (Viridhachalam)				
Rice-rice (E)	4.72	4.94	-	29672
Rice-groundnut (P)	4.87	1.93	-	33069
South Konkan coastal zone of Maharastra (Ratnagiri)				
Rice-greengram	2.75	1.09	-	24400
Rice-groundnut	2.74	3.19	-	36850
Rice-marigold	2.61	2.02	-	28500

Table 4. Integrated nutrient management in rice-rice sequence at selected locations

Treatments (*Kharif* & *Rabi*)	System yield (t/ha) over years (pooled: 15-21 years)			
	Bhubneshwar	Maruteru	Karjat	Karmana
100% Rec. NPK through fertilizers (*Kh* & *Rb*)	9.0	10.7	8.2	7.6
50% Rec. NPK through fertilizers + 50% through compost/FYM (*Kharif*) 100% Rec. NPK through fertiizer (*Rabi*)	9.8	10.5	7.7	8.1
75% Rec. NPK through fertilizers+25% through compost/FYM (*Kharif*) 75.% Rec.NPK through fertilizers (*Rabi*)	9.5	9.7	7.6	7.2
50% Rec. NPK through fertilizers+50% through crop residues (*Kharif*) 100.% Rec.NPK through fertilizers (*Rabi*)	9.4	10.4	7.9	7.9
50% Rec. NPK through fertilizers+50% through green manure /GLM/azolla (*Kharif*) 100.% Rec.NPK through fertilizers (*Rabi*)	9.7	10.7	8.5	8.5
75% Rec. NPK through fertilizers+25% through green manure azolla (*Kharif*) 100.% Rec.NPK through fertilizers (*Rabi*)	9.8	10.3	6.5	7.6
Recommended dose of N-P_2O_5-K_2O (kg/ha)	80-40-40	60-40-40	100-50-50	90-45-45

use of recommended doses of NPK, the application of sulphur @ 50 kg ha^{-1} and zinc @ 5 to 10 kg ha^{-1} was helpful in increasing the systems yield at Bhubaneswar, Maruteru and Thanjaur locations (Table 5).

Component technologies

The agronomic studies conduced at farmers field through on-farm centres of CSR to address the regional constraints have revealed that in east coast specially in north eastern zone of Tamil Nadu, the

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Table 5. Influence of secondary and micronutrients on the total productivity (t/ha) of different cropping systems

Treatments	Bhubneshwar Rice-rice	Maruteru Rice-rice	Thanjavur Groundnut-rice -sesame (REY)*
T_1: Recommended NPK for *kharif* and *rabi* every year	6.38	8.74	9.68
T_2: T_1 + Sulphur @ 25 kg/ha	6.85	10.24	10.58
T_3: T_1+ Sulphuyr @ 50 Kg/ha	6.98	10.79	12.79
T_4: T_1+ Zinc@5kg/ha through $ZnSO_4$	7.54	9.56	12.73
T_5: T_1+ zinc @ 10 Kg/ha through Zn SO_4	7.90	9.79	11.73

*REY= rice equivalent yield

Table 6. Agronomic management based on regional constraints

Cropping System		Yield (kg/ha)			% Increase
Kharif	*Rabi*	*Kharif*	*Rabi*		
East coast: north eastern zone (Viridhachalam) of Tamil Nadu, major constraint: weed management and prevailing **system**: rice-rice					
T_1 No weeding	No weeding	3.85	4.02	7.87	-
T_2 Butachlor @ 2.5 lit/ha mixed with 50 kg sand on 5th DAT and one hand weeding at 30 DAT	Anilophos @ 1.25 lit./ha mixed with 50 kg sand on 5th DAT and hand weeding at 30 DAT	4.63	4.82	9.45	40.1
Full package	Full package	5.09	5.25	10.34	62.7
C D (P=0.05)		0.12	0.17	-	-
East coast: southern & high rainfall zone (Tiruneveli) of T.N., major constraints: micro-nutrient (zinc deficiency) and prevailing system: rice-rice					
T_1 Farmer practice 62-25-25 kg NPK/ha	Farmer practice 62-25-25 kg NPK/ha	4.05	3.88	**7.93**	-
T_1 + ZnS04 @ 25 kg/ha	T_1 + $ZnSO_4$ @ 25 kg/ha	4.37	4.12	**8.49**	40.2
Full package (125-50-50 kg NPK/ha)	Full package (125- 50-50 kg NPK/ha)	4.92	4.85	**9.77**	46.5
C D (P=0.05)		0.12	0.17	-	-
West coast: south Konkan coastal zone (Ratnagiri) of Maharashtra, major constraints: nutrient management and prevailing system: rice-groundnut					
T_1 45-15-15 kg NPK/ha	20-15-0kg NPK/ha	4.72	2.44	**9.59**	-
T_2 100-50-50 kg NPK/ha	25-50-0 kg NPK/ha	6.38	3.12	**12.61**	31.6
Full package	Full package	7.46	3.77	**15.01**	56.4
C D (P=0.05)		0.16	0.11	-	-
West coast: coastal midland (Thrisur) of Kerala, major constraints: nutrient application and prevailing system: rice-rice					
T_1 Farmer practice 40-30-18 kg NPK/ha	Farmer practice 40-30-18 kg NPK /ha	4.13	4.85	8.98	-
T_2 T1+ cow dung @ 5t /ha	T_1 + cow dung @ 5 t/ha	4.07	5.50	9.57	6.6
T_3 Recommended practice (90-45-45 kg NPK/ha)	Recommended practice (90-45-45 kg NPK/ha)	4.60	5.60	10.20	13.6
T_4 T_3 (1/3 as basal + 30 kg LCC-3)	T_3 (1/3 as basal +30 kg LCC-3)	4.89	5.75	10.64	18.6
T_5 T_3 (1/3 as basal + 30 kg LCC-4)	T_3 (1/3 as basal +30 kg LCC-3)	4.84	6.05	10.89	21.3
C D (P=0.05)		0.49	0.37	-	-

weed problem was the major constraint. The use of full package of weed management was essential and significantly better than existing practice leading to 62.7% increase in systems yield (Table 6). But, in southern high rainfall zone of Tamil Nadu, the zinc deficiency was the major constraint and therefore application of zinc through 25 kg of $ZnSO_4$ alongwith use of recommended dose of 125-50-50 kg of N, P_2O_5 and K_2O as full package was significantly better than farmers' practice leading to 46.5% increase in yield. In south Konkan coastal zone of Maharashtra (Ratnagiri) in west coast, nutrient management was the major constraint. As such, the application of recommended dose of nutrients alongwith full package of other management practices was significantly better than existing practices in rice-groundnut system leading to 56.4% increase in total yield. Similarly, in coastal midland zone of Kerela (Thrisur), application of recommended dose of nutrients (90-45-45 kg NPK ha^{-1}) was significantly better than farmers' practice. But, application of 1/3 dose of N with full dose of P & K as basal while remaining N on LCC-4 based application was comparatively, better than all other treatments leading to 21.3% increase in yield over existing farmers practice, which was also better (7.7%) than the recommended practice of nutrient use of the zone.

It may be concluded that a very wide gap exist between the existing systems productivity and potential system productivity in coastal areas. Therefore, through popularization of systems based technologies already available a quantum jump in agricultural productivity is possible. A frame work for greater use of modern tools and procedures like digital modeling, remote sensing, GIS, distant learning through multimedia, etc for better coverage to the inaccessible and marginal situations in coastal areas is needed.

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Sustainability of Rice Based Long-Term Cropping Systems in Inceptisols under Coastal Hot Subhumid Ecoregion in India

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The long-term fertilizer experiments on Inceptisols under irrigated cropping system of rice-wheat at Barrackpore (after 28 years) and *kharif* rice- *rabi* rice at Bhubaneswar (after 14 years) showed declining yield and low sustainable yield index (SYI) due to unbalanced use of nutrients. The response of crop yields to fertilisers was in the order of control <N<NP<NPK<NPK+FYM. Agronomic efficiency (AE) for N was higher at the beginning which gradually declined over the years in both the cropping systems. However, reverse was true for AE in respect of P fertilization. The response to K was initially higher for rice at Barrackpore and *rabi* rice at Bhubaneswar. The values of SYI with control, N or NP were considerably lower (SYI 0.14-0.48) than 100% NPK (0.45- 0.55), 150% NPK (0.51-0.64) and 100% NPK+FYM (0.51- 0.69). The results showed that application of 100% NPK+FYM @ 10 t ha^{-1} would provide long term sustainability for rice based cropping system in Inceptisols of coastal agroecosystem.

(***Key words:*** *Coastal region, Fertilizer use, Inceptisols, Intensive cropping system, Sustainable yield index*)

Sustainability implies the maintenance and/or enhancement of productivity on a long-term basis through integrated land management. Many workers used SYI for identification of stable technology. For example, Bhindhu and Gaikawad (1998) evaluated soybean-wheat cropping system in terms of SYI as influenced by landform and soil site characteristics. Sarkar (1998) reported the maximum values of SYI for soybean and wheat with NPK+FYM in Alfisols of Ranchi. Here we evaluated the changes in yield responses in terms of AE and SYI under irrigated rice-based cropping systems in agroecological subregion of 12.2 (Bhubaneswar) and 15.1 (Barrackpore) under coastal hot subhumid climate of India.

MATERIALS AND METHODS

The soil of Barrackpore is sandy loam (Eutrochrepts) with dominance of illite and montmorillonite. Initial CEC was 19.0 cmol (p+) kg^{-1} with pH 7.1, OC 7.1 g kg^{-1} soil. The available N, P and K status of soil were 223, 41.5 and 143 kg ha^{-1}, respectively. The 100% N, P and K dose based on initial soil test values were 120, 26 and 50 for both rice and wheat. At Bhubaneswar, soil is lateritic alluvium fine loam (Aeric Haplaquept) with pH 5.6 and CEC [2 Cmol (p+) kg^{-1}]. It has kaolinite-illite dominated clay and poor OC status (2.6 g kg^{-1} soil). The 100% N, P and K were 100, 26 and 50 kg ha^{-1} for *kharif* as well as for *rabi* rice. The treatments under study consist of control (unmanured), 100% N, 100% NP, 100% NPK, 150% NPK and 100% NPK + FYM. The experiment was laid out in RBD with four replications. FYM was applied @ 10 Mg ha^{-1} only in *kharif* rice at both the centres. The efficiency indices were calculated as follows:

Sustainable yield index (SYI) = (Mean yield – Standard deviation) / Maximum yield;

Agronomic efficiency (AE) = (Yield from treatment- Yield from control)/ Nutrient applied.

RESULTS AND DISCUSSION

Agronomic efficiency (AE) for *kharif* rice, *rabi* rice and wheat crops have showed different responses to N, P and K nutrients over the years (Fig. 1). AE for N was higher at the beginning of experiments and gradually declined over the years in rice-rice as well as rice-wheat cropping systems. At Barrackpore, both rice and wheat crops responded well to N application during initial years (21.2 and 15.5) which thereafter declined to 7.0 and 10.0 kg grain per kg N applied, respectively. Unlike N, AE for P fertilization showed either low or negative response at the beginning and gradually magnitude of response increased over the years. The response to K was initially higher for rice at Barrackpore and *rabi* rice at Bhubaneswar. During recent years the higher response was recorded for *kharif* rice (8.6 kg grain kg^{-1} K applied) at Bhubaneswar.

The SYI was in the order of NPK+FYM>NPK>NP>N>control at both the centres. Low SYI after P application (NP) in *kharif* rice at Bhubaneswar in subsequent years was due to severe K deficiency which also aggravated Fe toxicity. The

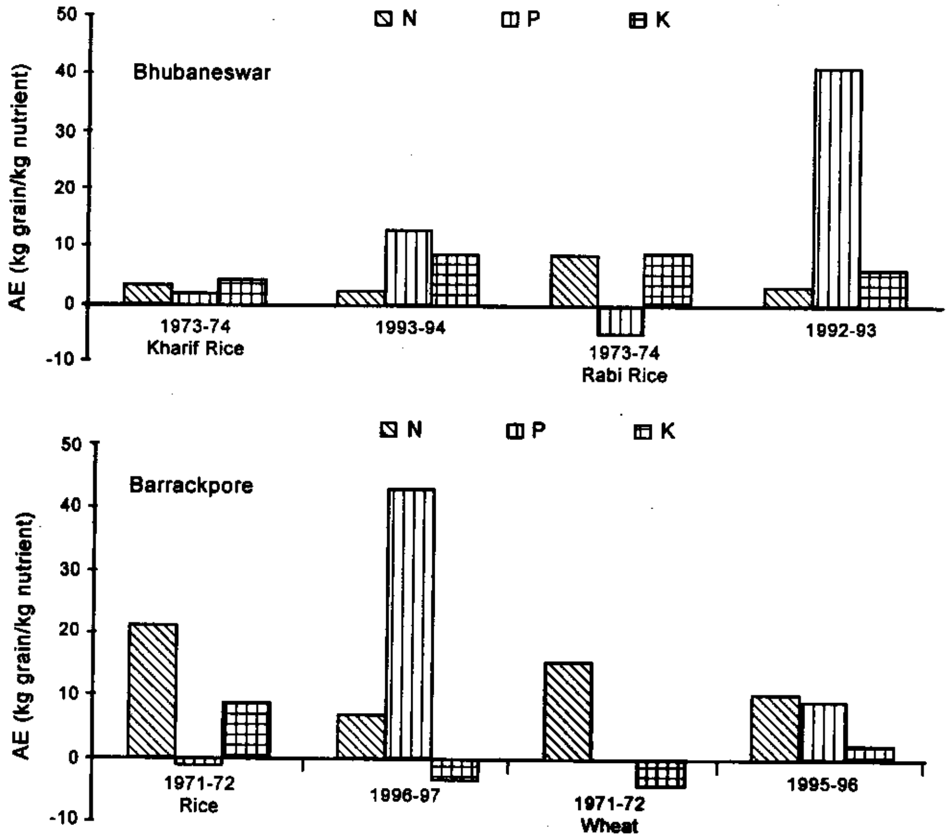

Fig. 1. Agronomic efficiencies for rice-rice at Bhubaneswar and rice-wheat at Barrackpore under long-term fertilizer experiment

Table 1. *Effect of continuous cropping and manuring on average grain yield (Mg ha^{-1}) and SYI over the years in longterm experiments*

Treatment	Bhubaneswar				Barrackpore			
	Kharif Rice		*Rabi* Rice		Rice		Wheat	
	AGY	SYI	AGY	SYI	AGY	SYI	AGY	SYI
Control	1.56	0.26	1.40	0.23	1.56	0.17	0.76	0.14
100% N	2.10	0.31	2.15	0.33	3.33	0.37	1.98	0.41
100% NP	2.22	0.34	2.67	0.48	3.73	0.44	2.25	0.48
100% NPK	2.75	0.46	2.95	0.55	3.87	0.45	2.33	0.52
150% NPK	3.02	0.51	3.28	0.61	4.26	0.53	2.89	0.64
100%NPK+ FYM	3.50	0.61	3.66	0.69	4.05	0.51	2.43	0.54
SD	0.70	0.13	0.81	0.17	0.99	0.13	0.72	0.17

addition of K got reflected in SYI in both *kharif* rice as well as *rabi* rice at Bhubaneswar (Table 1). The application of P and K showed consistent effect but N application increased yields regularly in both the crops over control since the inception of the experiment at Barrackpore. Similarly, intensive cropping (rice-wheat-jute) at Barrackpore has more demand for N than P and K which showed build up in soil. Therefore, in this case superoptimal (150%) NPK dose showed higher values for rice and wheat followed by 100% NPK + FYM and both were superior to control and N alone treatments.

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CSRC(S)5-2-2-5, a Promising Rice Variety for the Coastal Shallow Water

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An attempt of recombinant breeding (1984) at CSSRI Regional Station, Canning involving an adapted variety SR26B and a high yielding one Pankaj (as pollen parent) produced a prospective line CSRC(S) 5-2-2-5 following pedigree method of breeding. The performances of the variety (IET 12855/13354) in the coordinated trials (SATVT) in the coastal saline soils have been highlighted here. The mean grain yield (t ha^{-1}) over years (1991 to 2002) at Canning was 3.93, which was better than the check and qualifying varieties. Results particularly at the states where it was tested over years and over locations showed that the variety was superior in West Bengal (4.54), Maharashtra (3.37), Gujarat (5.61), and moderately good (occupying second position) in Orissa (2.98) and Andhra Pradesh (2.90). In view of the overall performances (t ha^{-1}) over years in coastal locations the variety occupied superior position (3.61) over other check and qualifying varieties. The variety was responsive to N fertilizers upto 80 kg ha^{-1} producing a grain yield of 3.43 t ha^{-1}. In addition to good cooking quality it showed moderate resistance to leaf blast, sheath blight, sheath rot, RTV, Stem borer and leaf folder. Based on the superior performances of the culture (IET 13354/12855) in the coastal saline soils, with a flowering duration of 100 days and long slender grains, the AICRIP (2003) recommended it for central release for coastal saline soils for shallow water i.e., 15-30 cm. The popular name given to the variety is "Bhut Nath".

*(**Key words** : High yielding rice, Recombinant breeding, Soil salinity, Shallow water)*

The topography of the coastal areas in the eastern part of the country is flat having some variation in elevation from the mean sea level and as such there occur variable waterlogging during the active monsoon. The entire belt experiences rains during the rainy season when only rainfed rice is grown, and the stresses of soil salinity predominant in the dry season reduces, to some extent, giving place for variable waterlogging. The adopted indigenous varieties of rice accommodate the existing stresses but with lower grain yield potential. On the contrary, the available high yielding varieties neither suit the soil salinity nor the waterlogging. This is the main reason behind the lower production and productivity level in the coastal areas and remaining static over the years. The shallow water ecosystem (15-30 cm) occupying about 40% area in West Bengal, Orissa and Andhra Pradesh with moderate soil salinity (Mandal and Sen, 2001), may be the target for enhancing production and productivity of rice. Siddiq (1994) had also emphasized for developing genotypes with higher genetic yield ceiling for shallow lowland conditions as a strategy for meeting the future threats of the nature. The paper describes results obtained to meet such a target.

MATERIALS AND METHODS

SR26B is a photoperiod sensitive adapted *kharif* variety mostly suited to the coastal saline soils with shallow to semideep water (15-45 cm) in West Bengal and Orissa. Similarly, Pankaj is a high yielding variety (HYV) suitable for normal soils and shallow water (15-30 cm). With an objective to combine adaptability of the former with the yield potential of the latter through recombinant breeding, a programme was undertaken in 1985. SR26B was the ovule parent and Pankaj was pollen parent. The F2 population was grown in the field and F3 lines were grown in the saline field (ECe 6.0 – 8.0 dSm^{-1}) in shallow water (15-30 cm), while plant-to-row progeny method was followed in the subsequent generations till the population was stabilized. Some of the stable lines were tested in the yield trials and a line designated as CSRC(S)5-2-2-5 was found quite promising.

RESULTS AND DISCUSSIONS

The preliminary screening trial (SASN) at Canning in *kharif* 1990 showed CSRC(S) 5-2-2-5 (3.82 tha^{-1}) superior to other check varieties in terms of grain yield viz. CST7-1 (3.64) and SR26B (2.60). Heading duration was earlier (106) for the test

Table 1. *Grain yield (t ha^{-1}) performances of CSRC(S) 5-2-2-5 (IET12855/11354), Coordinated (SATVT) traial at canning under coastal saline soils (Kharif 1991-1993 and 2000-2002)*

Varieties (IET No.)	Replaced by	Mean Performance over three years (1991-93)		Grain yield (t/ha)						Mean over years the varieties	% increase/ decrease over
		Plant height	Heading	1991	1992	1993	2000	2001	2002		
CSRC (S) 5-2-2-5 (12855/11354)	-	100	109	3.56	3.79	3.12	3.18	5.56	4.39	3.93	-
KR43 (11351)	IET16163	75	98	1.21	2.29	2.35	2.77	4.97	3.57	2.82	+39.36
CR644 (11365)	IET16151	130	121	2.97	3.02	3.17	2.78	4.52	3.27	3.29	+19.45
RP2597-3-246 (12864)	IET16159	78	94	2.04	2.54	1.57	2.59	3.72	2.95	2.57	+52.92
CSR10	CST7-1 Check	63	87	1.29	2.10	1.02	2.76	4.56	3.67	2.57	+52.92
Jaya	Check	65	95	2.21	2.46	0.77	2.38	3.50	2.18	2.25	+74.67
SR26B	Check	135	117	3.72	2.50	4.01	2.56	4.71	3.82	3.55	+10.71
CD at P = 0.05		-	-	0.38	0.36	0.67	1.05	0.37	0.40	0.57	-

Note : 1) The varieties CSR10 and IET11351, 11365 and 12864 were replaced by CST 7-1 and 16163, 16151 and 16159, respectively from 2000. 2) IET16163, 16151 and 16159 were replaced by IET 16889, 16890 and 17337, respectively from 2002.

Table 2. *Grain yield performances (t ha⁻¹) of CSRC(S) 5-2-2-5 (IET12855) in the coordinated trials (SATVT) in the* ***coastal*** *saline soils during* Kharif *2000-02 (Period B)*

Varieities	IET No.	2000 Canning	2000 Gosaba	2000 Motto	2000 Nawga	2000 Machili-Patnam	2000 Panvel	2000 Mean	2001 Canning	2001 Gosaba	2001 Nawga	2001 Machili-Patnam	2001 Panvel	2001 Mean
CSRC(S) 5-2-2-5	12855	3.18	7.63	2.44	5.32	4.27	4.00	4.47	5.25	1.97	4.04	7.79	1.36	4.08
QL-1 VRS-12	16163	2.77	5.53	3.37	3.57	5.68	3.78	4.12	4.97	0.70	2.25	7.18	3.44	3.71
QL-2 CSR-93IR-2	16151	2.78	3.28	3.87	3.25	4.16	3.11	3.41	4.52	1.04	2.26	7.10	3.37	3.66
QL-3 NDRK-5050	16159	2.59	4.57	3.50	3.17	3.50	3.78	3.52	3.72	1.27	2.19	8.47	3.43	3.80
CST7-1	Check	2.76	-	3.96	5.16	3.93	3.89	3.94	4.56	2.45	2.53	8.10	4.65	4.46
Jaya	Check	2.38	4.92	3.76	4.21	2.43	3.83	3.52	3.50	2.01	2.54	6.33	4.50	3.78
CD at P=0.05		0.46	2.62	0.33	0.21	1.85	0.96	1.07	0.37	0.45	0.87	0.73	0.27	0.54

Varieities	IET No.	2000 Canning	2000 Gosaba	2000 Motto	2000 Nawga	2000 Machili-Patnam	2000 Panvel	2000 Mean	Overall mean (gr.) yield) over year over location
CSRC(S) 5-2-2-5	12855	4.39	2.56	2.63	3.01	2.57	2.60	3.08	3.88
QL-4 CN 1413	16889	3.75	3.65	1.95	3.41	1.90	2.50	2.86	3.56
QL-5 CSR-92-IR-4	16890	3.27	2.75	2.82	3.77	3.61	2.17	3.07	3.38
QL-6 NDRK-5073	17337	2.95	2.37	1.95	4.12	3.41	2.86	2.94	3.42
CST7-1	Check	3.67	3.41	2.39	3.71	2.84	2.66	3.11	3.84
Jaya	Check	2.81	2.67	2.29	4.44	2.10	2.45	2.69	3.33
CD at P=0.05		0.40	0.21	0.96	0.91	1.13	0.37	0.66	0.76

Note: The initial check variety CSR 10 & the qualifying varieties KR 43, CR644 & RP 2597 were replaced by CST7-1 & QL-1, QL-2 & QL-3, respectively from 2000. The latter three were replaced by QL-4, QL-5 & QL-6, respectively from 2002.

Table 3. *Grain yield (t ha⁻¹) performances of CSRC(S) 5-2-2-5 (IET12855) in the coordinated trials (SATVT) in coastal saline soils during* Kharif *1991-1993 (Period A) and 2000-2002 (Period B)*

Varieties	IET No.	Period A				Period				Overall mean grain yield over A & B
		1991	1992	1993	Mean	2000	2001	2002	Mean	
CSRC(S) 5-2-2-5	12855	3.48	3.48	2.97	3.31	4.47	4.08	3.08	3.88	3.60
KR 43	11351	2.09	2.79	1.86	2.25	QL-1 4.12	3.71	QL-4 2.86	3.56	2.91
CR-644	11365	4.00	2.83	3.28	3.37	QL-2 3.41	3.66	QL-5 3.07	3.38	3.38
RP-2597	12864	2.26	2.69	1.95	2.30	QL-3 3.52	3.80	QL-6 2.94	3.42	2.86
CSR-10	Check	1.89	1.39	0.93	1.40	CST-7-1 3.94	4.46	3.11	3.84	2.62
Jaya	Check	2.42	2.83	0.94	2.06	3.52	3.78	2.69	3.33	2.70
C Dat P=0.05		0.57	0.85	0.53	0.65	1.07	0.54	0.66	0.76	0.71

Note: The check variety CSR 10 & the qualifying varieties IET 11351, IET 11365 & IET 12864 were replaced by CST7-1 & Q-1 (IET 16163), QL-2 (IET 16151) & QL-3 (16159), respectively from 2000. The latter three were replaced by !L-4 (IET 16889), QL-5 (IET 16890) & Q-6 (IET 17337), respectively from 2002. Replacement required due to dropping of eariler varieties by DRR.

Table 4. *Grain yield performances of CSRC(S) 5-2-2-5 (IET12855) in the Institute Trials in coastal saline soils at Canning during* Kharif, *1992-2000*

Varieties	Mean grain yield (t ha⁻¹)									Grand mean over years		
	1992	1993	1994	1995	1996	1997	1998	1999	2000	Plant ht (cm)	Heading (day)	Grain yield (t ha⁻¹)
CSRC(S) 5-2-2-5	3.75	4.12	5.18	3.59	5.11	3.89	4.25	4.63	3.65	111	110	4.24
CST7-1	3.75	3.67	4.17	3.34	3.89	2.28	2.86	3.97	3.37	81	112	3.48
Pankaj	3.54	3.63	4.81	3.36	4.06	3.31	3.57	4.43	2.86	104	122	3.73
SR26B	3.50	4.15	3.49	3.11	3.80	2.18	3.65	4.06	2.75	141	122	3.41
Nona Bokra	1.77	1.91	1.96	3.81	4.08	2.20	2.04	3.29	2.90	112	105	2.66
CD at P=0.05	0.50	0.35	0.76	0.55	0.45	0.50	0.48	0.35	0.24	-	-	0.46

cultivar as compared to SR26B (116). Plant height was moderate (106 cm) for the test cultivar and less than SR26B (124 cm), which thus suits coastal shallow water (15-30 cm). Mandal and Sen (2002) have reported recently a variety CSRC(S) 2-1-7 (SUMATI) having the similar plant height for coastal shallow water.

The mean grain yield (tha⁻¹) of CSRC(S) 5-2-2-5 at Canning (Table 1) under the coordinated trial (SATVT) over years (1991-93 and 2000-2002) was 3.93, which was better than other check and qualifying varieties. The mean grain yield of the test cultivar at Gosaba was still higher (5.11 t ha⁻¹).

Similarly, the mean grain yield performances of the variety under SATVT during the period (Tables 2 and 3) referred to as 'B' (2000-2002) was very good in Maharashtra (3.73) and Gujarat (5.61),

Table 5. *Summary results of grain yield et different furtilizer dose at Canning during* Kharif, *2000-02*

Varieities	Fertilizer dose																Overall mean grain yield (t ha^{-1})			Grand mean grain yield over years	Optimum N dose (kg ha^{-1})
	Control (No)				40 kg N ha^{-1}				80 kg N ha^{-1}				120 kg N ha^{-1}								
	2000	2001	2002	Mean	2000	2001	2002	Mean	2000	2001	2002	Mean	2000	2001	2002	Mean	2000	2001	2002		
CSRC(S) 5-2-2-5	3.15	2.93	2.23	2.77	3.51	4.45	3.80	3.92	4.13	4.95	4.76	4.61	4.13	4.88	5.13	4.71	3.73	4.30	3.98	4.00	80
CSRC(S) 7-1-4	3.2	2.95	1.73	2.63	3.56	4.33	3.13	3.67	3.69	4.50	4.16	4.12	4.62	4.63	4.40	4.54	3.76	4.10	3.36	3.74	40
CSRC(S) 13-4-1	2.75	2.63	1.80	2.39	3.05	4.30	2.93	3.43	3.17	3.85	3.83	3.61	4.14	3.68	4.03	3.95	3.28	3.62	3.15	3.35	40
CST7-1	3.1	2.88	1.37	2.45	3.29	3.75	3.27	3.44	3.60	3.93	4.30	3.94	3.88	4.38	4.67	4.31	3.47	3.74	3.40	3.54	120
SR 26 B	2.7	2.50	1.50	2.23	3.21	4.08	3.00	3.43	2.76	3.43	3.43	3.21	3.17	3.45	3.70	3.44	2.96	3.37	2.91	3.08	40
Mean	3.8	2.80	1.83	2.54	3.35	4.22	3.27	3.61	3.59	4.20	4.16	3.98	4.11	4.24	4.46	4.27	3.51	3.87	3.43	3.60	

Table 6. *Grain quality characteristics of CSRC(S) 5-2-2-5 and other varieties*

Varieties	IET No.	Mill (%)	HRR (%)	KL (mm)	KB (mm)	L/B ratio	Grain type	Grain Chalkiness	ASV	A/C (%)	GC mm
CSRC(S)5-2-2-5	12855	68.0	62.5	6.89	2.16	3.19	L.S.	VOC	4.0	26.19	48
CR1413	16889	69.7	65.7	5.89	2.50	2.36	S.B.	VOC	5.0	27.17	62
CSR-92IR-4	16890	71.5	68.0	6.42	2.05	3.13	L.S.	A	4.0	23.88	49
NDRK5073	17337	64.7	20.7	5.35	2.27	2.36	S.B.	VOC	7.0	27.35	51
Jaya		72.3	70.2	6.34	2.48	2.55	L.B.	VOC	7.0	26.61	51
CSR13		68.0	58.5	6.32	1.92	3.29	L.S.	VOC	5.2	28.14	63
CSR27		65.0	56.0	6.27	2.21	2.83	L.B.	VOC	7.0	29.74	55
CST7-1		68.0	58.0	5.53	2.41	2.29	S.B.	VOC	6.0	23.35	49

and moderately good in Orissa (2.98) and A.P. (2.90). The Institute trial at Canning conducted during *kharif* 1992 to 2000 showed a mean grain yield ($t\ ha^{-1}$) of the variety as 4.24 with a heading duration of 110 days and the other varieties yielded low, including CST 7-1 (3.48) with a duration 112 days (Table 4).

The variety-cum-fertilizer (N) trial (Table 5) using six varieties and four N doses conducted at Canning during *kharif* 2000 to 2002 (three years) showed 80 kg N per hectare was the optimum dose of N for CSRC(S)5-2-2-5 producing mean grain yield of 4.61 $t\ ha^{-1}$, whereas for SR26B the optimum dose was only 40 kg N ha^{-1}, giving a mean grain yield of 3.43 $t\ ha^{-1}$.

So far the reaction of the variety to major diseases was concerned it was resistant to brown spot, sheath rot, sheath blight, and Tungrovirus. The variety was moderately tolerant to stem borer and leaf folder.

Regarding grain quality characteristics the variety was long-slender type with very good milling and head rice recovery and intermediate alkali spreading value (5.0), which indicated good cooking quality (Table 6).

From the review of the performances of the variety it appears that the intermediate plant height due to which it suits the shallow water without lodging is an important trait The mean grain yield is 3.937 ha^{-1} is an important trait. The overall performance of the check variety CST7-1 was comparable to CSRC(S)5-2-2-5 but the former does not suit the water regimes as the later does.

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Identification of Suitable Rice Varieties for Coastal Saline Areas of Orissa

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Rice varieties were evaluated in both dry and wet seasons (on-farm research) in replicated trials in supercyclone affected areas, at Kiada (Ersama) in Jagatsinghpur district and Timer (Astharanga) in Puri district of Orissa. The varieties like Gayatri, SR-26B, Lunishree and Sonamani were found suitable to grow in wet season with yield level of 3 to 4.5 t ha^{-1}. In dry season the varieties like CSR-4, Canning 7, Annapurna and Khandagiri with yield level of 3.0 to 3.5 t ha^{-1} could be grown at ECe level of 4.5 – 6.0 dSm^{-1}.

(***Key words:*** *High yielding rice, Wet & Rabi season, Soil Salinity, Waterlogging*)

In Orissa, the saline area extends through the coastal districts of Balasore, Bhadrak, Jajpur, Kendrapara, Jagatsinghpur, Khurda, Puri and Ganjam and estimated to be about 2.4 lakh hectares. The ecology of these areas are highly fragile due to several abiotic stresses of which cyclone, waterlogging and salinity are the most important. Rice is the important monocrop of these areas grown during monsoon season only and the crop suffers mainly from waterlogging and salinity. The majority of farmers of these coastal areas are marginal and small. They grow the age-old salt tolerant rice varieties and harvest very poor yield (less than 1 t ha^{-1}) (Sen *et al.*, 2001). To improve the production and productivity of rice of these coastal saline areas, it is important to find out suitable salt tolerant rice variety tolerant to waterlogging condition as well with high yield potential. Hence, the present study was undertaken at cyclone affected area of Kiada (Ersama block) in Jagatsinghpur district and Timer (Astharanga block) in Puri district of Orissa. The suitability of the rice varieties for both dry and wet seasons for both the areas were discussed.

MATERIALS AND METHODS

In *kharif* 2002, twelve rice varieties including CST 7-1 (N. Check) and Kalapanka (Local) were evaluated at Kiada (Ersama) in Jagatsinghpur district and Timer (Astharanga) in Puri district of Orissa in replicated trials to find out the suitable rice varieties. These were : Indravati, Ramachandi, Tulashi, Kanchan, Samba mahsuri, Sonamani, Lunishree, SR 26B, Gayatri, Culture 1590 Imp. Local), CST 7-1 (N. Check), and Kalapanka (Local).

The seedlings were raised in non-saline soil/ plot and 40 day-old seedlings were transplanted in the puddled field in standing water of 15 – 20 cm with soil/water ECe of 4.5 to 5.0 dSm^{-1} at 20 x 15 cm spacing with three replications. The gap filling was done after 7 days of transplanting. The salinity condition of soil and water of the experimental field at both the sites were observed throughout the crop growth period i.e., at transplanting, tillering and flowering. The observations on 50% flowering, yield and yield attributing characters viz., plant height, panicle length, ear bearing tiller (Ebt), sterility percentage and sub-plot yield of each variety were recorded.

In dry season, 12 short duration rice varieties including CST 7-1 were evaluated at Kiada (Ersama) and Timer (Astharanga) in replicated trials to find out suitable rice varieties for *rabi* season in coastal saline area. These were : CR 749-20-2, Khandagiri, Bhoi.

Thirty day-old seedlings were transplanted in the puddled field with ECe of 5.5 to 6.0 dSm^{-1} at a spacing of 15 x 15 cm. The observations on surviving plants and days to 50 percent flowering were recorded. Observations on yield and yield attributing characters were recorded. In wet season the incidence of white year head due to yellow stem borer infestation was recorded in the replicated trial.

RESULTS AND DISCUSSION

In 2002 wet season the transplanting was done in 2nd week of August at both the sites in a standing water of about 20 cm and the gap filling was done after one week of transplanting. The survival percentage of plants in each variety was recorded 15 days after transplanting and there was no

Table1. *Mean yield and yield attributing characters of varieties in* kharif

Sl. No.	Genotypes	Days to 50% Flowring	Pl. ht (cm)	P.Length (cm)	Ebt.	St.%	Grain yield (kg ha^{-1})
1.	Indravati	104	94.7	23.3	8.3	38.0	1840
2.	Ramachandi	95	101.2	23.6	6.8	43.2	3353
3.	Tulashi	135	121.4	27.0	7.0	44.9	3100
4.	Kanchan	98	109.1	23.3	7.0	35.0	3456
5.	Sambamahsuri	95	82.1	21.0	10.0	30.9	3186
6.	Sonamani	125	121.7	23.6	9.6	27.7	3801
7.	Lunishree	100	143.6	25.3	5.0	27.1	3503
8.	SR 26B	105	143.7	25.3	6.0	29.2	4268
9.	Gayatri	135	93.1	21.6	10.0	26.3	4591
10.	1590 (I. Local)	135	107.9	22.3	8.0	42.6	3446
11.	CST 7-1 (NC)	81	73.9	20.6	7.6	42.8	948
12.	Kalapanka	100	138.7	26.3	6.6	43.2	2517
	Mean	109	111.2	23.63		36.4	3.17
	CD at P = 0.05		13.55	1.90	0.35	3.8	50.89
	CV		7.2	4.76	7.43	6.16	9.46

significant mortality observed in specific variety, though the mortality of the seedlings was observed @ 3 – 5 percent in each variety.

The salinity level of the experimental plot at both the sites was recorded throughout the crop growth period. The ECe of the experimental plots before the crop was observed to be 9.2 dSm^{-1} at Kiada and 8.5 dSm^{-1} at Timer. At transplanting the ECe of puddled field water was observed to be 4.0 to 4.5 dSm^{-1} at Kiada and 2.5 to 3.0 dSm^{-1} at Timer. The decrease of EC was observed due to rain and waterlogging condition of the experimental plots. The pH of the soil and water of experimental plots were observed to be 6.2 to 6.5 at both the places.

The observations on days to 50% flowering, plant height (cm), ear bearing tiller (Ebt), panicle length (cm), sterility percentage and sub-plot yield were recorded and presented in Table 1. The data revealed that days to 50% flowering ranged from 81 days (CST 7-1) to 135 days (Gayatri, Tulashi and 1590 (I. Local) with average of 107.6 days. Plant height ranged from 73.9 cm (CST 7-1) to 143.7 cm (SR 26B) with a mean of 111.20 cms. The plant height in case of Gayatri was 93.1% cm with stem stiffness due to which the variety did not lodge. Due to higher plant height and thinner stem the variety Kalapanka lodged completely, while for varieties, Lunishree and SR 26B the lodging was partial. Similarly, the ear bearing tillers per plant was observed maximum (10.0) in case of Sambamahsuri and Gayatri and minimum (5.0) in case of Lunishree. The panicle length of the varieties was observed within the range of 20.6 cm (CST 7-1) and 27.0 cm (Tulashi). The sterility percentage was observed less (26.3 to 29.2) in case of varieties viz., Gayatri, Lunishree, Sonamani and SR 26B and in case of varieties like Tulashi, Ramachandi it was observed high up to 44.9 percent. The sub-plot yield was recorded and the yield per hectare was calculated. The highest yield was observed in case of variety Gayatri (4.5 t ha^{-1}) followed by SR 26B (4.2 t ha^{-1}), Sonamani (3.8 t ha^{-1}) and Lunishree (3.5 t ha^{-1}), whereas in case of CST 7-1 (NC) the yield was observed lowest (0.9 t ha^{-1}) and Kalapanka (L.C) yielded 2.5 t ha^{-1}. The highest yield was observed in case of Gayatri as the salinity level was lower due to rain and the plant was semitall and resistant to waterlogged situation. The higher yield of the varieties like SR 26B, Sonamani and Lunishree was observed due to the low sterility percentage and tolerance to waterlogging situation. The variety (CST 7-1 (N.C) could not perform better as the plant height was less and could not tolerate the waterlogging situation. The incidence of white ear head due to yellow stem borer recorded lowest (3–5%) in varieties viz., Tulashi, Sonamani, Lunishree, SR 26B and Kalapanka, which were below ETL (5%) as compared to CST 7-1 (N.C) (29.0%).

Table 2. *Yield and yield attributing parameters in* rabi *at Timer*

Sl. No.	Varieties	Days to 50% Flowring	Pl. ht (cm)	P.Length (cm)	Ebt.	St.%	Grain yield (kg ha^{-1})
1.	CR 749-20-2	84	100.2	22.73	10.8	16.2	2218
2.	Khandagiri	80	74.7	19.63	13.0	10.2	3470
3.	Bhoi	95	100.2	21.80	10.2	20.4	1823
4.	CR 769-2	95	101.7	20.40	10.4	22.3	2587
5.	Lalat	99	89.4	24.0	9.2	18.6	2676
6.	Khitish	96	89.6	22.8	11.0	14.2	2611
7.	Panvel-3	98	91.5	22.73	9.9	22.0	2633
8.	CRM 898	99	94.6	23.76	9.6	23.6	2967
9.	CST 7-1 (NC)	90	81.6	20.23	8.0	16.2	1774
10.	Annapurna	80	68.5	21.30	10.4	8.6	3608
11.	Canning-7	82	85.1	18.96	10.2	9.0	3347
12.	CSR-4	82	83.4	19.60	9.7	8.5	3435
	Mean	90	88.37	21.50	10.2	15.81	2772
	CD at P = 0.05	4.53	17.91	1.40	2.03	—	1152
	CV	2.965	12.12	3.78	11.72	—	24.54

At Astharanga, the variety Lunishree gave the highest yield (3.4 t ha^{-1}) followed by Gayatri, SR 26B and Sonamani due to similar situation of waterlogging and low salinity level as reported by Sen *et al.* (2001).

In dry seasons (January to April, 02) the varietal evaluation was made at both the sites viz., Ersama and Astharanga using 12 short duration rice varieties in replicated trials. Varieties were transplanted in the 2nd week of Feb., '02. Due to high salinity situation at Kiada (Ersama) the crop could not sustain. The ECe of the experimental plot was observed to be 5.0 to 6.5 dSm^{-1} at transplanting which gradually enhanced and reached more than 10.0 dSm^{-1} before flowering due to scarcity of irrigation water.

The enhancement of ECe was observed in March due to lowering of ground water table coupled with increase in the evaporation rate of field water due to high temperature. The mortality of the plant were recorded in weekly intervals after transplanting till March. In the middle of March, 2002 as water scarcity occurred the salinity (ECe) increased beyond 10 dSm^{-1} and the plants died in each variety and therefore nothing could be harvested at Kiada.

At Timer (Astharanga) the field water ECe was recorded throughout the crop growth period and it ranged from 4.5 to 5.5 dSm^{-1}. As frequent irrigation was given, the crop could survive and was harvested. Data on growth parameters are given in Table 2.

The data revealed that out of 12 rice varieties, the varieties like Annapurna, CSR-4, Canning-7 and Khandagiri yielded at par in the range of 3.3 to 3.6 t ha^{-1} as compared to the yield of CST 7-1 (NC) (1.9 t ha^{-1}). The four varieties performed well due to lower sterility percentage of 8.5 to 10.2 and early maturity of the varieties (days to 50% flowering of the varieties i.e., 69 to 85 days). These four varieties were found suitable for dry season with low salinity (ECe 4.5 to 6 dSm^{-1}) situation in coastal saline areas of Orissa where adequate irrigation facility is available.

It is concluded that in wet season due to rain and waterlogging situation the salinity reduced and the varieties like Gayatri, Lunishree, SR 26B and Sonamani were found suitable to grow in coastal saline areas of Orissa. In dry season it is difficult to grow rice in high salinity situation (ECe more than 8 dSm^{-1}) while under controlled salinity (if irrigation facility is available) the varieties viz., Canning 7, CSR 4, Annapurna and Khandagiri are the suitable ones.

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Rapid Multiplication Technique for Production of Quality Planting Materials in Tropical Tuber Crops

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Tuber crops have been traditionally cultivated in many parts of India, especially in the coastal belt and low fertility marginal lands, mostly as food for the tribals and poor masses. Experiments have been conducted on cassava (direct and transplanted) and amorphophallus for optimizing the minisett size. In cassava, two node minisetts planted at closer spacing (60x 60 cm) was found to be the ideal for rapid multiplication of planting material. Compared to direct planting, transplanting of cassava seedlings was found to be the better technique to eliminate CMD infected plants and to avoid the possible risk of drying up of minisetts in main field due to delay in rains. In the case of amorphophallus, minisetts of size 100 g planted at the spacing (60x60 cm) was found to give higher yield with about 87 percentage establishment.

(***Key words** : Tuber crops, Rapid multiplication technique*)

Low availability of quality planting material is the major hindrance to the cultivation of tuber crops. High yielding varieties released by research stations take several years to reach the end user because of the extreme low multiplication rate in tuber crops. It has therefore become imperative to explore the possibilities to enhance multiplication ratio of these crops by adopting minisett techniques.

Minisett technology developed at CTCRI in yams has proved to be quite practical in rapid seed yam multiplication which has substantially increased its multiplication rate. This is a clear indication of the potential of the tuber crops for rapid multiplication through agro-techniques. However adequate information on rapid propagation in other tuber crops is lacking. In the present study, objectives envisaged were production of quality planting material in amophophallus and cassava, development of suitable agro-techniques for production of planting materials and cultural manipulations for maximizing production of planting materials.

MATERIALS AND METHODS

Rapid minisetts production in cassava

The experiment was conducted in factorial RBD with three replications. The treatments were different size of planting materials/minisetts (Single, two and three node cuttings), different spacings (45x45 cm, 60x45 cm, 60x60 cm and 75x45 cm), and two methods of planting (flat and ridge methods). Separate experiments were conducted for minisetts planted directly in main field and for transplanted minisetts after being grown in nursery. The experiments were conducted in two seasons during 2001-2003.

Rapid seed corm production in Amorphophallus

Field experiment was conducted in factorial RBD with three replications. Different size of planting materials used were 100 g, 200 g, 300 g minisetts in four different spacings (45x45 cm, 60x45 cm, 60x60 cm, and 75x45 cm). Observations on growth and productions were recorded.

RESULTS AND DISCUSSION

Rapid minisetts production in cassava

From the field experiments it was observed that establishment percentage was significantly higher in transplanted cassava minisetts as compared to direct planted cassava minisetts. Compared to single node minisetts, three and two node minisetts had shown higher establishment, however, these were on par.

Method of planting, type of planting, and size of minisetts failed to give a significant difference in dry matter production (DMP). But in closer spacings DMP was much higher than that of wider spacings. Among different spacings 45 x 45 cm had producted highest amount of dry matter (Table 1). Similar result was observed with regard to leaf area index. Further 45 x 45 cm spacing performed better as compared to other spacings, which were at par.

Root spread was fairly higher in direct planted cassava minisetts, compared to transplanted ones. All other treatments viz., method of planting, size of minisetts and spacing failed to give any significant difference in root spread. (Table 1).

***Table 1.** Growth parameters of different cassava minisetts planted at different spacings and by different methods of planting*

Treatments	Establishment (%)	DMP (t ha^{-1})	LAI	Root spread (cm)	Number of nodes	Multiplication ratio (based on production of nodes)
Direct planting	75.18	4.068	3.79	53.69	5.661	118.5
Transplanting	92.42	4.179	3.87	41.91	4.895	125.7
CD (P=0.05)	2.871	0.2530	NS	2.862	0.3381	NS
Ridge method	89.00	4.201	3.89	48.00	5.329	131.8
Flat method	88.60	4.046	3.77	47.60	5.226	128.8
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Single node	76.79	4.015	4.00	47.73	5.110	86.77
Two node	85.94	4.160	3.76	46.52	5.259	62.9
Three node	88.68	4.196	3.73	49.15	5.465	45
CD(P=0.05)	3.516	NS	NS	NS	NS	15.1
45x45 cm	79.30	5.602	4.39	46.79	6.798	109
60x45 cm	81.42	4.314	4.18	47.78	5.524	121.5
60x60 cm	88.66	3.221	3.19	49.62	4.132	131.7
75x45 cm	85.83	3.356	3.55	47.00	4.657	138
CD(P=0.05)	4.060	0.3578	0.690	NS	0.4781	8.11

Number of nodes in a hectare, which could be considered as a scale for measurement of planting material production in cassava minisett technique, was higher in direct planted cassava minisetts. Three node minisetts produced more number of nodes compared to single and two node minisetts (Table 1). Even though this value is statistically insignificant there was a trend of gradual increase in node production as the size of minisett was increased.

Among different spacings, 45 x 45 cm produced statistically highest number of nodes per hectare followed by 60 x 45 cm. In other spacings, it was significantly less and were on par (Table 1). Mohankumar *et al.* (1980) reported higher production of planting materials by adopting 90x45 cm spacing.

Even though tuber production is of secondary importance when planting material production in cassava is considered, it was however observed that direct planted cassava minisetts produced more number of tubers compared to transplanted cassava (Table 2). Closer spacing also gave significantly higher tuber yield as compared to wider spacing.

From these observations it could be inferred that two and three node cuttings are comparatively better minisetts for rapid multiplication in cassava. But since there is no significant difference between two and three node minisetts, in plant growth and production we could take two node minisett as the ideal planting material size because this could further enhance the multiplication ratio. Similar finding were reported by Cock *et al.* (1976). In the case of spacings, 45 x 45 cm has been found to be ideal for planting material production.

Even though the establishment percentage was higher in transplanted cassava, growth and production were higher in direct planted cassava. However, a major advantage in transplanted cassava is that mosaic disease (CMD) infected plants could be eliminated while in nursery, and uniformly established crop could be obtained. Further by this method we could elude drying up in the main field due to delay in rains. Nair (1990) found that by using meristem culture disease free planting material could be obtained.

Rapid seed corm production in Amorphophallus

Sprouting percentage was found to be higher in 100 g and 200 g minisettts of amophophallus as compared to 300 g. It was also observed that spacing had no effect in the sprouting of amophophallus minisetts (Table 3).

With regard to vegetative growth parameters like girth of plant, canopy cover and height of plant, minisetts of 200 g and 300 g size performed better compared to 100 g minisetts. But this was not reflected

Table 2. *Yield parameters of different cassava minisetts planted at different spacings and by different methods of planting*

Treatments	Number of tubers (cm)	Girth of tubers (cm)	Length of tuber (t ha^{-1})	Tuber yield (t ha^{-1})	Multiplication ratio (based on production of nodes)
Direct planting	7.55	14.06	25.13	32.44	75.18
Transplanting	5.50	12.84	17.95	28.40	92.42
CD(P=0.05)	0.664	0.583	1.302	2.624	2.871
Ridge method	6.61	13.65	21.88	29.61	89.00
Flat method	6.44	13.26	21.20	31.23	88.60
CD(P=0.05)	0.664	0.583	1.302	2.624	NS
Single node	5.05	13.61	21.88	32.82	76.79
Two node	7.23	13.25	21.38	28.76	85.94
Three node	7.29	13.50	21.36	29.68	88.68
CD(P=0.05)	0.813	0.714	1.594	3.214	3.516
45x45 cm	6.22	13.11	21.69	37.39	79.30
60x45 cm	6.91	13.36	21.88	31.31	81.42
60x60 cm	6.35	13.87	21.32	26.68	88.66
75x45 cm	6.61	13.48	21.27	26.30	85.83
CD(P=0.05)	0.939	0.824	1.841	3.711	4.060

Table 3. *Performance of different amorphophallus minisetts planted at different spacings*

Treatments	Tuber Yield (t ha^{-1})	Multiplication ratio	Sprouting percentage	Plant girth (cm)	Canopy cover (cm)	Height of plant (cm)	Girth of tuber (cm)
100 g	53.35	14.84	88.8	11.83	69.3	49.2	47.23
200 g	50.43	7.01	87.3	12.40	81.1	55.0	46.41
300 g	53.35	4.95	84.0	13.40	80.8	55.1	50.30
CD(P=0.05)	NS	8.45	3.9	1.304	9.40	5.66	NS
45x45 cm	80.71	8.17	88.0	12.18	83.5	56.0	48.40
60x45 cm	75.69	10.22	89.2	13.10	78.3	52.5	49.67
60x60 cm	65.84	11.85	88.5	12.72	70.9	51.4	47.28
75x45 cm	67.60	11.41	81.1	12.17	75.6	52.4	46.57
CD(P=0.05)	5.13	1.98	NS	NS	NS	NS	NS

in growth (Table 3). Further, there was no significant difference in tuber yield and girth of tuber among different size of minisetts. This showed that different sizes of minisetts had no effect in tuber yield.

It was also observed that spacing had no effect in sprouting, girth of plant, canopy cover, height of plant and girth of tuber (Table 3). But the tuber production was higher in closer spacing (45x45 cm) which indicated that closer spacing should enhance the production of amorphophallus remarkably.

From these observations it is inferred that 200g minisetts at 45x45 cm spacing would be ideal for rapid planting material production in amorphophallus.

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Seedling Emergence and Early Growth Parameters of Castor (*Ricinus communis*) Germplasm for Salt Tolerance

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A laboratory investigation was carried out at Hyderabad during 2002-2003 to evaluate castor (*Ricinus communis*) germplasm under four salt concentrations (0, 6, 8 and 10 dSm^{-1}) for their response to germination and seedling growth parameters. Seed germination declined with increasing level of salt concentration. Castor germplasm viz., SKI-200 and SKI-218 recorded significantly higher germination percentage at 8 dSm^{-1} level compared to other accessions. Among the accessions tested, SKI-200, SKI-218 and SKI-273 recorded higher root lengths even at EC 10 dSm^{-1} level while accessions, SKI-232, SKI-271 and SKI-283 produced seedlings with shorter root lengths. Castor accessions, SKI-200 and SKI-218 have recorded consistently higher vigour index. Castor germplasm accessions, SKI-200 and SKI-218 have relatively higher salt tolerance as evidenced by the germination percentage and early growth parameters and may be tried as source of tolerance in developing salinity tolerant genotypes.

(*Key words: Castor germplasm, Soil salinity, Early growth parameters, Vigour index*)

Castor germplasm differed in their capacity to germinate under inland saline conditions (Muralidharudu and Haripriya, 2000, Muralidharudu *et al.*, 2001). Though information on the relative salt tolerance of few oilseed crops (Chandru *et al.*, 1994, Muralidharudu *et al.*, 1997, More *et al.*, 2002, Lallu and Dixit, 2001) is available, genotypic variation of castor for salt tolerance is meagre. Screening of castor germplasm for salt tolerance can be of much use to identify the tolerant lines for cultivation in salt affected coastal areas of Andhra Pradesh, Gujarat and other parts of the country. In this investigation, castor germplasm were studied for their germination and seedling growth parameters different graded salt concentrations.

MATERIAL AND METHODS

Ten castor germplasm accessions viz., SKI-200, SKI-202, SKI-215, SKI-218, SKI-225, SKI-232, SKI-271, SKI-273, SKI-281 and SKI-283 procured from Castor unit, Sardar Krushinagar (Gujarat) were used for the present study during 2002-03. Twenty treated seeds of germplasm accessions were subjected to different salt concentrations i.e., EC0, 6, 8 and 10 dSm^{-1} under laboratory conditions in 150 mm petri dishes having Whatman No. 1 filter paper. Each treatment was replicated thrice and kept in seed germinator at 27^{0}C for a period of 12 days to test the effect of different salt concentrations. Growth parameters viz., germination percentage, shoot and root length, fresh and dry weight, and vigour index were recorded on 12th day.

RESULTS AND DISCUSSION

Germination percentage (Table 1) declined with increase in salt concentration in all the castor accessions. SKI-200 and SKI-218 recorded significantly higher germination percentage at EC8 dSm^{-1} level compared to other accessions. Statistical analysis of the data revealed that, except SKI-202, SKI-273 and SKI-271, all other accessions maintained significantly higher germination percentage even at EC10 dSm^{-1} level. Decline in germination percentage with the increase in salinity was also observed in other oilseed crops viz., safflower (More *et al.*, 2002) mustard (Lallu and Dixit, 2001) and sunflower (Muralidharudu *et al.*, 1998). Interaction between salt concentrations and germplasm was found statistically significant.

The mean root and shoot lengths (Table 1) in all the accessions were found to decrease gradually with the increase in salt concentration. Among the accessions tested, SKI-200, SKI-218 and SKI-273 recorded higher root lengths of 11.8, 7.7 and 6.4 cm, respectively at 10 dSm^{-1} level, while accessions SKI-232, SKI-271 and SKI-283 produced seedlings with shorter root lengths. Accessions SKI-218, SKI-200 and SKI-225 recorded higher shoot lengths of 9.7, 7.3 and 6.3 cm, respectively at EC10 dSm^{-1} level, while at the same salt concentration, SKI-271and SKI-283 produced seedlings with shorter shoot lengths. Root and shoot length ratio decreased with the increase in salt concentration in SKI-200 and SKI-218 compared to other germplasm.

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Table 1. *Effect of salt concentrations on germination percentage, shoot and root lengths in castor germplasm of S.K. Nagar*

Genotypes/salt concentration (dS/m)	Germination (%)				Shoot length (cm)				Root length (cm)				Root -Shoot ratio			
	0	6	8	10	0	6	8	10	0	6	8	10	0	6	8	10
SKI-200	100	100	90	83	11.0	10.6	8.9	7.3	24.0	23.2	14.7	11.8	2.2	2.2	1.7	1.6
SKI-202	100	77	67	40	16.3	15.1	8.6	5.4	13.8	11.6	6.8	4.7	0.8	0.8	0.8	0.9
SKI-215	100	83	72	62	10.6	8.0	6.8	3.1	9.2	7.3	7.0	4.6	0.9	0.9	1.0	1.5
SKI-218	100	97	87	73	12.7	11.2	10.1	9.7	13.4	11.3	7.8	7.7	1.1	1.0	0.8	0.8
SKI-225	100	88	79	71	10.2	9.2	7.0	6.3	11.3	4.6	4.5	4.0	1.1	0.5	0.6	0.6
SKI-271	100	73	53	20	11.3	10.0	4.8	-	11.3	7.4	5.3	-	1.0	0.7	1.1	-
SKI-273	100	52	36	24	16.4	8.1	4.8	2.4	15.6	9.9	9.6	6.4	1.0	1.2	2.0	2.7
SKI-281	100	100	83	72	12.9	11.5	9.1	2.4	14.2	13.1	9.8	6.0	1.1	1.1	1.1	2.5
SKI-283	100	97	93	77	14.3	10.1	4.6	-	11.0	9.8	5.8	-	0.8	1.0	1.3	-
SKI-232	100	93	79	69												
C.V%				7.7				19.5				22.3				
C.D (P = 0.01) Varieties				5.5				1.8				2.3				
Salt conc.				3.5				1.2				1.5				
Varieties x Salt conc.				10.1				3.7				4.5				

Table 2. *Effect of salt concentrations on shoot and root dry weights and vigour index in castor germplasm of S.K. Nagar*

Genotypes/salt concentration (dS/m)	Shoot dry weight (mg)				Root dry weight (mg)				Vigour index			
	0	6	8	10	0	6	8	10	0	6	8	10
SKI-200	0.051	0.051	0.050	0.047	0.032	0.029	0.026	0.025	3500	3380	2124	1585.3
SKI-202	0.064	0.059	0.049	0.037	0.042	0.033	0.029	0.025	3010	2055.9	1031.8	404.0
SKI-215	0.052	0.038	0.036	0.028	0.019	0.017	0.016	0.014	1980	1269.9	993.6	477.4
SKI-218	0.053	0.050	0.050	0.043	0.020	0.020	0.018	0.016	2610	2182.5	1557.3	1270.2
SKI-225	0.033	0.030	0.022	0.022	0.008	0.008	0.007	0.006	2150	1214.4	908.5	731.3
SKI-271	0.083	0.064	0.060	-	0.041	0.040	0.023	-	2260	904.8	363.6	-
SKI-273	0.087	0.051	0.047	0.030	0.044	0.042	0.040	0.022	3200	1800	1195.2	633.6
SKI-281	0.079	0.079	0.077	0.025	0.040	0.038	0.038	0.015	2710	2386.2	1757.7	646.8
SKI-283	0.081	0.074	0.046	-	0.045	0.039	0.028	-	2530	1850.7	821.6	-
C.V%			55.51					29.16				
C.D (P = 0.01) Varieties			0.031					0.008				
Salt conc.			NS					NS				
Varieties x Salt conc.			NS					0.016				

In general, root and shoot dry weights of all the accessions decreased gradually with the increase in salt concentrations (Table 2). Accessions, SKI-200, SKI-202, SKI-218 and SKI-273 recorded maximum shoot and root dry weights compared to other accessions (SKI-271, SKI-283, etc.) at EC10 dSm^{-1} level.

Vigour index decreased in all the germplasm with increase in salt concentration. Castor accessions, SKI-200 and SKI-218 have recorded consistently higher vigour index, which can be attributed to ion exclusion mechanism of these lines, while SKI-271and SKI-283 recorded low, at all salt concentrations. Decrease in vigour index with increase in salinity was also observed in mustard germplasm (Lallu and Dixit, 2001).

From the above studies, it is inferred that castor germplasm accessions SKI-200 and SKI-218 have relatively higher salt tolerance and to be tested further, in field under saline soil conditions, and also as source of tolerance for developing salinity tolerant genotypes.

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On-farm Study on Integrated Nutrient Management for Coastal Saline Soils under Rice Based Cropping System

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The experiment on integrated nutrient management for coastal saline soils of Sundarbans region in West Bengal was conducted in farmers' field by using rice as test crop in *kharif* and vegetables (chilli and lady's finger) in *rabi*. Inorganic N-fertilizer (urea) in combination with different organic sources of N (city compost, green leaves of locally available trees viz., *Glyricidia* spp., *Delonix* spp. & *Exocaria* spp., and FYM, each applied @ 5 t ha^{-1} on fresh wt. basis), and biofertilizer (*Azotobacter* spp. & *Azospirillium* spp. in equal proportion) were tested. Inorganic and organic sources of N and biofertilizer were applied to rice crop, whereas only inorganic N and biofertilizer were applied to vegetables. The results indicated that yields of both rice and vegetables were better when combined sources of N viz., inorganic + organic, were applied to soil instead of inorganic source of N (urea) alone. Best results were obtained by using green leaves of locally available tree spp. as organic component among the combined sources of N. Application of city compost also produced encouraging results. Application of biofertilizer resulted in significant improvement in yield of vegetables during *rabi* season but not of rice in *kharif* season. Nitrogen content in plant indicated higher value under combined application of nutrients. Analysis of soil samples showed that fertility status of soil in respect of N was much improved due to application of combined sources of N while application of inorganic source of N alone did not show any improvement in available N status of soil. Available P content of the soil indicated significant increase in P status of the soil in *kharif* due to application of combined sources of N. Available P status of soil was not significantly influenced by the treatments in *rabi* when the residual effect of the organic materials was studied. Application of combined sources of N did not reveal any significant differences among the treatments in terms of available K content of soils.

(***Key words:*** *Integrated nutrient management, Biofertilizer, Organic sources of N*)

The coastal region of India is mostly monocropped growing rainfed rice *kharif* season. The yield of *kharif* rice and that of a few *rabi* crops which are grown in the region on limited areas are poor because of various constraints like high soil salinity, lack of irrigation water, meagre fertilizer use, low fertilizer efficiency, etc. The poor fertilizer use efficiency, particularly in respect of N, is primarily due to poor water management and high soil salinity besides other soil and climatic constraints. Bandyopadhyay and Rao (2001) indicated that fertilizer use efficiency is low in coastal soils when chemical fertilizers alone are used. The low biological activities in salt affected soils also lead to low bioavailability and transformation of nutrients in soil. The biological activities and biological processes in soil are improved due to application of organic material to soil (Bandyopadhyay and Bandyopadhyay, 1983, Rao, 1998, Rao and Pathak, 1996). Besides improving nutrient status, regular application of organic materials has been reported to improve the organic matter status of soil as well as render several soil physical, chemical and biological properties, which are very important for sustainable crop production in salt affected soils (Bandyopadhyay and Bandyopadhyay, 1983, Pathak and Rao, 1998, Rao and Rao, 1960, Wang *et al.*, 1988). Thus there is a strong consensus emerging now that integrated nutrient management system is essential for sustainable crop production in soil particularly in those which are problematic in nature. It is well understood that the supply of organic materials is limited but the supply of organic matter can be increased by recycling the organic wastes, green manuring, using locally available non-conventional organic sources, etc. including bioinoculation (through biofertilizers) of soils. With these in view, the present study was conducted in farmer's field to find out suitable locally available organic for integrated nutrient management and efficient fertilizer management practices for coastal ecosystem.

MATERIAL AND METHODS

Field experiments with rice-vegetable crop rotation were conducted for two years in split-plot design in *kharif* and *rabi* seasons in farmer's field at Rendokhal, South 24 Parganas, representing typical coastal saline soils of West Bengal. The soil of the experimental site was clay loam in texture, nearly neutral in pH (6.2), saline in nature (5.2 dSm^{-1} in *rabi*), having high available K (390 kg K ha^{-1}) and P (19.2 kg P ha^{-1}), and low available N (0.08%) contents. Rice, *Oryza sativa* (cv. Swarna)) was grown as test crop during *kharif* and chilli, *Capsicum annum* (cv. Suryamukhi) and lady's finger, *Abelmoschus esculentus* (cv. Anamika) were grown as test crops during *rabi*. There were 6 main plot treatments (T) and 2 subplot treatments (B) with 3 replications. The doses of organic materials were on fresh weight basis and applied only in *kharif*, and their residual effects were studied in *rabi*. Biofertlizers were applied in both *rabi* and *kharif*. Phosphorus and potassium fertilizers were not applied since there was no response for these fertilizers and the soil was rich in available P and K. The details of the treatments in *kharif* and *rabi* seasons are given below.

Kharif season

Main plot treatments (T)

T_1: Control (Farmer's practice; 20 kg N ha^{-1}) applied through urea as basal dose

T_2: N recommended dose (100 kg N ha^{-1}) applied through urea in 3 splits

T_3: N half (50 kg N ha^{-1}) of the recommended dose through urea in 3 splits

T_4: Green leaf (equimixture of leaves of locally available tree species viz., Glyricidia i.e. *Glyricidia spp.*, Siris i.e. *Delonix spp.* and Geon i.e. *Exoecaria agallocha)* @ 5 t ha^{-1} + urea N (in 3 splits) making total N dose as 100 kg N ha^{-1}

T_5: Well decomposed farm yard manure (FYM) @ 5 t ha^{-1}+ urea N (in 3 splits) making total N dose as 100 kg N ha^{-1}

T_6: City Compost @ 5 t ha^{-1}+ urea N (in 3 splits) making total N dose as 100 kg N ha^{-1}.

Subplot treatments (B)

B_0: Without biofertilizer

B_1: With biofertilizer (*Azotobacter* and *Azospirillum* in equal proportions)

Rabi season

Main plot treatments (T)

T_1: Control (Farmer's practice; 20 kg N ha^{-1}) in 1split applied through urea

T_2: N recommended dose (i.e. 120 kg N ha^{-1}) applied through urea in 3 splits

T_3: N half (i.e. 60 kg N ha^{-1}) of the recommended dose applied through urea in 3 splits

T_4 to T_6: Half (60 kg N ha^{-1}) of the recommended dose of N applied through urea in 3 splits but no organic material

Subplot treatments (B)

B_0: Without biofertilizer

B_1: With biofertilizer (*Azotobacter* and *Azospirillum* in equal proportions)

During the crop growth period biometric observations of the plants were recorded and soil and plant samples were collected intermittently. Soil samples were analysed for available P, K, organic carbon, pH, salinity (EC_e), total N, etc. and plant samples were analysed for estimation of uptake/ concentration of different nutrients following standard methods.

RESULTS AND DISCUSSION

The pooled data of the experiments for the two years were statistically analysed and presented separately for *kharif* and *rabi* seasons.

(a) *Kharif* season

Yield of rice

The grain and straw yield of rice (Fig. 1) revealed that there was a significant increase in yield of rice when combined sources of N (organic + inorganic) were applied (T_4-T_6) compared to control (T_1) and full dose of inorganic fertilizer (T_2). These results are in aggrement with that reported by Bandyopadhyay *et al.* (2003). Application of green leaves (T_4) emerged as the best treatment with significant increase in both grain and straw yields over full N (T_2). Lowest value for both straw and grain yields were recorded in control (T_1). The grain yield under other organic treatments namely, FYM (T_5) and city compost (T_6) were at par with green leaves (T_4). The biofertilizers did not show any significant effect on grain and straw yields of rice.

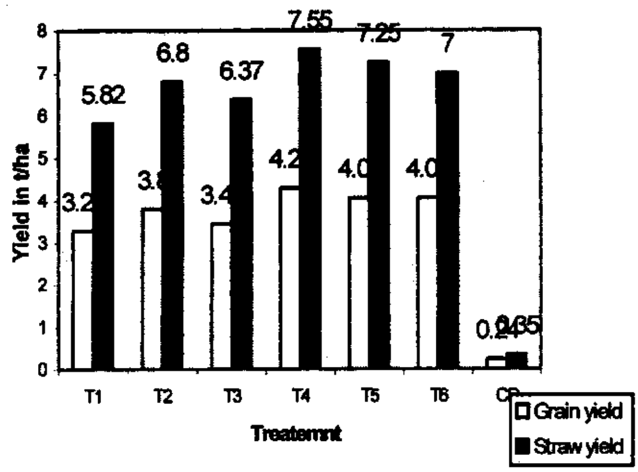

Fig. 1. *Grain and straw yield of rice at different treatments*

Soil properties

The total N content of soil was found to increase significantly (Table 1) over full dose of N (T_2) due to application of green leaves (T_4) and city compost (T_6) and highest value was obtained under green leaf (T_4). Total N content in soil with FYM (T_5) was at par with the full dose of N (T_2). However, the organic carbon content of soil at T_2 was statistically at par with all other combined sources of nutrients except for green leaves (T_4). Significant improvement in P status of soil was observed due to application of green leaves (T_4) and city compost (T_6). The improvement in P status alongwith nitrogen content in the soil due to addition of organic material was also reported by Bandyopadhyay and Bandyopadhyay (1984). Application of organic materials did not have any significant influence on the available K and salinity status of soil (data not presented). The biofertilizers applied to rice also did not show any significant effect on available nutrient content of soil.

Nutrient content in rice

In general, N content in rice plant (grain and straw) was higher when combined sources of organic and inorganic nitrogen (T_4-T_6) were applied (Table 2). Similar findings also reported by Bandyopadhyay *et al.* (2003). Nitrogen content in rice at green leaves (T_4) and city compost (T_6) was found significantly higher than in T_2. Application of combined sources of N (T_4-T_6) also caused a general increase in the P content of grain while, there was no effect on P content of straw. No significant differences in K content of plant were observed owing to application of organic materials. Biofertilizers did not show any significant effect on nutrient content in plant. (data not presented).

(b) *Rabi* season

Yield of rabi crops

The increased yield (Table 3) of *rabi* crops (chilli and lady's finger) under treatments (T_4-T_6), where organic materials were applied during *kharif*,

Table 1. *Available nutrients in soil at harvest of rice*

Treatment	Total N (%)	Av. P (kg ha^{-1})	Org. C (%)	Av. K (kgha^{-1})
T_1	0.058	19.0	0.80	522
T_2	0.072	19.5	0.82	520
T_3	0.062	20.1	0.84	520
T_4	0.079	24.5	0.89	520
T_5	0.072	23.4	0.84	520
T_6	0.077	20..5	0.87	521
Mean	0.070	21.4	0.84	522
CD(P= 0.05)	0.001	0.82	0.06	NS

Table 2. *Nutrient concentration in rice (grain and straw) at harvest*

Treatment	N concn. (%) in plant		P concn. (%) in plant		K concn. (%) in plant	
	Straw at harvest	Grain	Straw at harvest	Grain	Straw at harvest	Grain
T_1	0:32	0.79	0.14	0.24	1.01	0.24
T_2	0.47	0.86	0.14	0.27	1.06	0.27
T_3	0.38	0.83	0.14	0.26	1.14	0.26
T_4	0.57	1.08	0.20	0.31	1.01	0.31
T_5	0.53	1.06	0.18	0.29	1.06	0.29
T_6	0.54	1.02	0.17	0.31	1.07	0.31
Mean	0.47	0.93	0.16	0.28	1.05	0.28
CD(P=0.05)	0.06	0.09	0.04	NS	NS	NS

indicated that there was an appreciable residual effect of the organic matter applied in *kharif*. The residual effect of organic material applied in *kharif* was also reported by Bandyopadhyay and Bandyopadhyay (1984) for *rabi* crop grown after harvest of *kharif* rice in coastal salt affected soil. The yield of lady's finger was highest under green leaves + urea (T_4) treatment and it was significantly higher than the full dose of fertilizer (T_2) which received double dose of N (120 kg N ha^{-1}) compared to T_4 (60 kg N ha^{-1}). All the three organic + inorganic treatments (T_4-T_6) also differed significantly among themselves and T_4 emerged as best treatment. Yield of chilli reflected the same trend as that of lady's finger. Biofertilizer treatment was found to be highly significant in enhancing yield of both chilli and lady's finger although the effect of biofertilizer was not significant during *kharif* season.

Nutrient content in soil and plant

Due to the residual effect of organic material (T_4-T_6) there was a general trend of higher organic carbon content, total N and available P in soil for both lady's finger and chilli crops (Table 4). Since

Table 3. *Yield (t ha⁻¹) of chilli and lady's finger*

Treatment	Lady's finger			Chilli (green)		
	B_0	B_1	Mean	B_0	B_1	Mean
T_1	6.20	8.56	7.38	1.03	1.52	1.28
T_2	7.60	10.05	8.83	1.26	1.80	1.53
T_3	6.79	9.60	8.20	1.15	1.47	1.31
T_4	8.57	10.43	9.50	1.64	2.12	1.88
T_5	8.33	9.78	9.06	1.42	1.78	1.60
T_6	8.54	9.90	9.22	1.50	1.81	1.66
Mean	7.67	9.72	8.70	1.33	1.75	1.54
CD (P=0.05)						
B	0.061			0.055		
T	0.072			0.064		
B x T	NS			NS		

Table 4. *Soil properties at harvest of* rabi *crop (lady's finger)*

Treat	Org. C (%)			Total N (%)			Av.P (kg ha⁻¹)	Av.K (kg ha⁻¹)	ECe (dS m⁻¹)	pH
	B_0	B_1	Mean	B_0	B_1	Mean	Mean	Mean	Mean	Mean
T_1	0.76	0.79	0.78	0.058	0.061	0.60	19.7	532	4.71	6.1
T_2	0.74	0.75	0.75	0.072	0.076	0.74	19.2	535	4.79	6.2
T_3	0.78	0.77	0.78	0.061	0.065	0.63	19.3	532	4.87	6.4
T_4	0.84	0.84	0.84	0.079	0.081	0.80	23.8	529	4.99	6.2
T_5	0.81	0.82	0.82	0.072	0.076	0.74	21.5	533	4.95	6.3
T_6	0.83	0.82	0.83	0.071	0.077	0.74	19.2	532	4.94	6.1
Mean	0.80	0.80	0.80	0.069	0.073	0.72	20.3	533	4.88	6.1
CD										
(P=0.05)	NS			0.002			NS	NS	NS	NS
B	0.36			0.003			NS	NS	NS	NS
T	NS			NS			NS	NS	NS	NS
B x T										

the trend was same for both chilli and lady's finger the data for lady's finger only are presented. The residual effect of organic material towards increase in organic carbon content, and N and P status in soil was also reported by Bandyopadhyay and Bandyopadhyay (1984). The highest values were obtained under green leaves (T_4) for both the crops. The biofertilizer showed significant effect in case of total N content of soil. There was no significant change in available K content, pH, and salinity (ECe) of soil due to application of the treatments.

The results thus indicated that application of combined sources of nutrients (inorganic and organic) are highly beneficial for sustainable yield of crops on coastal salt affected soils. The biofertilizers may be more beneficial when used in *rabi* season instead of *kharif* season.

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Effect of Organic and Inorganic Nitrogen Combination on Rice Growth, Yield, Nutrient Uptake and N—Use Efficiency

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A field experiment was conducted to study the effective combination of organic and inorganic sources of N on growth, nutrient uptake and N-Use efficiency on rice in coastal saline soils with cv. MTU 2077. Application of 5 t ha^{-1} of green leaf manure and remaining N in the form of urea enhanced growth, yield, uptake and nitrogen use efficiency (NUE). Among the organic sources, easily degradable green leaf manure (glyricidia) and daincha @ 5 t ha^{-1} were found to be the best choice to improve crop productivity and NUE. Pressmud, azolla can also be thought as alternatives to the above organic sources.

***(Key words:** Integrated nutrient management, Nitrogen use efficiency)*

Integrated nutrient supply system plays a vital role in sustaining soil fertility on longterm basis. On account of continuing world energy crisis and increasing prices of chemical fertilizers the use of organic manures as renewable sources of plant nutrients is gaining importance. In this endeavour, proper blends of organic and inorganic fertilizer are of utmost importance not only for increasing yields but for soil health. Salt affected soils generally have low N status with poor N fertilizer use efficiency. The salt affected soils in coastal plains of Andhra Pradesh is about 4.5 lakh ha. In this paper efforts were made to evaluate appropriate combination of inorganic and organic sources of N and NUE of rice in salt affected regions of Krishna district of Andhra Pradesh coastal belt.

MATERIALS AND METHODS

The study was conducted at farm of ARS, Ghantasala, ANGRAU for two consecutive years, 2001 and 2002 on salt affected silty clay loam soil. The available nutrients contents were 265 kg ha^{-1} of N, 18.5 kg ha^{-1} of P and 490.9 kg ha^{-1} of K. The soil had pH 8.1, ECe 4.92 dS m^{-1}. Experimental design was split plot with four replications and eight treatments.

The treatments consisted of biofertilizers, green manures, organic and inorganic sources of fertilizers. The components of integrated nutrient management such as, green manure (dhaincha, *Sesbania aculeata*), green leafy manure (glyricidia, Glyricidia maculata), organic manures (FYM and Pressmud), biofertilizer (azolla) and inorganic fertilizers are applied with combination of various doses of nitrogen in inorganic form (urea). The treatments were:

T_1 : Control (Farmers practice) NPK (kg^{ha-1}) 60 : 40 : 30

T_2 : Full recommended dose of N P K (kg^{ha-1}) 80 : 40 : 30

T_3 : Half recommended dose of N

T_4 : Dhaincha @ 5 t ha^{-1} + N as urea

T_5 : Green leaf manure @ 5 t ha^{-1} + N as urea

T_6 : FYM @ 5 t ha^{-1} + N as urea

T_7 : Azolla @ 500 kg ha^{-1} + N as urea

T_8 : Pressmud @ 5 t ha^{-1} + N as urea

For the treatments, T_4 to T_8 balance N through urea was applied through soil test to make up for the full recommended dose of N. Nitrogen use efficiency was calculated by the formula:

RESULTS AND DISCUSSION

Growth

Integrated use of organic and inorganic sources of N improved the growth characters of rice like plant height and number of tillers at 30 DAT. Nitrogen mineralized during decomposition of green manure, FYM and pressmud resulted in increased contribution of nitrogen to crop. This nitrogen availability in rhizosphere favoured higher nutrient uptake resulting in better growth (Table 1). Enhanced crop growth due to integrated nitrogen management was also observed by Chandrasekharan (1984) and Sridevi (1988).

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Table 1. *Effect of organic and inorganic nitrogen combination on plant height (cm) and no. of tillers per hill of paddy (30 DAT)*

Treatments	Plant height (cm)			No. of tillers per hill		
	2001	2002	Pooled	2001	2002	Pooled
T_1	50.5	53.5	52.0	14.3	14.1	14.2
T_2	51.4	50.3	50.8	16.0	15.5	15.8
T_3	43.8	46.0	44.9	12.3	11.3	11.8
T_4	45.1	54.0	49.6	12.6	14.0	13.3
T_5	49.8	50.4	50.1	14.4	14.3	14.3
T_6	48.8	50.0	49.4	13.3	13.3	13.3
T_7	47.5	48.6	48.1	12.5	13.4	12.9
T_8	46.5	47.0	17.1	12.8	12.5	12.6
SEm(±)	2.3	2.2	1.6	1.1	0.6	0.6
CD at P=0.05	4.6	4.4	3.1	2.2	1.2	1.2

Yield attributes

Significant influence on yield parameters was observed due to addition of both organic and inorganic sources of nitrogen. Pooled application of green leaf manure (glyricidia) @ 5 t ha^{-1} with remaining N through inorganic fertilizers produced the highest number of productive tillers (Table 2) and higher test weight. The supremacy of yield components due to the application of organic manures might be due to the release of major nutrients during decomposition. Dhaincha @ 5 t ha^{-1} is the next best treatment followed by FYM @ 5 t ha^{-1} and pressmud @ 5 t ha^{-1}. Application of biofertilizers resulted in high yield attributes compared to the treatments receiving only inorganic nitrogen.

Grain and straw yields

Application of glyricidia @ 5 t ha^{-1} alongwith inorganic N recorded higher grain and straw yields (4829, 6128 kg ha^{-1}, respectively), which was at par with that obtained under dhaincha @ 5 t ha^{-1} and FYM @ 5 t ha^{-1} alongwith inorganic N (Table 2). Regarding inorganics, application of recommended N through inorganic fertilizers recorded significantly higher grain yield than half recommended N application. Aapplication of glyricidia as green leaf manure not only increased N, P and K availability in soil but also markedly increased the yield of transplanted rice possibly because of faster decomposition in soil than any other organic sources.

The superiority of organic manures applied alognwith inorganic fertilizer over sole application of inorganic fertilizer for increased productivity of rice has also been reported by Bhattacharya *et al.* (1992), Singh *et al.* (1991) and Bal *et al.* (1992).

Nutrient uptake

Application of glyricida @ 5 t ha^{-1} with inorganic favours the highest nutrient uptake followed by dhaincha (5t ha^{-1}) application. The lowest nutrient uptake was observed in the treatment, which received half of the recommended N through inorganic sources (Table 3). This trend was followed for both grain and straw uptake. The highest nutrient uptake might be due to the fact that glyricidia leaves contain upto 2.7% nitrogen and have a narrow C : N ratio of about 13. Besides having low lignin (Kang and Mulongoy, 1989) and polyphenolic content (Palm and Sanchez, 1991), it decomposes rapidly in the soil and mineralized nitrogen tends to become available within 10-15 days after incorporation. Applications of organic manures not only improve the physical properties but also enhances the response per unit of nutrient added (Pillai and Subbaiah, 1990).

Nitrogen use efficiency

The highest NUE was recorded with 5 t ha^{-1} of glyricidia application alongwith inorganic N and the lowest was with the farmer's practices in which entire N was supplied through inorganic (Table 2). Among the organics tested, glyricidia was found to increase the apparent N recovery appreciably.

Table 2. *Yield components, yield & NUE of paddy as affected by different N management practices*

Treatment	Productive tillers per hill			Test weight (g)			Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})			NUE
	2001	2002	Pooled	2001	2002	Pooled	2001	2002	Pooled	2001	2002	Pooled	
T_1	8.5	8.6	8.6	20.3	20.1	20.2	3763	4160	3962	5563	5106	5334	5.3
T_2	9.0	10.1	9.6	20.7	20.6	20.6	3923	4803	4363	5803	5288	5545	10.3
T_3	8.1	8.4	8.3	18.8	19.0	18.9	3248	3827	3538	5133	4783	4958	-
T_4	9.3	11.6	10.4	20.6	20.8	20.6	3911	4991	4451	5788	5442	5615	21.4
T_5	11.6	12.3	11.9	21.4	21.5	21.5	4357	5301	4829	6559	5697	6128	27.1
T_6	10.0	11.4	10.7	21.0	20.6	20.8	3978	4918	4447	6128	5387	5758	17.5
T_7	10.3	10.5	10.4	20.0	20.2	20.0	3770	4690	4230	5586	5126	5356	12.6
T_8	9.1	11.0	10.1	20.6	20.7	20.6	3818	4718	4268	5702	5201	5452	15.9
SEm(±)	0.8	0.7	0.5	0.5	0.6	0.4	190	154	129	197	156	135	-
CD at P=0.05	1.5	1.3	1.0	1.0	1.2	0.7	383	312	253	399	314	264	-

Table 3. *N, P and K uptake by straw and grain of paddy*

Treat ments	N Uptake (kg ha^{-1})						P Upake (kg ha^{-1})						K Uptake (kg ha^{-1})					
	Straw			Grain			Straw			Grain			Straw			Grain		
	2001	2002	Pooled	2001	2002	Pooled	2001	2002	Pooled	2001	2002	Pooled	2001	2002	Pooled	2001	2002	Pooled
T_1	25.8	29.3	27.6	39.5	40.7	40.1	4.1	3.8	3.9	7.4	6.8	7.1	52.3	54.3	53.3	9.1	7.7	7.4
T_2	30.5	34.0	32.2	44.3	52.5	48.4	4.2	4.0	4.1	8.1	9.6	8.8	61.9	58.5	60.2	8.0	9.7	8.8
T_3	23.0	28.1	25.5	30.5	37.6	34.0	3.1	3.1	3.1	5.6	6.4	6.0	44.3	47.7	46.0	5.4	6.9	6.1
T_4	25.8	35.5	30.7	45.0	61.8	53.4	4.4	4.1	4.2	8.5	11.6	10.0	59.7	63.1	61.4	7.6	11.0	9.3
T_5	41.0	38.6	39.8	56.3	67.1	61.7	5.9	5.3	5.6	9.7	12.6	11.2	85.7	71.8	78.8	11.1	12.4	11.8
T_6	33.1	35.0	34.1	50.0	56.4	53.2	4.3	3.9	4.1	8.7	11.0	9.8	72.7	59.0	65.9	9.9	10.3	10.1
T_7	26.2	32.9	29.6	41.1	48.7	44.9	3.7	3.8	3.8	6.7	8.8	7.7	55.7	50.8	53.3	7.6	8.8	8.2
T_8	28.7	33.6	31.3	42.5	48.9	45.7	4.2	4.0	4.0	6.4	9.4	7.9	60.9	57.3	59.1	8.1	9.1	8.6
SEm(±)	1.4	1.7	1.1	1.6	5.0	2.6	0.4	0.3	0.3	0.8	0.8	0.6	6.8	5.5	4.4	0.5	0.9	0.5
CD at P=0.05	2.9	3.5	2.2	3.2	9.9	5.1	0.9	0.6	0.5	1.6	1.7	1.2	13.7	10.1	8.6	0.9	1.9	1.1

Application of N fertilizers in combination with organic sources reduces losses with slow release of nutrients throughout the crop period, which also might help to enhance the uptake of N resulting finally in increased nitrogen use efficiency.

From this study, it can be concluded that application of green leaf manure along with inorganic N supply resulted in significant increase in growth, yield attributes, nutrient uptake, yield and nitrogen use efficiency. The combined application of organic and inorganic N is superior over N application through inorganic source alone.

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Response of Rice to *Ipomoea carnea* as Green Leaf Manure

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A series of experiments were conducted in coastal Orissa on integrated nutrient management by using the green leaf manure (*Ipomoea carnea*) and inorganic fertilizer (urea) and their combination to study the effect on rice production. *Ipomoea carnea* is most problematic weed with high regenerative capacity and is very difficult to eradicate this weedy plant. However, its leaves and twigs are used as green manure. The nitrogen content of *Ipomoea carnea* is about 0.25 - 3.0 % of fresh weight (1-1.25 % dry weight basis). *Ipomoea carnea* contains polysachharide (Ipomose), an anthracene glucoside, gums, alkaloids (jalpains and saponins) and growth hormones. Alkaloids act as slow N releasing materials and preserved native, applied, and biologically fixed N. The growth harmone are necessary auxins for the growth of rice plants. The rice production was 41.2 q ha^{-1} and 48.6 q/ha with 80 Kg N ha^{-1} through *Ipomoea carnea* alone and 40 Kg N ha^{-1} through *Ipomoea carnea* + 40 Kg N ha^{-1} through urea, respectively in comparision to the rice production as per farmers' conventional practice (31.3 q ha^{-1}).

(***Key words*** : *Ipomoea carnea, Rice production, Organic manure, Inorganic fertilizer, Nitrogen*)

Ipomoea carnea, commonly known as *sadabahar* or bush morning glory is available in abundance in all types of soil, climate and season, non-palatable to cattle and thornless which is very easy to collect and apply in the field. It is a semi-woody plant of varied habitats and rated as most problematic weed like water hyacinth. The plant is propagated by cuttings. It produces dense foliage and flowers practically throughout the year except during cold months. It is drought resistant and can be raised both under rainfed and irrigated conditions. The plant is with high regenerative capacity and is very difficult to be eradicated. *Ipomoea carnea* leaves and twigs are used as green manure.

Organic manures are considered as cheap source of plant nutrient and soil improvement. Complete dependence on chemical fertilizers is making the soil unfertile and less productive in absence of organic material into the soils (Khan *et al.*, 2003). Among the different organic manures, green manuring including green leaf manuring is the most important. Green leaf manuring refers to turning into the soil green leaves and tender twigs collected from shrubs and trees grown on farm *bunds*, wastelands and nearly forest areas. Leaf portion of green manure is rich in nitrogen, and when incorporated into the rice soil with an abundance of water, decomposes in about 4 -5 days and behaves like a quick acting inorganic fertilizers in supplying available nitrogen immediately after application. The stem and other woody portion which is hard to decompose (because of wider C : N ratio), however, take time and respond as other slow-acting bulky organic manures like compost and farmyard manure, and make nitrogen available at later stages. Increase in grain yield of rice with green leaf manuring had also been reported by Chatterjee *et al.* (1979). The nitrogen content of *Ipomoea carnea* is about 0.25 to 0.30 percent of fresh weight but 1 to 1.25 percent N on dry weight basis (Khan *et al.*, 2003).

Green manure use in rice-based cropping systems and its beneficial effects on soil conditions and rice yields have been reported by many workers (Vachhani and Murty, 1964, Chaudhary *et al.*, 1994, Khan *et al.*, 2000). Green manuring stimulates the activities of soil microorganisms. It concentrates plant nutrients in the surface layer of the soil. It increases the availability of certain plant nutrients like P_2O_5, Ca, K, Mg and Fe. It increases the water holding capacity and bulk density of the soil.

The paper presents results on application of different combinations of *I. Carnea* with urea on the growth and yield of rice.

MATERIAL AND METHODS

An experiment was conducted to utilize the indigenous source of organic (*Ipomoea carnea*) as green/organic manure as an alternative or/and supplement to chemical fertilizers. Fresh leaves of *Ipomoea carnea* were incorporated into the submerged soil during the monsoon season, before

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transplanting rice, in 5m x 4m size pulp. Transplanting of rice seedlings was done 3-5 days after incorporation. In one treatment 80 kg N ha^{-1} directly from the leaves of *Ipomoea carnea* and in another treatment 40 kg N ha^{-1} was supplied from the leaves of *Ipomoea carnea* alone and rest 40 kg N ha^{-1} was supplemented from urea as top dressing during tillering stage. In the fourth treatment urea alone was applied @ 80 kg N ha^{-1} in the following combination viz., 40:20:20 at basal, tillering and P.I. stage, respectively. These treatments were compared with the farmers' traditional method of cultivation without nitrogenous fertilizers/manures. The long duration (155-160 days) semidwarf rice variety CR-1018 (Gayatri) was transplanted. Pre-sowing and postharvest soil samples were collected to estimate the available N ha^{-1}. The treatments are as follows:

T_1 Control

T_2 80 kg N ha^{-1} through *Ipomoea carnea*

T_3 80 kg N ha^{-1} through urea (40:20:20 - basal, tillering & P.I. stages, respectively)

T_4 40 kg N ha^{-1} through *Ipomoea* + 40 kg N ha^{-1} through Urea

RESULTS AND DISCUSSION

Results (Table 1) revealed that application of organic manure (*Ipomoea carnea*) alone or in combination with urea gave significantly higher yield in comparison to the farmers' conventional practice. The new technology was more labour and energy efficient, improved rice crop stand, and gave significantly higher rice yield than the traditional crop establishment system of farmer. The rice yield under the farmers' traditional system was 31.3 q ha^{-1}, whereas yield was 41.2 q ha^{-1} (T_2) and 38.3 q ha^{-1} (T_4) in *Ipomoea carnea* incorpated plots. Green manure N, being a one-time application, may not adequately synchronize with or be sufficient to meet nitrogen demand, particularly on poor soils. Thus, organic N may have to be supplemented with inorganic N to match the need of the crop. The farmers may use *Ipomoea carnea* as a source of organic manure because it allows them to produce subsistence yield at low input levels.

Composite mixture of green leaves, succulent tops and bark of *Ipomoea carnea* were analysed for N content which was 0.25 to 0.30 percent on fresh weight basis but 1 to 1.25 percent N on dry weight basis (i.e., the dry matter content ranged from 24 to 25 percent). Apart from N and organic matter,

Table 1. *Grain and straw yield of rice as influenced by* Ipomoea carnea

Treatments	Grain yield, (q/ha)	Straw yield, (q/ha)
Control	31.3	41.2
80 kg N/ha through *Ipomoea carnea*	41.2	80.6
40 kg N/ha through *Ipomoea carnea* + 40 kg N/ha through Urea	48.6	94.2
40 kg N/ha Urea (basal) + 40 kg N/ha through Urea (top dressing at tillering)	38.2	75.1
C. D. at P = 0.05	19.4	NS

latex of *Ipomoea carnea* contains a number of chemical compounds like polysachharide (*Ipomose)* an anthracene glucoside, gums, alkaloids (jalpains and saponins) and growth hormones. Alkaloids might have acted as slow N releasing materials and preserved the native, applied and biologically fixed N. The growth hormones supplied necessary auxins for the growth of rice plants (Jha *et al.*, 1980). The presence of growth hormones probably enabled the plant to putforth new growth within short period. The green leaves and tops were succulent and easily decomposed in the puddled soil but the bark took longer time. The total quantity of N supplied through incorporation of *Ipomoea carnea* was although much lower than the same supplied through urea, yet the former was superior in terms of economic grain and straw yields and N uptake.

Application of succulent green leaves, tops and bark in the soil and their successive decomposition enabled the rice plant to ensure an almost continuous supply of N distributed over the entire crop growth period. Application of green leaf of *Ipomoea carnea* released more quantity of N in the submerged soil (Chatterjee *et al.*, 1979). Soil amendment with fresh vegetative parts of *Ipomoea carnea* significantly increased the biological fixation of atmospheric nitrogen (Jha *et al.*, 1980). Compounds released during the decomposition process of organic matter supplied organic acids, etc. that increased the solubility and availability of many essential nutrients (Gupta and Idnani, 1970). Alternate wetting and drying conditions prevailing in the field might have resulted in loss of nitrogen through oxidation of ammonical ion, leaching loss of nitrates, and finally through denitrification processes necessitating fractional application of nitrogen when urea was the only source. Conversely, where organic source like *Ipomoea carnea* was available, these risks and thereby chances of leaching loss were minimized.

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Integrated Effect of UB - DAP Placement and Glyricidia Green Manuring on Grain Yield of Sahydri Hybrid Rice in Partially Reclaimed Coastal Saline Soils

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Rice is the predominant crop in coastal saline soils of Maharashtra. Several reports indicated that practices of deep placement of urea briquettes containing diammonium phosphate (UB – DAP) in transplanted rice is agronomically more efficient than conventional application of prilled urea (PU) and phosphate fertilizer. The improved management practices consist of single band placement of properly sized UB-DAP with N: P ratio 4:1 (one briquette for every four hills) at 7-10 cm soil depth on the day or a day after transplanting using modified 20 x 20 cm spacing with plant population of 25 hills/m². The field study was undertaken to study integrated effect of UB-DAP placement and Glyricidia green manuring on yield of Sahyadri hybrid in patially reclaimed coastal saline soils of Khar Land Research Station, Panvel. The field study was conducted with same set of treatments during *kharif* 2001 and 2002. The test soil was partially reclaimed coastal saline soil having pH 6.91, EC 2.91 dSm^{-1}, SAR 18, organic carbon 1.30%. The available N, P, K were 205, 35 and 3032 kg ha^{-1}, respectively. The result indicated that use of UB-DAP with 5 ton ha^{-1} Glyricidia has increased Sahyadri hybrid rice grain yield by 20-97% over fertilizers with 44% saving in RDF and with 25 percent fewer hills per m² in coastal saline soil.

*(**Keywords:** Integrated nutrient management, Hybrid rice)*

Rice is predominant crop in coastal saline soils of Maharashtra. Three improved salt tolerant rice varieties namely Panvel-1, Panvel-2 and Panvel-3 are covering major area in Khar Land. Inspite of these varieties, growing of hybrid rice in partially reclaimed coastal saline soils is being practised by the farmers of coastal saline soils. For increasing the efficiency of fertilizer and potential yield of hybrid rice it is necessary to study the different levels fertilizers on hybrid rice namely Sahyadri under coastal saline soil conditions.

Several reports indicated that the practice of deep placement of urea briquettes containing diammonium phosphate (UB - DAP) in transplanted rice is agronomically more efficient than conventional application of prilled urea (PU) and phosphate fertilizer (Sawant and Stangel, 1995) . Recent advances in the production and use of UB - DAP as a source of N and P fertilizer for transplanted rice have made the use of this fertilizer more efficient, economically more attractive and less risky than the conventional placement of UB by hand (Sawant and Stangel, 1995).

Integrated use of green manure and inorganic source of nutrient is however increasingly considered as the best option for sustainable soil fertility management in coastal saline soils. Since, the information on effect of UB-DAP placement in transplanted area of partially reclaimed coastal saline soil was lacking, the field study was undertaken to study integrated effect of UB-DAP placement and glyricidia green manuring on yield of Sahyadri hybrid in partially reclaimed coastal saline soils of Khar Land Research Station, Panvel.

MATERIALS AND METHODS

The field study was conducted with same set of treatments consecutively for two seasons during *kharif* 2001 and 2002. The experiment was liad out in randomized block design with three replications. The test soil was partially reclaimed coastal saline soils having pH 6.91, EC 2.91 dSm^{-1}, SAR 18, organic carbon 1.30%. The available N,P,K were 205, 35 and 3032 kg ha^{-1}, respectively. Twenty-five day-old seedlings of Sahyadri rice hybrid was transplanted on 28.7.2001 during *kharif* season of 2001 and 2002. One UB-DAP briquette weighing 2.7 g with N:P ratio 4:1 was placed at 7-10 cm soil depth on the day of transplanting as per the treatments. The glyricidia green manuring was done before transplanting @ 5 t ha^{-1} m^{-2} and other treatments were given as per the Table 1. Transplanting of rice was done at modified 20 x 20 cm spacing (25 hills m^{-2}).

Table 1. *Mean grain yield of Sahydri hybrid rice as influenced by different treatments in coastal saline soils*

Sr. No.	Treatment details	Plant population (m^2)	Mean Grain yield (q ha^{-1})		
			2001	2002	Pooled
1.	Conventional PU application (N100 kg ha^{-1}) with conventional spacing	33	50.22	60.38	55.43
2.	Conventional PU fertilizer application (N125 kg ha^{-1}) with conventional spacing	33	52.33	52.39	52.38
3.	Conventional PU application (N 150 kg ha^{-1}) with conventional spacing	33	53.12	57.10	55.11
4.	Glyricidia @ 10 t ha^{-1} with conventional spacing.	33	64.47	69.51	66.99
5.	UB - DAP application (N56 : P14) with modified spacing	25	70.53	73.35	71.94
6.	UB - DAP application (N56 : P 14) + 5 ton ha^{-1} glyricidia with modified spacing.	25	74.01	73.85	73.93
7.	UB -DAP application (N56 : P14) + 10 ton ha^{-1} FYM with modified spacing	25	72.13	74.89	7351
	SE $\pm$		1.33	1.27	1.12
	CD at P = 0.05		3.98	3.82	3.44

RESULTS AND DISCUSSION

The mean rice grain yield data (Table 1) indicated that integration of UB - DAP with modified spacing, use of 5 ton ha^{-1} alongwith glyricidia as a green manuring crop produced brought highest grain yield during both the seasons. Similar tread was also observed in pooled analysis. The increase was to the tune of 20-97 % over of fertilizers with 44% saving in RDF and with 25 percent fewer hills m^{-2} Similar superior agronomic performance of UB DAP alongwith glyricidia has been reported earlier by Dhane *et al.* (2002).

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Nitrogen Management under Coastal Salt Affected Conditions for Bajra-Wheat Cropping sequence

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A field experiment was conducted (1992-1996) to study the effect of levels of N and methods of its application in factorial RBD at Agricultural Research Station (Fruit), GAU, Mahuva, growing bajra in *kharif* and wheat in *rabi*. The results revealed that the interaction between levels and methods of N application had significant effect on grain and fodder yield of bajra during 1995 and fodder yield during 1993 and 1996. Similarly, interaction between levels and methods of N application was found significant on grain and straw yield of wheat during 1993-94 and on grain yield in pooled results. Significantly higher grain yield of wheat was recorded with recommended dose of N having three equal splits and securing the highest cost benefit ratio of R. 1: 54.43.

(***Key words:*** *N management, Salt affected soil, Bajra-wheat sequence, Saline water).*

Salt affected soils are poor in available nitrogen and nitrogenous fertilizers are required 20-25 percent higher. No work on nutrient management aspects especially on N has been done. Therefore, the present investigation was conducted.

MATERIALS AND METHODS

A field experiment was conducted (1992-96) on coastal saline soil at Agricultural Research Station (Fruit), G.A.U., Mahuva growing bajra (GHB-15) in *kharif* and wheat (LOK-1) in *rabi* irrigating with saline water (Table 1). The experimental soil was alluvial (Ustifluvent) having silty loam texture, $EC_{2.5}$ 0.6 dSm^{-1}, $pH_{2.5}$ 8.7, ESP 17.9, $CaCO_3$ 36 g kg^{-1}, was low in available N (235 kg ha^{-1}), high in available P_2O_5 (60 kg ha^{-1}) and K_2O 596 kg ha^{-1}, which were estimated by adopting standard methods (Richards, 1954). The experiment was laid out in factorial RBD having three levels of N (D_1: Recommended dose (RD) of N, D_2: 25 % higher RD and D_3: 50 % higher RD) and two methods of application (M_1: ½ basal + ½ at tillering stage and M_2: 1/9 basal + 1/3 at tillering stage + 1/9 at ear head formation). The RD of bajra and wheat were 80:40:00 and 120:60:00 kg as N: P_2O_5: K_2O ha^{-1}, respectively and were common for all the treatments in the form of urea and DAP.

RESULTS AND DISCUSSION

Effect on crop yield : The results revealed that the interaction between levels and methods of N application significantly affected the grain and fodder yield during two out of five years of studies (Table 2). Similarly, the interaction between levels and methods of N application had significant effect on grain yield of wheat during 1993-94 and in pooled results (Table 3). For the sake of brevity the data on individual effect of different levels of N and methods of its application on grain and fodder yields of bajra and wheat during different years are not presented here. Significantly higher grain yield of wheat was recorded with RD of N with three equal splits (D_1M_2), followed by 150 % of RD with three splits of N application (D_3M_2). Both of these treatment combinations were found at par with each other and were superior to rest of the treatments.

Economics : Maximum additional return (Rs. 6531 ha^{-1}) was obtained with recommended N levels applied in three equal splits at basal, at tillering, and at ear head formation (D_1M_2). This treatment combination secured the highest CBR of Rs. 1:54.43 (Table 4).

Table 1. *Quality of irrigation water during the experimental period of wheat*

Properties	1992-93	1993-94	1994-95	1995-96	1996-97
EC (dSm^{-1})	7.8	6.7	7.6	9.4	11.0
pH	8.6	7.6	7.6	7.8	7.9
SAR	25.6	23.7	13.7	12.7	13.6
RSC	Nil	2.4	Nil	Nil.	Nil

***Table 2.** Interaction effect of levels of nitrogen and methods of its application on grain and fodder yield of bajra*

Treatments	Grain yield (kg/ha)						Fodder yield (kg/ha)					
	1992	1993	1994	1995	1996	Pooled	1992	1993	1994	1995	1996	Pooled
D_1M_1	959	4156	3875	1566	511	2213	2713	12188	7038	4531	4078	6110
D_1M_2	953	4266	3463	2034	1073	2358	2986	15000	6155	5234	5547	6984
D_2M_1	919	4578	3594	1441	931	2293	2647	14531	6947	4723	5219	6813
D_2M_2	797	4197	3609	1534	595	2147	2373	13125	6733	4453	3875	6112
D_3M_1	938	4500	3547	1281	819	2217	2753	13594	6916	4258	5281	6560
D_3M_2	1172	4219	3438	2016	766	2322	2876	13906	6855	5004	4813	6691
SEm±	82	180	185	63	63	92	188	586	337	159	215	319
CD p = 0.05	NS	NS	NS	191	188	NS	NS	1766	NS	480	650	NS

***Table 3.** Interaction effect of levels of nitrogen and methods of its application on grain and straw yield of wheat*

Treatments	Grain yield (kg/ha)				Straw yield (kg/ha)			
	1992-93	1993-94	1994-95	Pooled	1992-93	1993-94	1994-95	Pooled
D_1M_1	1806	1594	1453	1618	4781	3778	3078	3879
D_1M_2	1890	3328	1797	2339	5172	5194	3506	4624
D_2M_1	1969	2319	1703	1997	5406	4363	2844	4204
D_2M_2	1672	2525	1853	2017	4313	4147	3200	3886
D_3M_1	1906	2381	1619	1969	4906	4316	3209	4144
D_3M_2	1617	3019	1766	2134	4422	4997	3253	4224
SEm±	193	148	148	95	532	248	247	212
CD p = 0.05	NS	445	NS	270	NS	749	NS	NS

***Table 4.** Economics of the different treatments in Bajra -wheat cropping system*

Treatments	Additional bajra yield over control kg/ha		Additional wheat yield over control kg/ha		Total additional income over control Rs/ha/year	Additional expenditure over control Rs/ha/year	Additional net return over control Rs/ha/year	Net C.B.R.
	Grain	Fodder	Grain	Straw				
D_1M_1	-	-	-	-	-	-	-	-
D_1M_2	145	874	721	745	6651	120	6531	1:54.43
D_2M_1	80	703	379	325	3619	385	3234	1:8.4
D_2M_2	66	2	399	7	2387	505	1882	1:3.73
D_3M_1	4	405	351	265	2800	770	2030	1:2.64
D_3M_2	209	581	516	345	4705	890	3815	1:4.29

Prices of materials considered: Bajra grain: Rs. 6.25/kg, Bajra fodder: Rs. 0.50/kg, Nitrogen from urea: Rs. 7.70/kg, Wheat grain: Rs. 7.0/kg, Wheat straw: Rs. 0.35/kg.

From the above results it can be concluded that N fertilizers should be applied at RD but in three equal splits i.e., 1/3 at basal, 1/3 at tillering, and 1/3 at ear head formation stage for obtaining maximum net profit in bajra-wheat cropping sequence.

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Biofertilizers and Organics on Soil Micronutrient Status and Yield of Black Pepper

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An experiment involving organics (FYM, neem cake and wood ash) and biofertilizers (*Azospirillum*, P solubilizers and arbuscular mycorrhizal fungi) in combination with inorganics were conducted in black pepper (*Piper nigrum* L.) during 2000-2001 to know their effect on micronutrient availability in soil and yield. Treatments involving biofertilizers and biofertilizers + organics registered significant improvement in the status of available micronutrients in soil. However, the data on yield showed no marked variation among treatments, indicating the need for continuous application of organic sources for achieving significant improvement in yield.

(***Key words:*** *Biofertilizers, Organics, Micronutrient*)

Black pepper known as the 'King of Spices' is the most important item of spices exported from India. Owing to the growing health consciousness, especially in the developed countries, the importing countries are now insisting on organically produced spices across the world. In the international market, they are sold at impressive premia and production of organic pepper is a way to compete in the export market. The crop responds well to organics in heavy doses as well as to biofertilizers. However no detailed investigations were carried out in this crop integrating the use of organics, inorganics and biofertilizers. The present study aims to investigate the influence of nutrient management on soil micronutrients and yield of pepper.

MATERIALS AND METHODS

The study was conducted at the College of Horticulture, Vellanikkara on eight year-old pepper vines during 2000-2001. The test varieties were Panniyur 1(P_1) and Panniyur 2(P_2). It was laid out in randomized block design with nine replications. There were 13 treatments as listed below :

T_1 - 50% N as farm yard manure (FYM)+ *Azospirillum*+ P solubilizers + Arbuscular mycorrhizal fungi (AMF) + 100% K as inorganic

T_2 - 50% N as FYM+ *Azospirillum* + P solubilizers + AMF + 100% K as wood ash

T_3 - 50% N as FYM + 50% N as neem cake + 100% P and K as inorganic

T_4 - 50% N as FYM + *Azospirillum*+ 100% P and K as inorganic

T_5 - 50%N as FYM + *Azospirillum* + 50% P as inorganic + P solubilizers+100% K as inorganic

T_6 - 50%N as FYM + 50 % N and 100% P and K as inorganic

T_7 - 50%N as FYM + 50 % N as inorganic+ P solubilizers + AMF + 100% K as inorganic

T_8 - 50%N as FYM + 50% N and P and 100 % K as inorganic

T_9 - 50%N as FYM +50% N and P as inorganic + *Azospirillum* + P solubilizers + AMF + 100% K as inorganic

T_{10} - 50%N as FYM + 50% N and P as inorganic + *Azospirillum* + 100% K as inorganic

T_{11} - 50%N as FYM + 50% N and P as inorganic + P solubilizers + AMF + 100% K as inorganic

T_{12} - Recommended package of practices of KAU (50:50:150 g/vine/year of N, P_2O_5 and K_2O,

T_{13} - Control (No fertilizers)

Commercial cultures of *Azospirillum*, P solubilizers and AMF were applied at the rate of 25 g per vine towards the onset of monsoon. Quantities of FYM, neem cake and wood ash were fixed based on the nutrient status of these organics for getting the required 50 % N and 100 % K. The required amount of chemical fertilizers was provided as urea, mussoriephos and muriate of potash. The chemical fertilizers were applied two weeks after the application of biofertilizers and organics.

Fresh yield of the berries were recorded immediately after harvest. It was multiplied with drying percentage to get the dry berry yield per vine. Soil samples were collected prior to the flushing of vines (May). For the estimation of micronutrients i.e., Fe, Mn, Cu and Zn, DTPA extraction method using Atomic Absorption Spectrophotometer was utilized (Lindsay and Norwell,1978).

RESULTS AND DISCUSSION

The availability of soil micronutrients varied with treatments (Tables 1 and 2). Maximum iron content of 42.4 ppm and 41.2 ppm was obtained in T_4 (*Azospirillum*+inorganics+ FYM) and T_2 (all the three biofertilizers +FYM and wood ash i.e., complete organic), respectively in the variety Panniyur 1. In P_2 also T_4 showed highest value.

Table 1. *Organics and biofertilizers on iron and manganese content of soil*

Treatments	Iron (ppm)		Manganese (ppm)	
	Panniyur 1	Panniyur 2	Panniyur 1	Panniyur 2
T_1	39.2^{ab}	34.3	30.5^{a}	29.3^{abc}
T_2	41.2^{a}	36.7	31.0^{a}	32.7^{a}
T_3	36.8^{ab}	39.8	24.8^{bc}	22.5^{e}
T_4	42.4^{a}	41.4	20.0^{d}	20.9^{e}
T_5	39.1^{ab}	32.6	31.4^{a}	27.4^{bcd}
T_6	34.4^{ab}	34.5	21.1^{cd}	21.9^{e}
T_7	35.4^{ab}	28.1	24.4^{bc}	31.7^{a}
T_8	35.7^{ab}	35.6	28.1^{ab}	21.6^{c}
T_9	34.9^{ab}	35.6	28.1^{ab}	29.1^{abc}
T_{10}	35.7^{ab}	28.6	27.5^{ab}	31.1^{ab}
T_{11}	38.9^{ab}	29.4	28.3^{ab}	27.3^{bcd}
T_{12}	38.6^{ab}	35.8	27.6^{ab}	23.7^{de}
T_{13}	31.3^{bc}	28.5	21.9^{cd}	25.0^{cde}
Mean	36.4	33.5	26.2	25.4
CD p = 0.05	8.48	NS	4.01	4.25

Values having same notations in the suffix are not statistically different, NS = Not significant

Table 2. *Organics and biofertilizers on zinc and copper content of soil*

Treatments	Zinc (ppm)		Copper (ppm)	
	Panniyur 1	Panniyur 2	Panniyur 1	Panniyur 2
T_1	1.75^{abc}	1.68^{bc}	20.5	20.5
T_2	1.86^{a}	1.75^{ab}	18.1	18.9
T_3	1.35^{d}	1.59^{bcd}	23.4	23.2
T_4	1.20^{d}	1.40^{de}	18.7	16.7
T_5	1.48^{abcd}	1.44^{cde}	18.5	17.8
T_6	1.15^{d}	1.35^{de}	18.6	21.8
T_7	1.34^{d}	1.55^{bcde}	20.8	21.5
T_8	1.42^{cd}	1.32^{e}	24.0	17.3
T_9	1.82^{ab}	1.59^{bcd}	27.0	27.6
T_{10}	1.10^{d}	1.56^{bcde}	16.1	21.0
T_{11}	1.78^{abc}	1.55^{bcde}	18.3	17.9
T_{12}	1.49^{abcd}	1.80^{a}	25.4	21.4
T_{13}	1.45^{bcd}	1.46^{cde}	22.3	18.2
Mean	1.48	1.56	20.9	20.2
CD(0.05)	0.392	0.249	NS	NS

Values having same notations in the suffix are not statistically different, NS = Not significant

The complete organic treatment, T_2 and organic +inorganic + biofertilizer combination (T_1 and T_5) were superior in Mn content in the variety P_1. In variety P_2 also T_2 (32.7 ppm) followed by T_7 (FYM+AMF + P solubilizers +N and K as inorganic) showed higher content of Mn.

Regarding Zn availability, varieties P_1 and P_2 exhibited significant treatment effects. Treatment T_2 (1.86 ppm) followed by treatment T_9 (all the applied biofertilizers, FYM and NPK as inorganics) registered maximum available soil Zn in P_1. In P_2, T_{12} (recommended package of practices) followed by T_2 recorded 1.80 ppm and 1.75 ppm, respectively, the higher value. The copper availability was not statistically significant in both the varieties. However, T_9 was superior (27.0 and 27.6 ppm in P_1 and P_2, respectively) with respect to this nutrient.

In general, T_2 (complete organic) and the treatments involving biofertilizers exhibited higher amount of available micronutrients in soil, which reveals that biofertilizers helped in increasing their content. It is quite natural that when we apply organic manure, micronutrient content of the soil will improve since organic manures are good sources of micronutrients. Microorganisms also help in improving the soil availability by enhancing the microbial action in the soil. Results obtained by Kumari and Balasubramanian (1993) in coffee support the results. The combined inoculation of *Azospirillum* and AMF led to significantly increased uptake of N and P as well as micronutrients such as Fe, Mn, Cu and Zn.

Yield variation was not significant statistically during the first year of harvest. However, T_5 (*Azospirillum*, P solubilizers + 50% N as FYM+100 % K as inorganic) in Panniyur 1 (1.355kg per vine) and T_9 (FYM, all the three biofertilizers and inorganics) in Panniyur 2 (2.077kg per vine) recorded higher yields (Table 3).

Treatment T_8 (FYM+ inorganics) recorded lower yield in both the varieties, the values being 0.757 and 0.751(kg per vine) in P_1 and P_2, respectively. Results on integrated nutrient management studies in pepper by Kanthaswamy *et al.* (1996) gave similar results. According to them, application of *Azospirillum* and chemical fertilizers as N, P and K in addition to FYM resulted in the highest dry berry yield. Biofertilizer studies conducted in clove and nutmeg for four years indicated that inorganic+organic+biofertilizer combination is effective in increasing the yield in both the tree spices (AICRPS, 2000).

Table 3. *Organics and biofertilizers on yield of dry berry (kg/vine/annum) of black pepper*

Treatments	Panniyur 1	Panniyur 2
T_1	0.8193	1.336
T_2	1.257	1.169
T_3	0.836	1.510
T_4	1.032	1.579
T_5	1.001	2.077
T_6	1.323	1.034
T_7	1.054	1.136
T_8	0.757	0.751
T_9	1.355	1.427
T_{10}	1.127	0.956
T_{11}	0.934	1.152
T_{12}	1.216	1.470
T_{13}	1.088	1.097
Mean	1.072	1.284
CD p = 0.05	NS	NS

NS = Non-significant

CONCLUSION

The micronutrient availability of the soil has improved with the application of organics and biofertilizers. However, no significant yield improvement was obtained with organic and biofertilizers in the first year of study. At the same time the sudden shift to complete organic and organic + inorganic did not also reduce the yield. The results indicated that yield improvement in pepper can be expected only after continuous application of organic and biofertilizers.

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Gypsum and FYM Application for Bajra - Wheat Sequence in Coastal Area

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A field experiment was conducted (1988-1992) on coastal saline soil in SPB with two levels of FYM as main plot and ten levels of gypsum as subplot treatment at Agricultural Research Station (Fruit), GAU, Mahuva. The results revealed that EC and pH of soil were not affected significantly by FYM or gypsum. The ESP of the soil was significantly reduced by these treatments. The grain and fodder yield of bajra and wheat were significantly enhanced with FYM and gypsum. The highest grain yield of bajra was recorded with application of gypsum @ 75 % of GR at every year, while that of wheat with 100 % GR at every alternate year.

(***Key words:*** *Bajra-wheat sequence, FYM, Gypsum, Saline soil, Soil amendment*)

Use of poor quality ground water in irrigation adversely affects the productivity of soil and crop. Location specific technology will have to be develop for better utilization of poor quality ground water. Keeping this in view, a field experiment was conducted on coastal saline using saline well water.

MATERIALS AND METHODS

A field experiment was conducted (1988-1992) on coastal saline soil at Agricultural Research Station (Fruit), GAU, Mahuva growing bajra (GHB-30) in *kharif* and wheat (Kalyan Sona) in rabi irrigating with saline water (Table 1). The

Table 1. *Effect of FYM and gypsum levels on soil properties at the end of experiment and average grain and fodder yield (kg/ha) of Bajra and Wheat*

Treatment	Soil depth						Bajra (Pooled)		Wheat (Pooled)	
	0-15 cm			15-30 cm			Grain	Fodder	Grain	Fodder
	$EC_{2.5}$ dS/m	$pH_{2.5}$	ESP	$EC_{2.5}$ dS/m	$pH_{2.5}$	ESP				
FYM levels										
F_0	3.2	8.2	15.4	2.9	8.2	16.8	1368	3545	591	1720
F_1	3.1	8.1	12.2	2.9	8.2	13.1	2027	4744	1121	3543
C.D. at P = 0.05	NS	NS	2.20	NS	NS	NS	221	801	483	1362
Gypsum levels										
G_{00}	3.2	8.2	16.1	3.2	8.2	17.3	1080	2797	591	1939
G_{11}	2.7	8.2	11.5	2.4	8.3	12.2	2006	4776	1084	3494
G_{12}	3.2	8.1	13.2	2.9	8.2	16.2	1851	4349	811	2589
G_{13}	3.3	8.1	14.9	2.6	8.3	16.3	1802	4365	842	2708
G_{21}	3.8	8.2	12.0	3.5	8.2	10.9	2122	4838	992	2701
G_{22}	2.9	8.2	13.3	2.7	8.2	14.2	1750	4398	957	3004
G_{23}	3.1	8.1	14.8	2.7	8.2	15.1	1482	3870	845	2699
G_{31}	2.9	8.2	14.5	2.7	8.2	17.3	1619	3958	808	2569
G_{32}	3.3	8.2	13.5	3.0	8.2	13.6	2066	4870	1175	3298
G_{33}	3.3	8.1	10.7	2.9	8.2	12.5	1664	4315	741	2140
C.D. at P = 0.05	NS	NS	3.3	NS	NS	3.58	305	534	214	879.5
F x G	NS	NS	NS	NS	NS	NS	NS	NS	NS	670

***Table 2.** Interaction effect of FYM and gypsum on grain yield of bajra and wheat at individual years*

Gypsum	1988		1989		1991		1992	
	F_0	F_1	F_0	F_1	F_0	F_1	F_0	F_1
				Grain yield (kg/ha) Bajra				
G_{00}	1019	1265	1000	2583	642	838	485	808
G_{11}	1585	2529	2654	3225	1104	1944	1383	1625
G_{12}	1272	2675	2554	2583	1092	2071	1125	1488
G_{13}	940	2248	2433	3104	1083	1796	1217	1596
G_{21}	2313	2952	2625	2846	1038	2417	1204	1583
G_{22}	1383	1992	2292	3271	1104	1467	1054	1438
G_{23}	767	1977	1754	2688	1063	1554	783	1271
G_{31}	1156	1971	1968	2750	1200	1723	804	1383
G_{32}	2006	2413	2383	3208	1346	2350	1138	1688
G_{33}	1035	2079	2758	2625	919	1708	954	1229
CD P=0.05	402		484		255		NS	
CD P=0.05			Year x FYM x Gypsum 345.1					
$EC_{2.5}$ dS/m	2.31		1.43		1.27		2.45	
				Grain yield (kg/ha) Wheat				
G_{00}	137	1894	708	972	88	292	257	451
G_{11}	866	1903	1551	1667	333	1042	486	822
G_{12}	544	1287	1255	1301	215	921	280	683
G_{13}	417	1468	1278	1347	218	905	405	699
G_{21}	977	1921	1301	1366	255	1030	394	690
G_{22}	440	1884	1157	1648	282	1037	532	671
G_{23}	326	1727	1144	1347	282	810	336	787
G_{31}	347	1037	1472	1458	324	944	444	440
G_{32}	1310	2106	1319	1843	273	1238	521	787
G_{33}	227	1412	1204	1373	194	697	370	451
CD P=0.05	356		153		97		101	
CD P=0.05			Year x FYM x Gypsum 199.9					
$EC_{2.5}$ dS/m	2.62		2.70		2.85		3.15	
ECiw dS/m	8.4		8.9		9.6		10.10	

experimental soil was alluvial (Ustifluvent) having silty loam texture, ECe 10 dSm^{-1}, pHs 9.1, ESP 28.3, $CaCO_3$ 36 g kg^{-1}, was medium in available N low in available P_2O_5, and high in available K_2O.

The experiment was laid out in SPD with two levels of FYM (F_0: No FYM and F_1: 25 t ha^{-1}) in main plot and ten levels of gypsum (G_0: No gypsum, G_{11}: 50 % of GR at every year, at alternate year (G_{12}), and once in three years (G_{13}), G_{21}: 75 % of GR at every year, at alternate year (G_{22}) and once in three years (G_{23}), and G_{31}: 100% of GR (6.0 t ha^{-1}) at very year, at alternate year (G_{32}) and once in three years (G_{33}) in subplot. The bajra and wheat crops were uniformly fertilized with recommended dose of 80:40:00 and 120:60:00 kg as N: P_2O_5: K_2O ha^{-1}), respectively. After harvest grain and fodder yields were recorded and at the end of experiment the soil samples were collected and analyzed as per the standard methods (Richards, 1954).

RESULTS AND DISCUSSION

Effect on soil: The data (Table 1) showed that application of either FYM or gypsum failed to produce significant effect on soil salinity /sodicity, except ESP. The lowest ESP was recorded with G_{33} and G_{11} at surface and with G_{21} and G_{11} at subsurface layer, respectively.

Effect of crop yield: The results (Table 1) revealed that significantly higher grain and fodder yield of bajra and wheat were recorded with application of FYM @ 25 t ha^{-1}. Significantly higher grain yield of bajra was recorded with G_{21} while fodder yield with $G_{32.}$ The highest grain and fodder yield of wheat were recorded with the treatment G_{32} and G_{11}, respectively.

Significantly the highest grain yield of bajra was noted with F_1G_{21} during 1988 and 1991, respectively (Table 2). The highest grain yield of wheat were recorded with F_1G_{32}.

From the above results it can be concluded that the combined application of FYM @ 25 t ha^{-1} and gypsum @ 100 % of GR (6.0 t ha^{-1}) at every alternate year was found better for increasing grain yield of both the crops under poor quality of water.

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Economic Analyses of Different Cropping Systems in Coastal Ecosystem

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The economic analysis of crop production technology developed for coastal areas under All India Coordinated Research Project on Cropping Systems was undertaken. The rice-maize (cob)-greengram at Bhubneshwar, rice-rice -sesamum at Thanjavur, rice-maize (cob) at Karjat and rice-rice-sorghum fodder cropping system at Navsari were proved highly remunerative with respective net return of Rs. 63528, 57661, 74786 and 50077per ha. The integrated use of 50 percent recommended NPK through fertilizer and 50 percent by green manure (Azolla) in *kharif* rice and 100 percent NPK through mineral fertilizer in *rabi* rice earned maximum profit to Rs. 44157, 37136 and 31136 per ha at Maruteru, Bhubneshwar and Karjat, respectively. The use of 25 kg ha^{-1} sulphur with recommended fertilizer also showed higher return from rice-rice sequence at Bhubneshwar while application of 10 kg ha^{-1} zinc alongwith recommenaed fertilizer was appeared economical at Maruteru. The analysis of experimental data at Navsari further indicated that incorporation of crop residue generates more profit as compared to its burning and removal. Regarding tillage, broadcasting blackgram in standing crop of rice was found more beneficial than normal tillage at Thanjavur. The net income could be enhanced to the tune of Rs. 49,961 ha^{-1} with the use of 150% recommended dose of NPK through chemical fertilizers at Bhubneshwar while application of 10 t ha^{-1} FYM realized maximum profit (Rs. 46524 ha^{-1}) at Karmana.

***(Key words:** Cropping systems, Coastal areas, Economic analysis)*

The extensive adoption of technological innovations of the sixties in rice farming and rice based cropping systems have been the key to the growth and stability of foodgrain productions in India. Out of the thirty cropping systems identified in the country (Nair *et al.*,1998) rice-rice cropping systems spread over many states covering an area of six million hectares. The coastal regions plays an important role for rice production which contributes nearly 40-45 % of the total rice production in the country. However, the average productivity of rice of the region remained around 1.3 - 2.0 tonnes per hectare which is far below from the non traditional areas like Haryana and Punjab (3.5 t ha^{-1}). To bridge this gap, several technologies have been evolved under All India Coordinated Research Project on Cropping Systems for Coastal farmers. But, these technologies still awaits their popularization due to various socioeconomic constraints. In fact coastal farmers are resource poor and as such the technology which are productive with low cost only seems to be acceptable by the farmers of coastal areas.

Based on the input data of National Account Statistics, growth in agricultural output is being achieved with increasing cost per unit of out put as the index of input at the constant price has been rising faster than output. In such scenario, emphasis needs to be given to make comparative economic analysis of the technology developed for this region from time to time. As the information on these aspects is scare and scattered, an attempt has been made to examine the profitability of various technologies developed for betterment of the farmers settled in coastal areas.

MATERIALS AND METHODS

For economic analyses of different cropping systems under All India Coordinated Research Project on Cropping Systems following items were considered viz. (i) identification of economically viable cropping systems (ii) integrated nutrient management, (iii) use of secondary and micro-nutrients, (iv) residue management, (v) tillage and planting management and (iv) maximum yield research. The research works carried out through centres based at Bhubneshwar (Orissa), Maruteru (AP), Thanjavur (Tamil Nadu), Karjat (Maharastra), Navsari (Gujarat) and Karmanan (Kerala) representing coastal belts form the base for present study. The yield and fertilizers data of different cropping systems pertaining to the experiments under study was collected from Annual Progress Reports for the period from 1990 to 2002. While working out the economics, only cost of fertilizer was taken into account and other factors were assumed constant. The simple averages and ratio were used as analytical tools to assess the economic feasibility of the technologies developed for the region.

RESULTS AND DISCUSSION

The comparative economic analysis of different cropping systems tested at Bhubneshwar, showed highest return Rs. 63587 ha^{-1} from rice-maize (cob)-greengram (Table 1). The second economically viable systems were rice-maize-greengram and rice-rajmesh-sesamum in the order of merit, which provided Rs. 53140, Rs. 53061 ha^{-1} respectively as net income. At Thanjavur, rice-rice-sesamum followed by groundnut-rice-blackgram was judged to be more remunerative compared to other rotations. These results are in line with Shukla and Gangwar (2000). At Karjat, rice-maize(cob) with net return of Rs. 74746 ha^{-1} $year^{-1}$ and at Navsari, rice-sorghum-groundnut with net return of Rs. 50077 ha^{-1} $year^{-1}$ was ranked first when compared to other cropping systems. Adopting large scale adoption of these sequences in Maharashtra and Gujarat is advisable to improve the economic condition of the farmers. The economic analysis of integrated nutrient management showed maximum profit by using 50% of recommended NPK through chemical fertilizer and 50% through green manure (Azolla) in *kharif* rice and 100% recommended NPK through mineral fertilizer during *rabi* in rice-rice sequence at Maruteru, Bhubaneshwar, and Karjat. These findings are in agreement with (Shukla and Gangwar, 2000, Reddy *et al.*, 2002 and Shukla *et al.*, 2004). However, use of 50% recommend NPK through fertilizer and 50% N by crop residue during *kharif* and 100% recommended NPK through

Table 1. *Comparative economics (Rs/ha/year) of cropping systems in coastal areas*

Location State//Crop sequence	Gross Return	Cost of fertilizer	Net Return
Bhubneshwar (Orissa)			
Rice-maize-greengram	57981	4841	53140
Rice-maize(cob)-greengram	68428	4841	63587
Rice-mustard-greengram	45557	4409	41148
Rice-groundnut-greengram	52418	3764	48654
Rice-sunflower-greengram	47027	4052	42975
Rice-rajmesh-sesamum	57401	4340	53061
Thanjavur (Tamil Nadu)			
Rice-rice-pigeonpea	58235	6184	52051
Rice-rice-sesamum	63656	5995	57661
Blackgram-rice-blackgram	42816	4618	38198
G.Nut-rice-blackgram	59335	4740	54595
Soybean-rice-sunhemp	44093	4399	39694
Sunhemp-rice-cotton	49388	4161	45227
Karajat (Maharashtra)			
Rice-chickpea	32995	3119	29876
Rice-groundnut groundnut	45442	2990	42452
Rice-maize(cob)	78835	4089	74746
Rice-dolichesbean(pod)	56941	3875	53066
Rice-rice	30816	3945	26871
Navsari (Gujarat)			
Rice-wheat-greengram	45895	4241	41654
Rice-chickpea-sorghum(F)	48205	3618	44587
Rice-sorghum(F)-sesamum	43399	3582	39817
Rice-sorghum-groundnut	53695	3618	50077
Rice-wheat-greengram	40952	3427	37525
Rice-groundnut	37419	2372	35047

Table 2. *Economics of integrated nutrient management in rice-rice sequence*

Treatments (*Kharif & Rabi*)	Net income (Rs/ha)			
	Maruteru	Bhubneshwar	Karja	Karmana
Control	24328	17533	22604	29839
50% Rec. NPK through fertilizers +50% N through crop residue during *kharif* and 100% Rec. NPK through fertilizers (*Rb*)	37547	30574	28596	32795
100% Rec. NPK through fertilizers (*Kh&Rb*)	**43834**	35695	30259	30756
50% Rec. NPK through fertilizers 50% by compost/ FYM(*Kh*) and 100% NPK through fertilizer (*Rb*)	**42941**	34915	26087	30968
75% Rec. NPK through fertilizers + 25% through compost/FYM (*Kh.*) 75% Rec. NPK through fertilizers (*Rb*)	**41138**	35163	26657	29244
50% Rec. NPK through fertilizers + 50% through crop residues (*Kh*) 100% Rec. NPK through fertilizers (*Rb*)	**41378**	**33991**	27187	30129
50% Rec. NPK through fertilizers + 50% by green manure (Azolla) (*Kh*) 100% Rec. NPK through fertilizers (*Rb*)	**44157**	**37136**	31747	31922
75% Rec.NPK through fertiizers + 25% through green manure (Azolla) (*Kh*) 75% Rec.NPK through fertilizers (*Rb*)	**43421**	**36474**	25940	30199

chemical fertilizer during *rabi* season in rice-rice system generated highest income at Karmana in comparison to other treatments (Table 2). The results corroborate with the finding of Varughese *et al.* (2002). The use of recommended NPK through chemical fertilizer both for *rabi* and *kharif* was found next best only at Maruteru and Karjat. These findings emphasized the need for integrated use of chemical fertilizer and organic manures for sustaining the rice productivity in coastal areas.

The analysis of data (1992-97) of secondary and micronutrient showed highest return by using 25 kg ha^{-1} sulphur as basal dose with recommended fertilizer in the rice-rice sequence at Bhubneshwar, while applying 10 kg ha^{-1} zinc with fertilizer gave lowest income compared to other treatments except control. The findings are in conformity with Shukla and Gangwar (2000) and Samui and Mandal (2003). On the other hand, these treatments did not find beneficial at Maruteru. The result indicates deficiency of sulphur and zinc at Buhneshwar and Maruteru soils. The use of these micronutrients with fertilizer increased the productivity of rice-rice systems at these locations resulting in higher profit. Using lower dose of zinc (5 kg ha^{-1}) showed wide variation in net return compared to (10 kg ha^{-1}) at Maruteru. This indicates higher deficiency of zinc in Maruteru soils which reduce the crop yield even after applying full dose of fertilizer. The residue management studies at Navsari (Gujarat) in rice-wheat-sequence indicated a net return to Rs. 32100 ha^{-1} by incorporating crop residue in the soil before sowing. The second best beneficial treatment was observed wherein residue was removed.

The analysis of tillage management data showed an additional profit of Rs. 1938 ha^{-1} from blackgram in rice-blackgram system when blackgram was broadcast in the standing crop of rice at Thanjavur. The sowing of blackgram after land preparation of rice field indicated comparatively lower return (Table 3). As it was a low cost technology, its quick dissemination was essential to benefit the resource poor farmers of coastal belts of Tamil Nadu (Thanjavur). Using 150% of recommended NPK through fertilizer by maintaining 100% plant population in rice-rice system yielded an additional income of Rs. 8198 ha^{-1} at Bhubneshwar in comparison to application of 100% recommended fertilizer under maximum yield research. A marginal difference in profit to Rs. 233 ha^{-1} was recorded when fertilizer was replaced by 10 t ha^{-1} of FYM. Since, the use of organic manure makes the soil healthy which

Table 3. Benefit from tillage and planting management in rice-blackgram sequence at Thanjavur

Treatments	Net profit (Rs/ha)	
	Rice	Blackgram
Broadcasting the seed of black gram in standing rice	25591	7426
Sowing of second crop behind the plough after harvest of rice	25550	6100
Normal land preparation and sowing	25545	5488

Table 4. Economics of maximum yield research of rice-rice sequence

Treatments	Net income (Rs/ha)					
	Bhubneshwar			Karmana		
	100% RFD	125% RFD	150% RFD	100% RFD	125% RFD	150% RFD
100%Plant Population	40763	45424	49961	45880	46502	46083
125% Plant Population	43750	48171	48571	48345	44691	42963
No FYM	40449	44496	48802	48500	46524	44624
10t FYM/ha	44069	49097	49728	48147	44779	46863

RFD, Recommended fertilizer dose

is essential for sustaining the crop yield, the marginal difference in profit may be avoided and farmers may be encouraged to replace fertilizer by organic manure subject to its availability. The experiment carried out Karmana showed highest return (Rs. 48147 ha^{-1}) by applying 10t ha^{-1} FYM (Table 4).

Constraints and future needs

Drought and flood, use of local cultivars, and low investment and low farm income are the major constraints restricting adoption of these technologies by the farmers. Besides, lack of irrigation and marketing facility and non-availability of credit are the other reasons limiting the crop production in coastal areas.

Inclusion of high value crops in the cropping systems and identification of low cost technology should be given priority for improving economic condition of the farmers. Further, the emphasis may be given for integrated farming systems research for augmenting the small and marginal farm income. Credit facility and marketing infrastructure needs to be strengthened to benefit the coastal farmers. Since there is always uncertainty of crop production because of natural calamities, it is utmost essential to introduce Crop Insurance Scheme to safeguard the coastal farmers.

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Physiological Responses and Nutrient Composition in Guava and Sapota Varieties under Coastal Saline Conditions of Sundarbans

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The studies were conducted with three varieties of sapota (*Achras sapota L.*) and three varieties of Guava (*Psidium guajava L.*) to find out the effect of soil salinity and to identify the suitable varieties of fruit crops for coastal saline areas. In both the species salinity has affected root growth and their distribution pattern. It was observed that under less saline soils roots move vertically down but under higher salinity where irrigation was given by normal water roots move horizontally. Experiments revealed that leaf area, leaf area ratio and leaf area index were reduced gradually with the increase in salinity. It was noticed that Vitamin C content was very high in case of guava as compared to sapota. Sodium accumulation has increased with increase in soil salinity but higher sodium accumulation was found in leaves of main stem. Potassium accumulation decreased with the increase in salinity. Studies revealed that Guava should be grown only up to ECe 6.0dSm^{-1} and sapota was suitable up to ECe 10.0 dSm^{-1}.

(***Key words:*** *Fruit crops, Salinity in water, Nutrient composition in plant parts, Physiology of plant*)

Salinity stress may be attributed to non-availability of water, reduction in photosynthesis through loss of turgor (Gufran,1994) and may affect nutrient uptake causing deficiency on ion toxicitity in plant tissues (Bal and Chattopadhaya,1989). It may also impair synthesis of biochemical substances such as enzymes, sugars and proteins (Singh *et al.*, 2001). Bal and Chattopadhaya (1987) pointed out that salinity stress was more harmful at early phase of plant development and it varied with their growth stages. In India about 8.1 million hectares including 3.1 million hectares of coastal saline soils (Yadav *et al.*, 1983) has been rendered unproductive or less productive in respect of major cereal crops due to salt accumulation.

On an average more than 85% of cultivable area in Sundarbans in W.B. is monocropped with *kharif* rice with poor yield (Sen *et al.*, 1996). In the field of crop improvement considerable effort has been made for cereal crops, oil seeds etc., but not much on identification/evaluation and the performance of fruit crops, which have tremendous potentiality to fit into the farming system of the area. There fore, an attempt was made to identify varieties of suitable fruit crops based on their growth characteristics and physiological behaviour under varying levels of soil salinity.

MATERIALS AND METHODS

The experiment was carried out at CSSRI, RRS Canning Town, West Bengal in microplots with different levels of soil salinity. The salinity levels (ECe 2.5, 5.6, 8.6 and 10.6 dSm^{-1}) were created artificially by adding saline river water diluted to different proportions. The average composition of river water at salinity level (EC) of 35 dSm^{-1} at 25^{0}C was Na = 7571.3, K= 269.2, Ca= 403.8, Mg= 778.0, Cl= 314.3, SO_4= 969.1 ppm and pH= 7.8.

Three varieties of Sapota (*Achras sapota L.*) viz., *Badami*, *Cricket ball* and *Kalapatti* and three varieties of Guava (*Psidium guajava L.*) viz., *Kashi*, *L-49* and *KG* were taken as test crops. Three replications were followed, one year-old saplings of grafted sapota (root stock of *Mimusaps hexandra*) and saplings of Guava (air layered) were planted.

Normal management practices were followed. The observations were taken on periodical growth data, root proliferation pattern and sodium, potassium accumulation in different plant parts. To study the root proliferation in microplots, the roots were exposed *in situ* by wet excavation method (Joshi *et al.*,1982). Trenches were dug and profile wall was sprayed at high and low pressure so as to expose the root system. Nitrogen contents were analysed in stem and leaves of both the crops. Nitrogen was analysed by Kjeldahl method and Na, K were analysed in different plant parts (five parts were separated i.e., root, main stem, axillary stem, leaves of main stem and leaves of axillary stem), and it was estimated by the method as described by Jackson (1967) by Flamephotometer. The fruit yield was recorded and their characteristics were also noted. Nutrient characteristics of fruit were also analysed in both the crops. Vitamin C and Carbohydrate were analysed by the method of Guha *et al.* (1996) and Yemn *et al.* (1954), respectively.

RESULTS AND DISCUSSIONS

Growth data recorded from the 1st year revealed that root length decreased in sapota (39%) under higher salinity level (ECe 10.6 dSm^{-1}), whereas in case of guava it decreased by 40% at salinity level of ECe 8.6 dSm^{-1}. At ECe 10.6 dSm^{-1} guava could not survive and it was also observed that this fruit crop started dying after a year even at ECe 8.6 dSm^{-1}. It was noticed that generally under less saline and normal soil condition, roots move vertically down but under higher salinity stress where irrigation was given by normal water roots moved laterally/ horizontally and in this kind of condition lateral/ horizontal root length was more than vertical root length. Under higher salinity (ECe10.6dSm^{-1}) among the 3 varieties of sapota maximum root volume (20 ml) was observed in *var. Badami*, whereas in case of guava at ECe 8.6 dSm^{-1}, *var. KG* produced maximum root volume (20 ml). It is known that leaf area is the major determinant of crop growth under any kind of environment. Therefore, data on leaf area (LA), leaf area ratio (LAR) and leaf area index (LAI) were recorded and it was revealed that with the increase in salinity all these parameters reduced gradually in both the crops.

Fruit crops of guava and sapota revealed that weight length, girth, no. of fruits and volume of fruits were reduced with the increase in salinity in both the species. In case of guava it gave the fruit yield only up to ECe 5.6dSm^{-1}. Fruit analyses data of different varieties of sapota and guava showed (Table 1) that there was not much effect of salinity on moisture %, Carbohydrate, protein, phosphorous and vitamin C content. But in case of Ca it was observed that with the increase in salinity it increased in both the fruit crops. Data revealed (Table 1) that among the two fruit crops moisture % was much higher in guava than sapota, where as carbohydrate % and Ca was almost double in case of sapota than guava. It was interesting to observe that Vitamin C content was more than 200 (mg 100^{-1}g) incase of guava whereas it was 6-7 (mg 100^{-1}g) only incase of sapota.

The data on sodium, potassium accumulation in different plant parts of guava (Table 2) revealed that with the increase in salinity sodium accumulation increased in all the plant organs, but the reverse was true in case of potassium accumulation. Similar trend in cereal crops was noticed by Bal *et al.* (1986). But Singh and Pathak (1997) reported contrary to these findings, and they

Table 1. *Nutrient characteristics of fruit crops sapota and guava varieties under different salinity levels*

	Sapota											
Varieties	Badami				Cricket Ball				Kalapatti			
ECe (dSm^{-1})	2.5	5.6	8.6	10.6	2.5	5.6	8.6	10.6	2.5	5.6	8.6	10.6
Moisture (%)	73.7	73.6	73.7	73.4	74.0	75.0	74.0	73.1	73.5	73.4	73.2	73.0
Carbohydrate (%)	21.4	21.3	21.4	22.0	20.7	20.5	21.0	21.1	22.0	22.0	21.0	20.0
Protein %	0.70	0.75	0.78	0.77	0.75	0.75	0.79	0.79	0.80	0.90	0.90	20.0
Ca (mg/100g)	28	30	33	35	26	28	30	33	27	28	30	31
P (mg/100g)	27	27	26	27	25	26	26	25	25	26	26	27
Vit. C (mg/100g)	6	6	5	6	5	6	5	6	7	7	6	7
	Guava											
Varieties	L-49				KG				Kashi			
Moisture (%)	81.7	80.8	-	-	84.1	84.2	-	-	82.6	80.9	-	-
Carbohydrate (%)	11.2	11.4	-	-	10.5	11.0	-	-	12.0	12.1	-	-
Protein %	0.90	0.92	-	-	0.80	0.85	-	-	1.00	1.20	-	-
Ca (mg/100g)	10	13	-	-	11	12	-	-	11	13	-	-
P (mg/100g)	28	26	-	-	25	24	-	-	26	27	-	-
Vit. C (mg/100g)	212	213	-	-	200	202	-	-	210	208	-	-

Table 2. *Effect of salinity on sodium and potassium accumulation in different plant parts of sapota and guava varieties*

Varieties	SAPOTA											
	Badami				Cricket Ball				Kalapatti			
ECe (dSm^{-1})	2.5	5.6	8.6	10.6	2.5	5.6	8.6	10.6	2.5	5.6	8.6	10.6
					Na (% D.M.)							
Root	0.50	0.55	0.62	0.68	0.54	0.52	0.63	0.72	0.56	0.59	0.64	0.78
Leaves of Main Stem	0.34	0.42	0.87	1.48	0.32	0.60	0.88	1.34	0.44	0.59	0.66	1.22
Leaves of Axillary Stem	0.33	0.37	0.57	1.10	0.31	0.45	0.61	1.19	0.41	0.44	0.58	0.93
					K (% D.M.)							
Root	1.12	0.96	0.87	0.75	1.11	0.98	0.92	0.84	1.11	0.97	0.88	0.81
Leaves of Main Stem	1.95	1.77	1.55	1.22	1.45	1.40	1.37	1.03	1.81	1.71	1.68	1.32
Leaves of Axillary Stem	2.17	2.15	2.00	1.52	2.32	2.17	2.00	1.49	2.29	2.30	1.66	1.51
	GUAVA											
Varieties	L-49				KG				Kashi			
					Na (% D.M.)							
Root	0.37	0.81	0.98	-	0.42	0.72	0.89	-	0.40	0.42	-	-
Leaves of Main Stem	0.50	0.66	0.94	-	0.37	0.64	0.73	-	0.49	0.80	-	-
Leaves of Axillary Stem	0.35	0.55	0.64	-	0.32	0:50	0.58	-	0.39	0.71	-	-
					K (% D.M.)							
Root	1.04	0.93	0.95	-	1.00	0.95	0.87	-	1.10	0.75	-	-
Leaves of Main Stem	1.25	1.12	1.00	-	1.10	1.25	1.28	-	1.00	0.95	-	-
Leaves of Axillary stem	2.00	1.75	1.62	-	2.25	2.25	1.75	-	2.10	1.60	-	-

Table 3. *Effect of salinity on nitrogen content (% D.M.) in different plant parts of sapota and guava*

Varieties	ECe dSm^{-1}			
	2.50	5.60	8.60	10.60
		Stem of Sapota		
Badami	0.12	0.12	0.13	0.13
Cricket Ball	0.13	0.14	0.15	0.16
Kalapatti	0.13	0.13	0.14	0.14
		Leaves of Sapota		
Badami	0.72	1.40	1.50	1.67
Cricket Ball	1.00	1.08	1.54	1.60
Kalapatti	0.98	1.55	1.60	1.67
		Stem of Guava		
L-49	0.59	0.78	0.63	-
KG	0.75	0.75	0.71	-
		Leaves of Guava		
L-49	2.10	2.15	2.40	-
KG	2.09	2.05	2.32	-

found that in guava sp. Na and K content decreased with the increase in salinity level. However, in our experiment it was observed that maximum amount of sodium accumulated in leaves of main stem as compared to other plant organs (Table 2). Among the three varieties of guava variety *Kashi* accumulated maximum amount of Na in their leaves than Var. L-49 and KG. Maximum accumulation of K was noticed in case of leaves of KG variety.

In case of sapota it was observed that Na accumulation in root, stem and leaves increased with the increase in salinity. Main stem leaves accumulated maximum amount of Na as compared to other plant parts like guava (Table 2). Among the three varieties of Sapota Var. Kalapatti accumulated less amount of sodium in leaves of main stem under different salinity than Var. Badami and Cricket ball. Stem acuumulated less amount of Na than roots and leaves in all the varieties. It was observed that leaves of axillary stem accumulated maximum amount of K than main stem leaves, probably due to the higher number of young leaves in axillary stem. There were not much differences in K among the varieties with the increase in salinity, and it decreased gradually.

It was very interesting to observe that nitrogen content increased with the increase in salinity in both stem and leaves in each fruit crop, which leaves accumulated much higher amount than stem (Table 3). Comparison between the two species revealed that guava (Table 3) extracted much higher amount of nitrogen from the soil system than sapota.

The result of the experiments advocated that guava should be grown only up to ECe 6.0 dSm^{-1} and sapota can be grown safely up to ECe 10.0 dSm^{-1} under heavy textured soils of Sundarbans.

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Screening of Rice Germplasm Lines against Coastal Salinity

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Twenty-five germplasm lines of rice received from IRRI were screened against salinity in *Kharif* 2000. The results revealed that the genotypes CSR 88 IR-13, CSR 88-12, CSR 89 IR-11, CSR 89, IR 8, Nona Bokra, Panvel-1, Panvel-3, CSR 89 IR-15, CSR 89 IR-8, IR 63731-1-1-3-3-2 and IR 42 were highly tolerant to salt injury followed by BR 5331, 93-2-8-4, pokalli, BW 267-3.

(***Key words***: *Rice germplasm, Salinity, Screening*)

In Maharashtra 65465 ha land is covered by coastal saline soils (*Anon.*, 1990). Amongst reclamation measures growing of salt tolerant rice variety is economical way to achieve the maximum productivity in coastal saline soils. The climatic situation of the last 5 years is very uncommon and occurrence of dry spell in the crop growth stage creates hurdle for getting optimum productivity in *kharif*. Therefore, screening of salt tolerant germplasm was done during *kharif*, 2000 at Khar Land Research Station, Panvel, and reported in this paper.

MATERIALS AND METHODS

Twenty-five germplasm lines of rice received from IRRI were sown in *kharif* 2000 in non-saline soils. The transplanting was done after one month at 15 x 20 cm. The susceptible lines viz., IR 28 and IR 29 were transplanted alternatively after five lines and salt tolerant check viz., Panvel-1 and Panvel-3 were also transplanted after every five lines Two replications were used. Fertilizer dose of 100:50:50 kg NPK was applied. The field screening was conducted under natural conditions. The salinity of the experimental plot at the time of transplanting was 5.00 dSm^{-1}, after 4 weeks it was 4.30 dSm^{-1}, and after 8 weeks it was 7.30 dSm^{-1}. Observations were recorded as a healthy plant counts at the beginning and salinity injured plants count were recorded at the time of harvesting. The salinity injury score was calculated and presented in Table 1.

Table 1. *Response of rice germplasm lines to salinity injury at Khar Land Research Station, Panvel*

Sr. No.	Scale (Salinity injury)	Germplasm
1.	1 (Growth and fillering nearly normal)	CSR-88IR-13, CSR88IR-12, CSR-89IR-11, CSR 89IR-8, Nona Bokra, Panvel-1, Panvel-3, CSR 89, IR 15 CSR 89 IR 8, IR 63731-1-13-3-2, IR 42.
2.	3 (Growth nearly normal but there is some reduction in fillering and some leaves discolored)	BR 5331-93-2-8-4, Pokalli, BW 267-3
3.	5 (Growth and fillering ceases; Most leaves discolored, any few elongettings)	BIS 11-13, DWCT 82-1-20, HTA 87030-16-1-3, ICR 88075-7-BL2-4-3, IR 26
4.	7 (Growth completely ceases; Mst leaves dry ; some plants dying)	HP 3319-2 WX -6-20-1 - B, HP 3319 - 2 WX -6-26 -3 -B, IR 28, IR 29, IR 5931 - 110 -1, PCR 89 187 - 4 B PCR 89303 -13-1-1-2, WAB 9630, WAB 9635, WAB 96 -5-1, WAB 99-100.
5.	9 (Almost all plants dead)	HP 3319-2 WX-6-4-1-B, HP 3319-2 WX -6-55-2-B, WAB 33-25, WAB 96-24

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Twenty-five germplasm lines of rice received from IRRI were sown in *kharif* 2000 in non-saline soils. The transplanting was done after one month at 15 x 20 cm. The susceptible lines viz., IR 28 and IR 29 were transplanted alternatively after five lines and salt tolerant check viz., Panvel-1 and Panvel-3 were also transplanted after every five lines Two replications were used. Fertilizer dose of 100:50:50 kg NPK was applied. The field screening was conducted under natural conditions. The salinity of the experimental plot at the time of transplanting was 5.00 dSm^{-1}, after 4 weeks it was 4.30 dSm^{-1}, and after 8 weeks it was 7.30 dSm^{-1}. Observations were recorded as a healthy plant counts at the beginning and salinity injured plants count were recorded at the time of harvesting. The salinity injury score was calculated and presented in Table 1.

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5.	9 (Almost all plants dead)	HP 3319-2 WX-6-4-1-B, HP 3319-2 WX -6-55-2-B, WAB 33-25, WAB 96-24

RESULTS AND DISCUSSION

The results revealed that the genotypes CSR 88 IR-13, CSR 88-12, CSR 89 IR-11, CSR 89, IR 8, Nona Bokra, Panvel-1, Panvel-3, CSR 89 IR-15, CSR 89 IR-8, IR 63731 -1-1-3-3-2 and IR 42 were highly tolerant to salt injury followed by BR 5331, 93-2-8-4, pokalli, BW 267-3 which registered salinity score of 3. Of the remaining, 7 genotypes were moderately tolerant, 11 genotypes registered 7 score while, 4 genotypes registered 9 score. Among these 26 genotypes CSR 88, IR-13, CSR 89, IR-11 recorded lowest salt injury with normal plant growth while, WAB 96-24 recorded 100% salt injury. Sawardekar *et al.* (2002) reported that Panvel-1, Panvel-3 had good salt tolerance and IR 28, IR 29 were susceptible to salt injury. Same observations were made in the present study also. The genotypes possessing highly salt tolerant could be utilized as donor lines in future breeding programme.

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Comparative Study of Tomato Genotypes in Coastal Orissa

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Five determinate and indeterminate genotypes of tomato were evaluated for their yield potential and other yield attributing components during 1998-99 and 1999-2000. Among the determinate types Utkal Pallavi and Utkal Deepti yielding 348.6 and 362.8 q ha^{-1} in 1998-99 and 382.8 and 370.4 qha^{-1}, in 1999-2000, respectively were suggested for commercialisation. Among the indeterminate types Utkal Kumari, BT-18 and Arka Vikash were suggqested for cultivation in the coastal zones of Orissa. In addition Roma and Punjab Chhuhara of determinate types yielding 375.1 & 368.2 q ha^{-1} and 398.1 & 364.4 q ha^{-1}, respectively in 1998-99 and 1999-2000 were suggested for wide cultivation where wilt is not a problem.

*(**Key words** : Tomato genotypes, Yield, Growth characters)*

Tomato (*Lycopersicum esculentum mill.*) is a popular vegetable crop grown all over India. It is highly nutritive as well as remunerative. Despite the improved technology and agronomic practices, the Indian farmers are getting an yield of 9.15 t ha^{-1} only, where as the world average is 25.09 t ha^{-1} (Singh, 1991). Several genotypes are cultivated by the farmers throughout Orissa and particularly in the coastal zone. But they differ in their adaptability to temperature, light, soil and other environmental factors. Introduction of high yielding genotypes tolerant to wilt and having better quality fruits will be a real boost and highly rewarding to this zone. Since much information are not available on the performance of tomato varieties grown in this zone, an attempt was made to evaluate the performances of ten genotypes for their yield potential and other yield attributing characters.

MATERIALS AND METHODS

The experiment was carried out at the Regional Research Station, OUAT, Bhubaneswar during *rabi* 1998-99 and 1999-2000 in a randomized block design with three replications in each year. Five determinates and five indeterminate tamato genotypes were tested with Pusa Early Dwarf and Pusa Ruby, respectively as check. Four week-old healthy seedlings were transplanted during the first week of November each year at a spacing of 60 cm x 45 cm in a plot size of 3.6 m x 2.7 m. All the plots were fertilized uniformly and recommended cultural practices were followed during experimentation. The observations were recorded on plant height (cm), number of branches per plant, number of fruits per plant, average fruit weight (g) and yield (q ha^{-1}) from ten randomly selected plants in each genotypes excluding border plants. The data for both the year were subjected to statistical analysis.

RESULTS AND DISCUSSIONS

The observations were recorded on growth, yield and yielding attributing characters of determinate and indeterminate genotypes and are presented in Table 1. Among the determinate types, the plant height was found to be non-significant in first year, but significant in second year. However Pusa Early Dwarf produced the smallest plants (46.8 cm and 41.2 cm in 1998-99 and 1999-2000, respectively). Hossain and Mohanty (1997) also recorded the small sized plants of Pusa Early Dwarf in a trial with seven varieties. The number of fruits per plant, single fruit weight and yield were significant during 1998-99 but plant height and number of branches were non-significant whereas, during 1999-2000 the plant height, number of branches, number of fruits and single fruit weight were significant but the yield was non-significant. It was observed (Figs. 1 and 2) that Roma and Punjab Chhuhara produced the large sized fruits (50.9 g and 45.1 g, respectively) but less in number (38.7 and 37.2, respectively). This finding corroborates the earlier works of Kalloo (1989) and Nandi (1992) regarding findings of Punjab Chhuara. Utkal Deepti and Utkal Pallavi recorded more number (64.9 and 75.6, respectively) of smaller sized

***Table 1.** Growth, yield and yield attributing characters of some tomato genotypes*

Genotypes	Plant ht (cm)		No. of branches		No. of fruits		Single fruits (g)		Yield (q/ha)	
	1998-99	1999-2000	1998-99	1999-2000	1998-99	1999-2000	1998-99	1999-2000	1998-99	1999-2000
Determinate										
Utkal Pallavi	51.6	52.7	6.8	5.1	53.4	64.9	28.2	30.4	348.6	382.8
Utkal Deepti	50.2	54.1	6.9	5.3	65.2	75.6	27.3	27.6	362.8	370.4
Roma	54.3	56.1	7.1	5.5	38.7	48.3	50.1	50.9	375.1	398.1
Punjab Chhuhara	57.4	47.2	6.8	5.8	37.2	43.4	42.7	45.1	368.2	364.6
Pusa Early Dwarf	46.8	41.2	5.9	4.6	36.9	38.1	35.5	33.5	344.5	331.9
SEm (±)	1.171	1.19	0.29	0.3	0.79	0.76	0.29	0.38	1.46	11.91
CD (p = 0.05)	N.S	1.69	N.S	0.43	1.13	1.07	0.41	0.54	2.06	N.S
Indeterminate										
Utkal Kumari	66.4	65.3	6.3	6.2	53.1	65.3	33.8	35.3	378.4	395.4
Arka Vikash	65.1	66.1	6.4	5.8	27.6	34.1	64.6	54.9	353.1	352.1
BT-18	70.7	79.6	6.5	6.3	49.7	57.6	35.4	35.5	370.2	367.8
Pusa Uphar	70.1	68.3	6.8	5.8	20.8	23.6	75.1	100.2	226.5	261.9
Pusa Ruby	67.6	66.6	5.6	5.2	42.4	61.8	24.3	36.2	338.4	357.3
SEm (±)	1.36	4.49	0.27	0.21	0.97	1.59	0.43	0.6	0.34	8.95
CD (p = 0.05)	N.S	N.S	0.39	0.30	1.38	2.25	0.61	0.84	0.48	12.66

fruits (28.2 g and 27.6g, respectively), although the yield was non-significant in 1999-2000 but was significant in 1998-99. The highest yield was recorded by the variety Roma in both the years (375.1 and 398.1 q ha^{-1} in 1998-99 and 1999-2000, respectively). Considering the fruit character, yield and tolerance to wilt Utkal Pallavi and Utkal Deepti may be popularized. It was found that both the varieties are highly tolerant to wilt (Anon., 1996). In areas where wilt is not a problem, these two varieties along with Roma and Punjab Chhuhara is suggested for popularization. Tikoo *et al.* (1985) also recorded that Punjab Chhuhara was a promising variety.

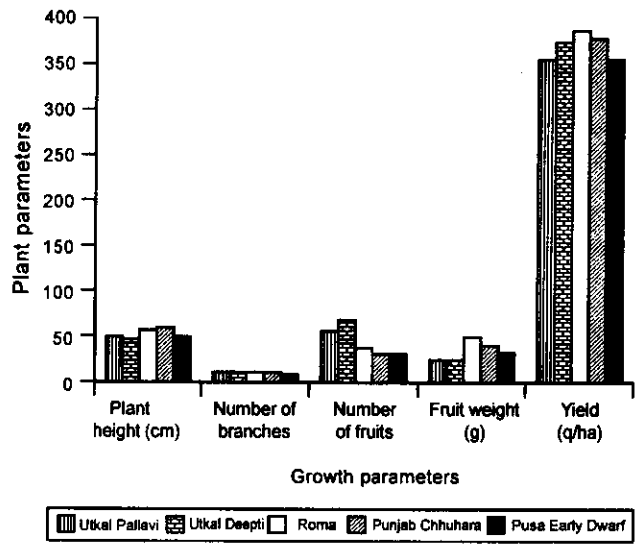

Fig. 1. *Growth parameters of determinate tomato genotypes in 1998-99*

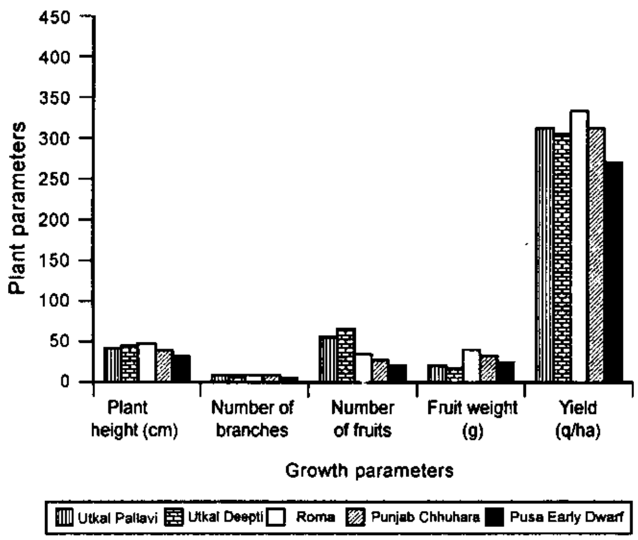

Fig. 2. *Growth parameters of determinate Tomato genotypes in 1999-2000*

Among inderminate types number of branches, number of fruits, single fruit weight and yield were significant but plant height was non-significant in both the years. BT-18 was observed as the tallest plants (70.7 and 79.6 cm during 1998-99 and 1999-2000, respectively). Most dwarf plants were found to be Arka Vikash followed by Utkal Kumari, Pusa Ruby and Pusa Uphar Figs. 3 and 4. Hossain and Mohanty (1997) also recorded medium sized plants of Pusa Ruby in a trial with nine varieties. Pusa Uphar recorded significantly higher fruit weight in both the years (75.1 g and 100.2 g in 1998-99 and 1999-2000, respectively) in comparison to other genotypes. Utkal Kumari produced smallest fruits followed by Pusa Ruby, BT-18 and Arka Vikash. However highest number of fruits was produced by

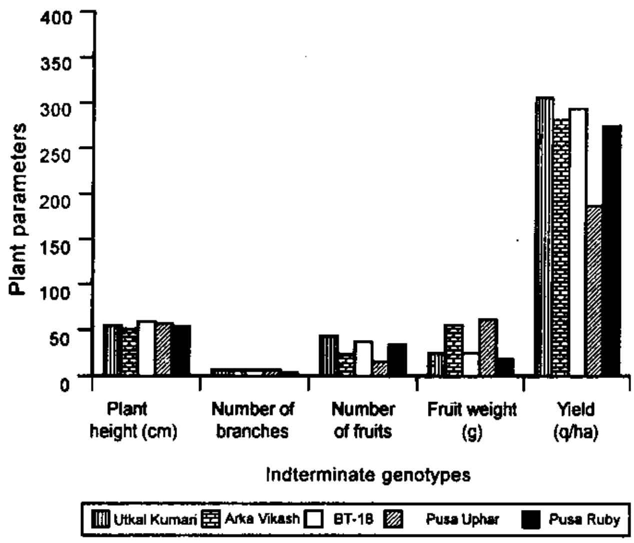

Fig. 3. *Growth parameters of indeterminate tomato genotypes in 1998-99*

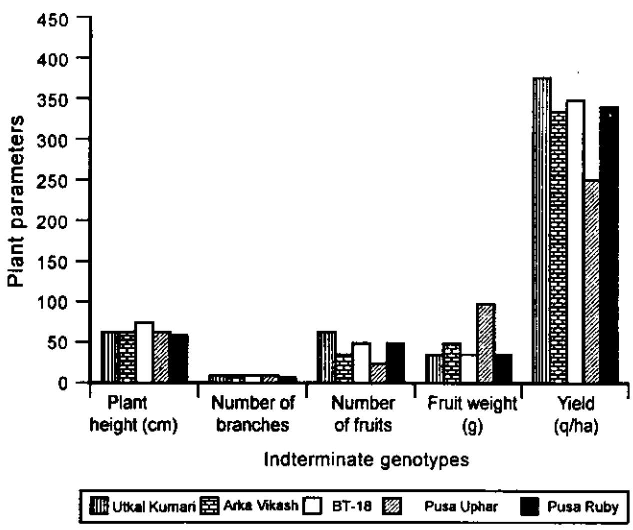

Fig. 4. *Growth parameters of indeterminate tomato genotypes in 1999-2000*

Utkal Kumari followed by BT-18 and Pusa Ruby. Whereas, genotype Pusa Uphar recorded the least number of fruits followed by Arka Vikash. The highest yield was recorded by Utkal Kumari (378.4 and 395.4 q ha^{-1} in 1998-99 and 1999-2000, respectively), followed by BT-18, Arka Vikash, Pusa Ruby and Pusa Uphar. Whereas Som and Paria (1983) reported Pusa Ruby and Pusa Early Dwarf as the top yielders in comparison the yield and yield attributing characters Utkal Kumari, BT-18 were at par with Pusa Ruby. The genotypes Utkal Kumari and BT-18 showed field tolerance to wilt, therefore these varieties are suggested for growing in wilt prone areas. Considering both the determinate and indeterminate groups together Utkal Pallavi, Utkal Deepti, Utkal Kumari, BT-18 and Arka Vikash were suggested for wide cultivation in this zone for both the yield, yield contributing characters and wilt tolerance.

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A Long Term Effect of Integrated Nutrient Management on Soil Properties and Crop Yield in Rice-Rice Cropping System in Coastal Ecoregion of Maharashtra

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A long term field experiment was initiated in 1993 in medium black soil at Regional Agricultural Research Station, Karjat, (Raigad) involving use of NPK fertilizers with and without organic and green manure (glyricidia on rice-rice cropping system. Addition of RDF-NPK and its combination with green manure (glyricidia) increased the rice grain yield significantly. The 100% recommended dose RDF of NPK (T5) has proved to be superior in *kharif*, *rabi* and in pooled analysis after a long range of experimentation; however in *kharif* 100% RDF-NPK was found to be at par with 50 and 75% levels of RDF-NPK fertilizer combined with organic manures. In *rabi*, 50% RDF+50% N glyricidia and 50% RDF +50% N paddy straw application were comparable with 100% RDF NPK but in rice- rice cropping system as such T5 was at par with 50% RDF-NPK along with 50% N Glyricidia, which was followed by 75% RDF NPK plus 25% N paddy straw. Thus, 50% substitution of fertilizer by glyricidia was recommended. It improved the nutrient uptake and soil properties due to integration effect of organic with chemical fertilizers.

(***Key words***: *Integrated nutrient management, Rice-rice cropping system, Nutrient uptake*)

Growing two or more crops of rice, with high dose of high analysis chemical fertilizers have necessitated changes in nutrient management under intensive cropping system. The nutrient mining by high yielding rice was usually more than that applied through fertilizers. This negative balance over the years led to impoverishment of soil fertility and decline in crop productivity (Pillai *et al.* 1990, Nambiar, 1994). The present study on integrated nutriment management system was initiated in the coastal ecoregion of Maharashtra for sustained crop production in order to meet a part of nutrient need of rice crop through locally available sources such as, crop residues, FYM, green manures, and other organics.

MATERIALS AND METHODS

A field experiment was started during the *kharif* and *rabi* season in 1993 at Regional Agriculture Research Station, Karjat (Raigad). The soil of the experiment site was medium black with sandy clay loam texture, pH 7.55, electrical conductivity 0.27 dSm^{-1}, organic carbon 1.25 %, available N, P_2O_5 and K_2O, 180,29.85 and 294.50 kg ha^{-1}, respectively. Recommended dose of fertilizer (RDF) N,P_2O_5,K_2O was applied both in *kharif* and *rabi* seasons. N was applied in the form of urea in three splits for both the crops while, phosphorus and potassium were applied at the time of transplanting. Manures viz., FYM, paddy straw and glyricidia were spread and incorporated in the field well in advance before transplanting. The experiment was laid out in the randomized block design with four replications and twelve treatments. Soils and plant samples were subjected to chemical analysis by standard procedures (Piper, 1966, Jackson, 1976). The treatment details are given in the Table 1. Amongst these, 6 treatments of 50 % RDF, 8 treatments of 75 % RDF, and 6 treatments of 100% RDF were in both the seasons. Out of these, 6 treatments were integration of chemical fertilizers with locally available cheaper sources like FYM, paddy straw (P.S.) and glyricidia (GLY), along with farmer's practice and control (no fertilizer/no manure). Palghr-1 and Karjat -3 rice varieties were used in *kharif* and *rabi* season, respectively.

RESULTS AND DISCUSSION

Effect of graded levels of nutrients on grain yield

In *kharif* treatment (T5), 100% RDF was found to be superior by producing higher grain yield of rice; but it was at par with rest of the treatments except (T2) 50% RDF, (T12) farmer's, practice and the control. No significant difference could be observed between the control and farmer's, practice. In *rabi* also, T5 was found to produce higher rice grain yield; however it was at par with (T10, GLY) and (T8, PS). In pooled analysis T5 maintained the same trend as rice grain production was higher over

Table1. *Treatment details of the experiment*

Treatment	*Kharif*	*Rabi*
T1	Control(no manures/no fertilizers)	Control (no manures/no fertilizers)
T2	50 % RDF of NPK fertilizer	50 % RDF of NPK fertilizer
T3	50% RDF of NPK fertilizer	100% RDF of NPK fertilizer
T4	75% RDF of NPK fertilizer	75% RDF of NPK fertilizer
T5	100% RDFof NPK fertilizer	100% RDF of NPK fertilizer
T6	50% RDFof NPK fertilizer +50 % N FYM	100% RDF of NPK fertilizer
T7	75% RDF of NPK fertilizer +25% N FYM	75% RDF of NPK fertilizer
T8	50% RDF of NPK fertilizer +50% N P.S.	100% RDF of NPK fertilizer
T9	75% RDF of NPK fertilizer +25% N P.S.	75% RDF of NPK fertilizer
T10	50% RDF of NPK fertilizer +50% N GLY	100% RDF of NPK fertilizer
T11	75% RDF of NPK fertilizer +25% N GLY	75% RDF of NPK fertilizer
T12	Farmer's practice (N:P:K 45:45:45)	Farmer's practice(N:P:K 90:45:45)

Table 2. *Effect of different treatments on soil fertility (Rice-Rice)*

Tr.no	pH (1:2. 5)		EC (dSm^{-1})		O.C (%)		Available nutrients (kg/ha)						Total uptake of nutrients (kg/ha)		
							N		P		K_2O				
	K	R	K	R	K	R	K	R	K	R	K	R	N	P_2O_5	K_2O
T1	6.46	6.31	0.17	0.19	0.43	0.51	167	172	8	12	261	265	124	20	192
T2	6.59	6.34	0.24	0.29	1.20	0.68	178	223	21	21	422	456	155	33	272
T3	6.67	6.37	0.21	0.27	0.95	0.78	198	190	24	25	428	612	173	45	293
T4	6.68	6.33	0.26	0.25	1.13	1.38	194	204	26	24	552	489	175	44	318
T5	6.66	6.39	0.25	0.26	1.17	0.99	186	191	29	29	647	641	181	50	310
T6	6.66	6.40	0.23	0.26	1.11	1.17	211	234	25	33	524	646	174	46	281
T7	6.69	6.00	0.26	0.24	1.18	1.13	206	191	25	26	502	493	157	44	307
T8	6.68	6.44	0.24	0.23	0.86	1.32	218	195	26	32	558	647	166	44	293
T9	6.60	6.38	0.21	0.27	1.22	1.01	201	187	24	25	526	575	163	43	324
T10	6.66	6.46	0.23	0.27	1.34	1.20	198	191	25	25	564	655	184	46	295
T11	6.55	6.44	0.22	0.29	1.45	1.20	213	194	26	28	535	616	177	46	286
T12	6.56	6.49	0.28	0.28	1.08	0.86	195	183	26	30	468	494	145	36	273
Initial	7.55	—	0.27	—	1.25	—	185	—	29.85	—	294.5	—	—	—	—

the rest the treatments except T10. Treatment T5 produced 46.62% more grain yield over the control, where as farmers practice (T12) produced 15.91% more yield over the control. The response to T2 (50% RDF) and T3 was 23.61 and 35.17%, respectively (Gupta *et al.*, 2000, Mohanty and Sharma, 2000). Treatment T5 (100% RDF) was though proved to be superior but at par with T10 (50% RDF NPK + 50 % N GLY). T10 was found to be at par with T9 (75% RDF NPK+25% P.S.).

Nutrient uptake and soil properties

It was revealed that (Table 2) treatment T10, T5 andT9 have recorded the highest total uptake of N, P_2O_5 and K_2O, respectively in rice crop. The uptake of nutrient was observed to increase due to combined application of organic with chemical fertilizers (Baskar, 2003).

Continuous application of chemical fertilizers along with organic manures influenced significantly. Soil pH and EC was lowered due to addition of organic manures. However, the level of organic carbon was found to increase due to the treatment T10 (GLY) (Table 2). The content of available N and K_2O was increased with decrease in P_2O_5 as compared to initial values. The results confirm the findings of Hegde (1996) and Raju and Reddy (2000).

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Study on the Integrated Phosphorus Management on the Growth, Yield and Nutrient Uptake of Sesame in Coastal Sodic Soil

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A pot culture experiment was carried out in the Department of Soil Science and Agricultural Chemistry, Annamalai University during Feb –April, 2003 to study the effect of integrated phosphorus management on the growth, yield and nutrient uptake of sesame in coastal sodic soil. The results of the study revealed that integrated P application as organics and biofertilisers increased significantly the growth, yield and nutrient uptake of sesame in coastal sodic soil. Among the various treatments, 75 and 50 % recommended P along with humic acid coated P excelled over all other treatments to record higher growth, yield and nutrient uptake by sesame. The treatments 75 and 50% recommended P with humic acid coated P application registered a sesame seed yield of 41.69 and 40.28 g pot^{-1}, respectively. The post-harvest soil also showed increased nutrient availability under integrated phosphorus management treatments.

*(**Key words**: Integrated phosphorus management, Sesame growth & yield, Nutrient uptake, Soil physicochemical properties)*

Sesame, one of the important oil seed crops, is grown in the coastal areas under nutrient starved and salinity condition. The restricted availability of phosphorus under saline condition greatly reduces the sesame production in these areas, the average yield being 200 – 300 kg ha^{-1} as compared to 800 – 900 kg ha^{-1} in other areas. Hence, an attempt was made to study the integrated phosphorus management on the growth, yield and nutrient uptake of sesame in coastal sodic soil.

MATERIALS AND METHODS

A pot culture experiment was carried out at Annamalai University during Feb–April 2003 in a coastal sodic soil. The experimental soil was collected from a coastal village Alappakkam in Cuddalore District of Tamil Nadu and had pH 8.94, EC 1.90 dS m^{-1}and ESP 29.34. Texturally the soil was sandy clay loam with low available N and P status. The treatments included in this study were: Control (T_1), 75% recommended P + 25 % P through humic acid coated P (T_2), 50% recommended P + 50 % P through humic acid coated P (T_3), 75% recommended P + 25% P through enriched FYM (T_4), 50% recommended P + 50% P through enriched FYM (T_5), 75% recommended P + Phosphobacterium (T_6), and 50% recommended P + Phosphobacterium (T_7). The treatments were replicated thrice in a randimised block design with sesame as test crop. The humic acid coated phosphorus was prepared by taking required quantity of lignite humic acid which was treated with 0.1 N KOH slution to make it a slurry and finally coated over super phosphate using coaltar as an adhesive. The enriched FYM was prepared by adding calculated quantities of super phosphate with FYM @ 750 kg ha^{-1} and incubated under anerobic condition for 30 days.

Forty kg of processed soil were taken in a cement pots. Gypsum at 50 % requirement was added to pots and water was ponded, which was then drained after three days. A fertilizer dose of 35:22.5:22.5 kg ha^{-1} of NPK was followed. Required quantities of fertilizers, organics and biofertilizers were applied to each pot as per the treatments schedule. Sesame seeds var TMV 4 were sowed and thinned after 15 days to maintain 6 plants per pot. The growth characters like height and DMP and yield, yield attributes like no. of branches and no. of capsules, and seed and stover yield were recorded at harvest. The seed and stover samples were analysed for the contents of NPK as per the standard procedure (Jackson, 1973). The physicochemical properties and available major nutrients were analysed in the post-harvest soil as per the procedure outlined by Jackson (1973).

RESULTS AND DISCUSSION

Growth and yield

Integrated application of phosphorus in the form of humic acid coated P, enriched FYM and biofertilizer significantly increased the growth and yield of sesame (Table 1). The maximum plant height

Table 1. *Effect of integrated phosphorus management on the growth and yield of sesame*

Treatments	Plant height (cm)	DMP (g/pot)	No.of branches/ plant	No.of capsules/ plant	Seed yield (g/pot)	Stover yield (g/pot)
T_1	80.62	128.77	10.37	38.46	30.46	83.32
T_2	114.76	159.37	14.89	53.58	41.69	120.68
T_3	112.56	153.03	14.56	50.60	40.28	117.86
T_4	107.28	149.60	13.68	45.76	38.85	106.92
T_5	103.84	144.46	13.19	44.19	38.88	105.82
T_6	96.05	139.43	12.95	40.88	34.37	96.06
T_7	94.25	140.60	12.23	40.21	34.56	97.23
SEm(±)	3.04	3.93	0.47	1.88	1.23	3.63
CD(P=0.05)	6.08	7.86	0.92	3.75	2.46	7.25

Table 2. *Effect of integrated phosphorus management on the nutrient uptake by sesame*

Treatments	N (mg/pot)		P (mg/pot)		K (mg/pot)	
	Seed	Stover	Seed	Stover	Seed	Stover
T_1	855.15	665.93	135.84	83.86	154.15	686.48
T_2	1442.47	1232.49	197.63	168.12	217.63	878.67
T_3	1313.13	1169.27	195.57	159.18	215.19	859.17
T_4	1227.38	1101.74	187.22	148.01	209.46	840.20
T_5	1143.07	993.31	188.29	137.76	202.18	828.39
T_6	990.36	818.45	159.78	122.07	183.92	776.83
T_7	950.40	791.72	159.34	117.82	183.97	759.26
SEm(±)	44.78	42.48	7.63	4.86	6.20	41.58
CD(P=0.05)	89.56	84.95	15.25	9.72	12.40	83.16

Table 3. *Effect of integrated phosphorus management on the physicochemical properties and available nutrient status of soil*

Treatments	pH	EC (dS m^{-1})	ESP	Org. carbon (%)	Nitrogen (ppm)	Phosphorus (ppm)	Potassium (ppm)
T_1	8.90	1.65	28.74	0.26	87.52	4.08	121.75
T_2	8.52	1.21	21.56	0.42	98.56	4.89	133.72
T_3	8.57	1.24	21.79	0.41	96.78	4.82	133.00
T_4	8.65	1.29	24.50	0.36	96.12	4.76	128.75
T_5	8.69	1.32	24.62	0.37	94.85	4.73	126.52
T_6	8.86	1.48	27.96	0.27	92.88	4.71	122.65
T_7	8.88	1.49	27.88	0.26	92.67	4.70	122.08
SEm(±)	0.06	0.02	0.96	0.01	1.58	0.11	2.14
CD(P=0.05)	0.12	0.04	1.92	0.02	3.16	0.21	4.27

(114.76 cm), DMP (159.37 g/pot), no. of branches (14.89) and no. of capsules per plant (53.58) were recorded with 75 % P + 25 % P through humic acid coated P application. Phosphorus substitution at 50 % through humic acid coated P maintained parity with the above treatment. The highest seed and stover yield of 41.69 and 120.68 g pot^{-1} was recorded with 75 % P + 25 % P through humic acid coated P application which represented 36.87 and 44.83 % increase over control. The treatment 50 % P substitution as humic acid coated P was also equally efficacious in recording higher yield. The enriched FYM application rated next best in increasing the yield of sesame. The better growth and yield of sesame under integrated P application might be due to the increased nutrient availability which was supplied by the organics and biofertilisers. Further it enabled the crop to accumulate greater amount of photosynthates by higher seed production. The present finding corroborates with the earlier report of Singaravel (1990) and Ram and Pareek (2000).

Nutrient uptake

In the present study, the increased uptake of NPK by sesame with the integrated P management was well evidenced (Table 2). The highest uptake of major nutrients was observed under 75 % P + humic acid coated P (T_2). The treatment T_2, recorded 1442.47 and 1232.49 mg pot^{-1} of N, 207.63 and 197.13 mg pot^{-1} of P, and 217.63 and 878.69 mg pot^{-1} of K by seed and stover, respectively. Enriched FYM at both the levels and phophobacterium application also proved their worthiness in increasing the uptake of nutrients. The increased nutrient uptake can be attributed to increased efficiency of sesame crop to utilize more nutrients because of increased growth and vigour when organics and biofertilizers were applied. The earlier reports of Babu (1989) and Ram and Pareek (2000) lend support to the present findings.

Post-harvest soil

Integrated application of P through organic forms of humic acid and enriched FYM accounted for a reduction in pH, EC and ESP (Table 3). In these treatments, the pH, EC and ESP ranged from 8.52 - 8.69, 1.21 - 1.32 dS m^{-1} and 21.56 - 24.62 as compared to 8.90, 1.65 dS m^{-1} and 28.74 in control. The improved soil properties might be due to the acid and organic complexes contributing for the improvement in physical properties with organics. The earlier report of Clarson *et al.* (1983) lent support to the present findings. The availability of NPK in the post-harvest soil was significantly improved with the integrated P application (Table 3). Application of 75 % P + 25 % P through humic acid coated P recorded the maximum available N (98.56 ppm), P (4.89 ppm) and K (133.72 ppm). The other treatments evaluated in the study i.e., enriched FYM and Phosphobacterium, also significantly increased the available nutrient status as compared to control. The improved availability of nutrients with humic acid treatment might be due to acidic nature and its effect on pH. Further, the humic acid have the myriad of functional groups which chelate the nutrient ions thereby preventing their precipitation in soil at high pH and increasing their availability (Decock, 1955).

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On-Farm Response of Rice-Rice Cropping System to N, P and K in Coastal Region

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An on-farm experiment on 100 farmers' fields was conducted during 2000-01 to 2002-03 to determine the response of rice –rice cropping system to applied nutrients in coastal area of Ernakulam (Kerala) and Ratnagiri (Maharashtra) falling in west coast and Ambasamundram, Viridhachalam (Tamil Nadu) and Ranital of (Orissa) in east coast areas of coastal ecosystem. In all, five treatments viz., control N, NP, NK and NPK were evaluated on 20 farmers fields in 5 districts and analyzed in simple randomized block design treating each location as replication. The systems yield increased from 2.8 to 4 t ha^{-1} in east coast and 1.9 to 4.5 t ha^{-1} in west coast with NPK treatment compared to control. Average yield responses of the systems were 5.6 kg grain kg^{-1} N, 9.2 kg grain kg^{-1} P_2O_5 and 10.9 kg grain kg^{-1} K_2O applied. The average economic responses were Rs. 4.7, 3.8 and 7.7 per rupee invested on N, P and K, respectively. But ecosystemwise, the response to N and K was more pronounced in west coast than that in east coast. However, the magnitude of response of rice-rice cropping system to applied K was more or less the same in both east and west coast areas.

(***Key words:*** *Nutrient response, Rice-rice cropping system, Economic response*)

At the present level of food production, the off-take of major (N+ P_2O_5 + K_2O) plant nutrients from Indian soils is about 25 million metric tonne (million mt), almost matching the present level of fertilizer consumption. In near future (2006-2007) such consumption will shoot up to 30 mmt vis-à-vis crop response to applied nutrients. It is possible to sustain high response if fertilizer regimes are updated regularly to maintain the congruence between demand and supply from soil and fertilizer (Dobermann *et al.*, 2000). The increase in nutrient use is considered to be positively related with increase in production and productivity of any crop and cropping system. Rice-rice system is the dominant system in coastal area with average productivity of about 3.2 t^{-1}ha^{-1}year^{-1}. In fact the yield potential of a cropping system is a function of several factors like choice of crop cultivars, nutrient status of soil, level of applied nutrient, management practices, etc. On the other hand, the response of a cropping system to applied nutrient principally depends on the soil nutrient status and the level of applied nutrient although the other factors like cultivars and management practices are also important. We must try to increase this response by exploiting the yield potential as much as possible.

In general, crop responses are reported based on the on-station experimental data. But, responses based on experiments on farmer's field have an added advantage for its validity and relevance. Such studies on rice-rice system to applied N, P and K have rarely been attempted. Therefore, the present experiment has been conducted with the objective to determine the response of rice-rice cropping system to applied nutrient like nitrogen, phosphorus and potassium, so that suitable management strategies may be followed by planners, researchers, extension workers and farmers to boost the crop production in coastal areas.

MATERIALS AND METHODS

The experiment was conducted on rice-rice cropping system during three consecutive years during 2000-01 and 2001-03 through five on-farm centers of AICRP on Cropping Systems under Project Directorate for Cropping Systems Research, Modipuram, Meerut. These trials were laid out in districts of Ernakulam (Kerala) and Ratnagiri (Maharashtra) of west coast and Ambasamudram (TN), Vriddhachalam (TN) and Ranital (Orissa) in east coast. The initial average values of pH, organic carbon, nitrogen, phosphorus and potash in the selected districts are given in Table 1. Five treatment viz., N, NP, NK, NPK and control were tested at 20 farmers fields at each centre, treating each field as replication, and analyzed using simple randomized block design. The rice varieties used at different locations were Jyothi in Enrnakulum (both the crops), Kajrat-2 (in *kharif*) and Kajrat-3 (in *rabi*) at Ratnagari, ASD-16 in Ambasamundaram (both the crops) CO-42 (in *kharif*) and CO-43 (in *rabi*) at Viridhachalam, and Swarna during *kharif* and Lalat in *rabi* at Ranital.

***Table 1**. Recommended doses of fertilizer applied and average initial soil fertility at different districts/ locations*

Centres/State	Fertilizer doses (N: P_2O_5: K_2O in kg ha^{-1})			Fertility status (N, P, K in kg ha^{-1})			
West coast region	1st crop	2nd crop	pH	OC (%)	N	P	K
Ernakulam (Kerala)	90:45:45	90:45:45	5.3	0.62	-	23	130
Ratnagiri (Maharashtra)	100:50:50	120:50:50	-	-	-	-	-
East coastal region							
Ambasamundram (TN)	125:50:50	150:60:60	6.9	0.72	271	61	341
Vridhachalam (TN)	150:50:50	120:40:40	7.8	-	255	28	243
Ranital (Orissa)	80:40:40	80:40:40	5.7	0.55	182	9	89

The response (agronomic efficiency) of N, P and K was calculated as given below:

$$\text{For N} = \frac{N^Y - O^Y}{N^L}, \text{For } P_2O_5 = \frac{NPK^Y - NK^Y}{P^L}, \text{For, } K_2O = \frac{NPK^Y - NP^Y}{K^L}$$

Here O^Y, N^Y, NP^Y, NK^Y and NPK^Y indicate the yield obtained at different levels of nutrients, and N^L, P^L, K^L indicate the levels of nutrients applied.

Response of crops in the rice-rice system to applied N was calculated by subtracting the yield under control from that under N treated plot. The response to N was calculated both for *kharif* and *rabi* rice. The sum of these responses divided by total amount of N applied during *kharif* and *rabi* was used to calculate the response of rice-rice cropping system in kg rice kg^{-1}N applied. Similarly, response of rice-rice system to applied P was calculated by subtracting the yield under NK from that under NPK treated plot for each of the crops of the system. By adding of these figures devided by total quantum of applied P gave rise to ultimate system response per kg P_2O_5 applied. NPK-NP =response to K for each rice crop. The total yield as obtained when divided by the total quantity of K applied to the system gave the system response per kg grain to applied K_2O. The economic response in rupees per rupee invested in fertilizer nutrient was calculated by converting the system response figures into monetary terms both for rice and nutrients. The planting dates and methods, number of irrigations, and other package of practices were as per recommendations. Statistical analysis was made as per standard methods.

RESULTS AND DISCUSSION

Systems yield

Application of N alone or in combination with P and K significantly increased the yield of rice crops during *kharif* and *rabi* (Table 2) when compared with control. The increase was maximum (4.5 tha^{-1}) when all major nutrient (NPK) applied in coastal district Ranital of Orissa representing north eastern coastal zone. The highest response in this zone was mainly attributed to low initial N, P, K content in the soil. In district Ambasamundram representing southern zone of Tamil Nadu, the increase in yield was upto

***Table 2**. Response of rice-rice system to applied nutrients*

Coastal area zone	Systems yield (t ha^{-1})					CD at P=0.05	Systems response (kg grain kg^{-1} nutrient)			Economic response (Rs Re^{-1} investment on nutrient)		
West coast region	N_0	N	NP	NK	NPK		N	P	K	N	P	K
Ernakulam (Kerala)	7.1	8.5	8.7	8.7	9.9	0.42	8.3	10.1	12.6	6.7	3.5	8.8
Ratnagiri (Maharashtra)	4.3	5.8	6.7	7.2	8.3	0.28	6.5	11.4	16.2	5.3	3.9	11.3
East coast region												
Ambasamundram (TN)	7.7	8.1	8.6	8.9	9.6	0.30	1.3	6.5	9.2	1.1	2.3	6.4
Vridhachalam (TN)	5.8	8.0	8.6	8.3	8.3	0.16	8.3	12.1	8.1	6.7	4.2	5.7
Ranital (Orissa)	5.0	6.5	8.2	8.0	9.5	0.31	3.7	8.9	8.5	3.5	5.3	6.1

1.9 tha^{-1} due to NPK application when compared with control. While, the response to NPK was upto 2.5 tha^{-1} in district Virdhachalam of Tamil Nadu representing north eastern zone of east coast (Table 2). In west coast district of Ernakulam of Kerala which represents midland coastal zone, the response to NPK was upto 1.8 tha^{-1} while it was upto 4.0 tha^{-1} in district Ratnagiri representing south Konkan coastal zone of Maharashtra.

It was clear to note that the application of each nutrient had significant effect on systems yield but increase was maximum when all the three nutrients (NPK) were applied. When analyzed over locations, the response of NPK treatment was 2.94 tha^{-1}. It was interesting to note that the yield under recommended dose of N and K was less than when N was applied alongwith P. Integrated nutrient use was advocated for coastal districts (Beena and Balachandram, 2002).

Economic response

In west coast area, the response of rice-rice system was judged to be 7.4 kg rice grain per kg nitrogen, 10.8 kg grain per kg phosphorus and 10 kg grain per kg potassium applied. On economic scale, there was a gain of Rs. 6.0 per rupee invested for N, Rs. 3.7 per rupee on P_2O_5 and Rs. 10.1 per rupee investment on K_2O clearly thereby showing more importance of N and K management.

In east coast, the average contribution of N, P_2O_5 and K_2O was adjudged to be 4.4, 9.2 and 8.6 kg grain on per kg of these nutrients, respectively. Similarly, the respective economic response was Rs. 3.8, Rs. 3.9 and Rs. 6.1 per rupee investment for N, P and K (Table 2). The general response to applied nutrients was more in west coast than that the east coast clearly indicating the need for effective nutrient management specially in coastal districts of Maharashtra in west and Orissa in the east coast.

It may be concluded that the effective nutrient management involving NPK in general and K in particular is desirable to obtain good yield from rice-rice system

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Effect of Concurrent Growing of Green Manure Crops on Nutrient Addition and Soil Fertility Status in Semidry Rice

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A field experiment was conducted during *kharif* 2002 at the Agricultural Research Station, Mannuthy, Kerala to study the influence of concurrent growing of different green manure crops on nutrient addition and soil fertility status in semidry rice. Results of the study revealed that concurrent growing of green manure crops has added substantial quantity of major nutrients and has thus significantly improved the fertility status. Cowpea was superior in nutrient addition and soil fertility build-up and hence was suitable during periods of normal monsoon. Horsegram, however, was found to be advantageous during periods of delayed monsoon.

(***Key words:*** *Concurrent green manuring, Semidry rice, Soil fertility*)

The importance of organic manuring in maintaining soil health, improving nutrient use efficiency and sustaining enhanced productivity in rice is well documented. Stagnant water normally facilitates effective incorporation and efficient decomposition of the added organic manures in lowland rice. But the absence of stagnant water in semidry rice during the initial 4-6 weeks causes serious problems with regard to application of organic manures, affecting the productivity adversely. To overcome the constraints in the incorporation and decomposition of organic manures in semidry rice, KAU (2002) has recommended concurrent growing of cowpea for green manure purpose exploiting the pre-monsoon showers. Cowpea, which is sown along with the rice, is incorporated by self decomposition at 4-6 weeks after sowing, when the water gets accumulated with the onset of south west monsoon. Though cowpea was found to be an ideal green manure crop for concurrently growing under favorable situations, it was found to have some disadvantages particularly when there is undue delay in the receipt of southwest monsoon. The trailing growth habit, poor susceptibility of the grown up plants to water stagnation, etc. are some such problems. The situation warrants further refinement of the technology including identification of appropriate green manure crop for the specific situations and hence the present study.

MATERIALS AND METHODS

The field experiment was conducted in semidry rice at Agricultural Research Station, Mannuthy during *kharif*, 2002. The soil of the experimental field was sandy clay loam in texture containing 0.66 percent organic carbon, 276 kg ha^{-1} available N, 19 kg ha^{-1} available P and 90 kg ha^{-1} available K. Fourteen treatments were laid out in randomised block design with three replications involving combinations of two green manure crops (cowpea and horsegram) for *in situ* green manuring by intercropping and six weed management treatments including four herbicides (butachlor @ 1.25 kg ai ha^{-1}, pendimethalin @ 1.50 kg ai ha^{-1}, pretilachlor @ 0.75 kg ai ha^{-1} and anilofos @ 0.40 kg ai ha^{-1}), a hand weeding and an unweeded control. Two control treatments with rice monocropping (hand weeding and no weeding) were also included. For intercropping, one row of green manure crop was dibbled between two rows of rice, which in turn was planted at a spacing of 20 x 10 cm. Pre-emergence herbicides were applied as per treatments on the second day of seeding. The cultural practices recommended by the Kerala Agricultural University (KAU, 2002) were followed uniformly. With the onset of southwest monsoon by around 55 days, water stagnated in the field and the green manure crops got completely decomposed and incorporated within a week.

RESULTS AND DISCUSSION

A comparison of the nutrient addition by the green manure crops at the time of self-decomposition indicated that the contribution of N, P and K by cowpea was almost double than that of horse gram (Table 1). It is a clear reflection of the increased production of biomass by cowpea, over horsegram, and is attributed to its quick growth rate in the early stages (Bridgit *et al.* (1994). Inspite of this, the

Table 1. *Nutrient addition and nutrient status of soil (kg ha*$^{-1}$*) as influenced by concurrent growing of green manure crops*

Particulars	Rice + cowpea	Rice + horse gram	Rice alone
Nutrient addition by green manure crops			
Nitrogen	103.7	56.2	-
Phosphorus	9.2	55.1	-
Potassium	5.8	28.2	-
Available nutrient status of the soil at the time of green manure incorporation			
Nitrogen	454.0	404.8	374.2
Phosphorus	30.3	223.1	26.8
Potassium	201.1	21.7	172.5
Available nutrient status of the soil after the crop			
Nitrogen	227.2	233.5	219.5
Phosphorus	16.0	83.9	15.3
Potassium	75.8	12.8	68.7

uptake of N, P and K by rice was found to be higher in the treatments intercropped with horsegram as compared to cowpea and this invariably resulted in increased yield of grain and straw in plots intercropped with horsegram. In the present study, there was a delay of around 10 days for water stagnation in the field due to delayed monsoon, leading to delay in the self-decomposition and incorporation of the green manure crops. This has led to overgrowth of cowpea causing competition to rice for nutrients, light and moisture. However, due to lesser growth rate, horsegram did not cause any competition to rice. So rice was fully benefited from concurrent cultivation of horsegram. The study thus revealed that under normal monsoons, cowpea is advantageous for intercropping as green manure crop. Under situations of delayed monsoon, horsegram is a better choice over cowpea.

Substantial buildup of soil fertility, with respect to NPK status, was observed in treatments involving intercropping, as compared to monoculture, immediately after the incorporation of the green manure crops (Table 1). The increase, on an average, was worked out to be 79.8, 8.6 and 50.6 kg ha^{-1} of N, P and K, respectively with respect to intercropping with cowpea. The corresponding values for horsegram intercropping were 30.5, 5.2 and 28.6 kg ha^{-1}, respectively.

Analysis of the nutrient status of the soil after the harvest of the crop indicated the continued superiority of treatments involving intercropping of green manure crops in respect of all the three major nutrients (Table 1). This indicated the positive influence of intercropping green manure crops in sustaining the nutrient status of rice soils, with the possibility of enhanced rice productivity in the succeeding rice. Increase in soil fertility status due to intercropping of green manure crops was reported by several workers (Sharma *et al.*, 2000).

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Residual Effect of Gypsum and FYM Application at Varying Leaching Levels on Yield and Nutrient Uptake by Fodder Sorghum

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A pot experiment was conducted to test the residual effect of FYM (F) and gypsum (G) at varying levels of leaching in factorial CRD with fodder sorghum. The results revealed positive and significant residual effect of F and G on germination, plant height, fodder yield of sorghum, as well as on EC and ESP of soil after harvest of the crop, but not on pH of the soil at 0-15 cm soil due to F. The uptake of almost all the nutrients by fodder sorghum was influenced significantly due to the residual effect of F and G, increased with increase at the individual element level, except Na, which decreased significantly. Similarly, plant height, fodder sorghum yield and uptake of nutrients were influenced significantly and found higher with leaching level, but reverse was true in case of Na concentration in fodder as well as EC, pH and ESP of soil.

*(**Key words** : Residual effect of gypsum, FYM, Saline-sodic soil, Fodder sorghum, Nutrient uptake, Soil chemical properties)*

Gypsum and FYM have been found to be beneficial (Singaravel *et al.*, 2001) and proved more effective in reduction of EC and ESP level in soil under higher levels of leaching (Polara *et al.*, 2002). The information on residual effect of soil amendments under varying leaching levels which reclaiming saline-sodic soils, and their effect on yield of crop and nutrient uptake is rather limited. Therefore, the present investigation was undertaken.

MATERIALS AND METHODS

A pot experiment was conducted with two levels of FYM (F_0: 0 and F_1: 25 Mg ha^{-1}), five levels of gypsum application (G_0: No gypsum, G_1: 25 % GR, G_2: 50 % GR, G_3: 75 % GR and G_4: 100 % GR), and three levels of leaching (L_1: 50 to 100% WHC, L_2: 50 to 150 % WHC, and L_3: 50 to 200 % WHC) in a factorial CRD. Sorghum crop as fodder (cv. GFSH 1) was grown (Polara *et al.*, 2002) with application of recommended dose of 80 ppm N and 40 ppm P_2O_5. Twenty seeds of sorghum were sown, which were thinned to five plants. A measured quantity of good quality water was applied to sorghum crop as per treatments i.e., L_1= 2.66, L_2 = 4.00 and L_3=5.32 liters per pot. The crop was irrigated when water-holding capacity reached upto 50 per cent (18.5 % moisture). At 70 days after sowing crop was harvested and treatmentwise stover and soil samples were collected. The soil samples were analyzed for pH, EC and ESP adopting the standard procedure (Jackson, 1973). The stover samples were analyzed for the various nutrient content and their uptake were calculated.

RESULTS AND DISCUSSION

The results (Table 1) revealed that L, F and G significantly influenced the germination percent, plant height and yield of fodder sorghum, except effect of L on germination percent. Sorghum stover yield increased significantly with increased levels of leaching. The beneficial effect of these treatments on crop yield was associated with improvement of soil properties due to L as evident from the data on EC and ESP of soil (Table 1). Similar results were also reported by Talati *et al.* (1983).

The residual effect of FYM registered significantly higher germination percent, plant height and yield of fodder sorghum and decreased EC and ESP values of soil (Table 1). The residual effect of gypsum at G_2 level registered significantly higher germination percent over G_0. With increase in gypsum levels, plant height and stover yield of sorghum increased significantly upto G_3 level. The results are in agreement with those of Singaravel *et al.* (2001).

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Table 1. *Residual effect of treatments on sorghum yield and chemical properties of soil*

Treatment	Germination (%)	Plant height (cm)	Sorghum yield (g/pot)	Chemical properties of soil					
				$EC_{2.5}$ (dS/m)		pH		ESP	
				0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
L_1	73.2	37.8	16.26	0.23	0.38	8.00	8.25	8.17	19.25
L_2	76.8	42.6	21.98	0.20	0.25	8.00	8.14	6.72	12.42
L_3	76.8	44.1	23.47	0.19	0.21	7.93	8.15	6.08	11.22
SEm±	1.4	0.6	0.33	0.003	0.003	0.03	0.022	0.15	0.35
CD(P=0.05)	NS	1.6	0.94	0.008	0.009	0.09	0.06	0.43	1.01
F_0	73.7	37.4	18.80	0.22	0.30	7.98	8.22	7.65	15.46
F_1	77.6	45.5	22.34	0.20	0.26	7.96	8.14	6.32	13.13
SEm±	1.2	0.4	0.27	0.002	0.002	0.02	0.018	0.12	0.29
CD(P=0.05)	3.3	1.3	0.77	0.006	0.007	NS	0.052	0.35	0.83
G_0	69.4	36.8	16.00	0.25	0.37	8.20	8.36	12.50	22.42
G_1	72.5	38.8	16.74	0.22	0.31	8.08	8.27	7.49	17.94
G_2	76.1	41.6	22.01	0.20	0.26	7.90	8.15	5.75	12.03
G_3	80.0	44.7	23.69	0.19	0.23	7.83	8.11	4.88	10.20
G_4	80.0	45.8	24.40	0.18	0.22	7.84	8.01	4.32	8.87
SEm±	1.8	0.7	0.43	0.004	0.004	0.004	0.03	0.19	0.46
CD (P=0.05)	5.3	2.0	1.21	0.01	0.011	0.13	0.08	0.56	1.31
Initial after harvest of wheat				0.38	—	8.10	—	12.1	—

Table 2. *Residual effect of different treatments on nutrient uptake (mg/pot) by fodder sorghum*

Treatments	N	P	K	Ca	Mg	S	Na	Fe	Mn	Zn	Cu
L_1	270	11.1	197	105	39.2	17.1	36.2	2.24	1.26	0.45	0.393
L_2	383	15.2	269	156	53.9	23.5	45.2	3.17	1.72	0.67	0.576
L_3	420	16.6	301	172	59.0	25.6	45.6	3.47	1.93	0.72	0.643
SEm±	6.7	0.32	6.3	3.3	1.6	0.48	1.13	0.05	0.03	0.014	0.018
CD(P=0.05)	19.0	0.91	17.8	9.5	4.4	1.36	3.20	0.15	0.09	0.040	0.051
F_0	315	12.4	216	125	45.0	19.7	40.6	2.68	1.46	0.53	0.457
F_1	400	16.3	295	163	56.5	24.4	44.0	3.23	1.81	0.70	0.618
SEm±	5.5	0.26	5.1	2.7	1.3	0.39	0.93	0.04	0.03	0.012	0.015
CD(P=0.05)	15.6	0.74	14.5	7.7	3.6	1.11	2.62	0.12	0.07	0.033	0.042
G_0	260	11.6	191	86	37.7	15.2	37.9	2.23	1.16	0.43	0.396
G_1	285	12.6	201	106	40.3	17.3	36.7	2.36	1.31	0.49	0.421
G_2	383	17.5	267	152	55.9	23.9	45.5	3.15	1.77	0.67	0.571
G_3	417	19.3	305	183	60.7	26.5	46.1	3.44	1.97	0.73	0.634
G_4	441	20.4	314	194	59.0	27.4	45.5	3.61	1.98	0.76	0.665
SEm±	8.7	0.42	8.1	4.3	2.01	0.62	1.46	0.07	0.04	0.018	0.023
CD (P=0.05)	24.6	1.17	22.9	12.2	5.70	1.76	4.14	0.19	0.12	0.053	0.066

The electrical conductivity, pH and ESP of the soils were found to decrease significantly with increase in the levels of FYM and gypsum, except soil pH with FYM (Table 1). Each level of leaching significantly decreased the EC, pH and ESP values of soil. These results are in agreement with the findings of Sigaravel *et al.* (2001).

The data (Table 2) revealed that the uptake of all the nutrients by fodder sorghum increased significantly with increasing level of leaching, except in case of Na, where L_3 was at par with L_2. The residual effect of FYM on nutrient uptake by fodder sorghum was significant for all the elements. These results are in conformity with the work of Mahajan *et al.* (1989). The residual effect of gypsum produced beneficial effects on uptake of all the nutrients by fodder sorghum. For almost all the nutrients, uptake was significant higher with G_4 level, which was at par with G_3 level.

From the above results, it can be concluded that germination percentage, plant height, fodder yield of sorghum and uptake of nutrients influenced significantly by the residual effect of FYM and gypsum and found maximum at its higher level.

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Weed Diversity in the Lowland Rice Ecosystems of Kerala

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Weeds form one of the major pests of rice in the lowland rice ecosystems of Kerala namely, the *kole lands* and *kuttanad*, causing about one-third yield reduction. A survey on the weed flora of these rice ecosystems was conducted during 2001. Among the grass weeds *Echinochloa stagnina* and *Echinochloa crusgalli* were the main weeds. The main sedges were *Fimbristylis miliacea, Cyperus iria* and *Cyperus difformis* while *Ludwigia parviflora* and *Monochoria vaginalis* were the major broad leaf weeds. The sedge *Eleocharis dulcis* was the weed with maximum abundance in the highly acidic *kari* soils. Among the few ferns noticed, *Marsilea quadrifolia* was present in all the regions while the alien invasive weed *Salvinia molesta* was a problem in the *kuttanad*.

(Key words: *Weed diversity, Lowland rice)*

Kerala has a long coastal line characterized by saline water intrusion, backwater systems and deltaic formations, which have resulted in a unique lowland ecosystem where rice alone could be cultivated. Kuttanad, the rice bowl of Kerala, forming the interface of marine, estuarine and fluvial systems, represents a highly complex ecosystem. It is a deltaic formation of four river systems together with the lowlying areas in and around Vembanad lake. The whole of Kuttanad area practically lies 1-2.5 m below mean sea level, and is subjected to continued flood submergence during the monsoon. Saline water ingression is a problem during the summer months. The *Kole* lands, which form the rice granary of Thrissur and Malappuram districts, are lowlying tracts extending over an area of 13,000 ha and is located 0.5 to 1m below mean sea level. The major portion of the area lies submerged for about six months in a year by the periodical inundation of floodwater. Acidity, salinity, poor drainage and presence of toxic salts make soils of this tract very unique. The physicochemical characteristics and morphology of the soils of *Kole* lands reveal close similarities to those of *Kari* soils of Kuttanad (Johnkutty and Venugopal, 1993).

Due to the continuous availability of water, weeds form one of the major pests of rice in these lowlands causing about one third yield reduction. Characterizing and understanding the spatial and temporal distribution of weed population in these rice ecosystems will help in the formulation of weed management practices. Therefore a study was conducted to understand the diversity in the major lowland rice ecosystems of Kerala namely, the *kuttanad* and *kole* lands.

MATERIALS AND METHODS

A survey was conducted across the major lowland rice ecosystem of Kerala viz.,*Kari*, *Karappadam* and *Kayal* lands of Kuttanad region. In each rice ecosystem, 20 sites in farmers field were selected. In each site, specieswise count of weeds was taken from three spots using a quadrat of 1m x 1m size and the average was recorded. To understand the distribution and dynamics of the weeds, weed vegetation parameters such as frequency, density, relative frequency, relative density and relative importance value (RIV) were worked (Wentworth *et al.,* 1984) separately for each region. Distinct characteristics of the ecosystems are :

1. **Kuttanad** : Lies 1-2.5 m below mean sea level. There are three classes of soils.

   a) ***Kari* soils:** Heavy ill drained soil with high organic matter content (10-30%). Highly acidic (pH 2.8-5.3) and periodically inundated with saline water (EC 4.6-6 dSm^{-1}).

   b) ***Kayal* soils:** Lies 1.5-2 m below mean sea level, submerged for 5-6 months slightly acidic (pH 4.5-6.1) to neutral and occasionally saline due to salt intrusion. EC (2.6-3.9 dSm^{-1}).

   c) ***Karappadam* soils:** Occur along the inland waterways and rivers. Highly acidic (pH 2.8 to 5.5) with high salt content (EC 2.4 to 3.6 dSm^{-1}).

2. ***Kolelands*:** Heavy soils rich in clay and organic matter (1.97 to 5.58 %), acidic (pH 2.6 to 6.3), EC ranges from 0.16 to 15 dSm^{-1}. High EC values noticed in areas vulnerable to seawater inundation.

RESULTS AND DISCUSSION

The species level analysis of the grass weed composition of *Kuttanad* revealed the presence of *Echinochloa stagnina, Echinochloa crusgalli, Oryza rufipogon* and *Isachne miliacea* as the most important grass weeds (Table 1). Among them, *Echinochloa stagnina* had the highest RIV indicating that it was the most dominant weed in the *Kari, Kayal* and *Karappadam* lands. In the *kolelands* also *E. stagnina* predominates with RIV of 18.93.

All these regions lie in the backwater areas, which are subjected to tidal action occasionally, and therefore the soil is slightly saline in nature. The occurrence of *E. stagnina* in the deepwater rice crop of *Kuttanad* also indicates its preference to water stagnation. Many workers have also reported *E. stagnina* as the dominant weed associated with deepwater rice (DeDatta, 1981, Abraham *et al.*, 1993).

Across the *Kari* lands of Kuttanad, *Eleocharis dulcis* had the highest RIV (14) among the sedges, and was the most important weed in terms of density (22 plants m^{-2}) and frequency (35%). Unlike the *Kayal* and *Karappadam* lands, the *Kari* lands of Kuttanad, which lie 1.5m below MSL, has very high content of unhumified organic matter and very low pH. Toxic proportions of Fe, Al and Mn are seen in these soils. The *Kari* soils come under the great group sulfaquent, and subgroup typic sulfaquent due to the presence of sulphidic materials within 50 cm of the mineral soil surface (Padmaja *et al.*, 1994).

In an earlier study on weed flora of Kuttanad region, Sasidahran *et al.* (1993) noticed that in *Kari* soils *Eleocharis plantagenia* (*E.dulcis*) was the only species found surviving in certain patches where the rice seedlings succumbed to extremely low pH. They observed a significant negative correlation between soil pH and population of *E. plantaginea*. Experiments conducted in the acid sulphate soils of Mekong delta of Vietnam also showed dominance of *Eleocharis* sp. in the highly organic and hydromorphic, hydraquentic sulfaquepts soils found at sites 75 cm below MSL (Husson *et al.*, 2000). Thus, it can be concluded that the high abundance of *Eleocharis dulcis* in an area may be an indication of the high acidity of the soil.

Among the sedges, *Fimbristylis miliacea* and *Cyperus sp* had cosmopolitan occurrence while, *Rhynchospora corymbosa* was noticed only in the *Kari* soil of *Kuttanad*. Chikoye and Ekeleme (2001) reported that many of the sedges occurred in high frequencies and densities making them the world's worst weeds in many crops.

Among the broad leaf weeds, the occurrence of Limnocharis flava in the Kole lands of Thrissur and the Kari and Karappadam lands of Kuttanad was noteworthy. Cook (1996) reported that this weed has assumed the status of a pest in South India due to its large population. *Eichhornia crassipes, Monochoria vaginalis* and *Nymphaea nouchali* were the weeds typically adapted to the waterlogged areas of Kari, Kayal and Karappadam lands.

Table 1. *Major weeds in the different rice ecosystems of Kerala*

Eco-system	Grasses	Sedges	Broad leaf weeds	Ferns
Kari lands	*Echinochloa stagnina*(18.93)*	*Eleocharis dulcis* (14.07)	*Monochoria vaginalis* (9)	*Salvinia molesta* (8.03)
	Oryza rufipogon (6.29)	*Fimbristylis miliacea* (9.43)	*Ludwigia parviflora* (6)	
	Isachne miliacea (3.9)	*Cyperus iria* (4.55)	*Limnocharis flava* (4.9)	
	Echinochloa crusgalli (3.0)	Rhynchospora corymbosa (4.11)	*Nymphaea nouchali* (4.1)	
			Eichhornia crassipes (3.66)	
			Ipomoea aquatica (2.33)	
Kayal lands	*Echinochloa stagnina* (15.93)	*Fimbristylis miliacea* (8.92)	*Ludwigia parviflora* (6.78)	*Salvinia molesta* (15.37)
	Echinochloa crusgalli (10.2)	*Cyperus pangorei* (6.29)	*Eichhornia crassipes* (6.58)	*Marsilea quadrifolia* (3.85)
	Sacciolepis sp. (7.09)		*Monochoria vaginalis* (6.2)	*Ceratopteris thalictroides* (2.40)
	Oryza rufipogon (5.55)		*Nymphaea nouchali* (4.68)	
			Lindernia crustacea (2.97)	
Karap padam lands	*Echinochloa stagnina* (15.88)	*Fimbristylis miliacea* (9.53)	*Monochoria vaginalis* (12.86)	*Salvinia molesta* (6.92)
	Isachne miliacea (9.63)	*Cyperus difformis* (8.66)	*Nymphaea nouchali* (9.63)	*Marsilea quadrifolia* (6.92)
	Oryza rufipogon (3.90)	*Eleocharis dulcis* (1.47)	*Limnocharis flava* (4.99)	
	Echinochloa crusgalli (1.47)		*Ludwigia parviflora* (4.41)	

*Values in the parenthesis are the RIV

Salvinia molesta, Marsilea quadrifolia and *Ceratopteris thalictroides* were the ferns present in the *Kuttanad* ecosystems. *Salvinia molesta* is a floating weed and needs water for its survival. The backwater of *Kuttanad* as well as that in other rice ecosystems faces serious threat from this alien invasive fern.

The study showed that although the main weeds were common between these ecosystems, some difference was noticed in the *kari* lands where the presence of *Eleocharis dulcis* was very prominent. Among the grass weeds *Echinochloa stagnina* and *Echinochloa crusgalli* were the main weeds. Sedges were predominated by *Fimbristylis miliacea, Cyperus iria* and *Cyperus difformis* while, *Ludwigia parviflora* and *Monochoria vaginalis* were the major broad leaf weeds. Among the few ferns noticed *Marsilea quadrifolia* was present in all the regions.

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Performance of Water Chestnut at Farmers Field in Coastal Area in Orissa

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As a part of crop diversification programme in waterlogged areas attempts were made to popularize water chestnut cultivation in supercyclone hit waterlogged area of Erasama in Jagatsinghpur district. Planting was done at seven water bodies in farmers field. Out of seven places, cultivation was successful in three places. In four places salinity level was relatively high (3-8.8 ppt) and crop did not grow well. The dissolved oxygen content, pH and temperature did not vary significantly in different places initially during monsoon. After recession of monsoon salinity increased appreciably in one place and crop growth was poor. Leaf area development over surface of water significantly decreased dissolved oxygen concentration. The productivity of nuts on an average ranged between 7.32 to 8.87 t ha^{-1}.

*(**Key words** : Water chestnut, Salinity, Leaf area, Yield of nuts)*

The water chestnut (*Trapa bispinosa* Roxb.), properly known locally as 'pani phal' or 'singhara', is one of the few neglected but ecnomically important aquatic horticultural crops grown in different parts of Bihar, Uttar Pradesh, West Bengal and Orissa (Ahmed and Singh, 1999, Banerjee and Thakur, 1980, Hazra *et al.*, 1996), etc. The crop is commonly grown mainly in the railway track side depressions or highway side depressions. Accumulation of water over vast tract of topographical depressions and poor drainage caused large part of our coastal land unfavourable for cultivation. Ingression of sea water in such depressions at times leads to salinity related problems. Thus water chestnut cultivation was attempted in farmers fields in coastal part of Ersama in supercyclone hit Jagatsinghpur district to assess their performance in relation to environmental condition of the growing aquatic environment.

MATERIALS AND METHODS

Seven farmers fields were was selected for cultivation of water chestnut. The average area of the eater bodies ranged between 125 to 300 sq m. The crop was planted during mid-June in 2002 ensuring full water in the water bodies. Both green varieties, Haldipada green and red variety, Haldipada red were planted in each pond in 1:1ratio. The vine of three seedlings at a time was tied loosely together and the knot was gently buried into mud bottom of the pond with the help of toe. The planting was done at a spacing of 1.5m X 1.5 m. The compost was applied @ 8 t ha^{-1} before planting. The N:P:K fertilizer @ 40:60:40 were applied in three splits. The one-third of N as urea and K as muriate of potash with full P as single superphosphate were applied as basal. The rest two-third N and K was applied in two splits at two and four months after planting. To minimise the infestation of singhara beetle (*Calerucella birmanica*) sevin @ of 1.5 kg ha^{-1} was applied three times from third month onward as and when infestation appeared.

The dissolved oxygen content and temperature of water were recorded with a YSI 550 hand held dissolved oxygen and temperature system (YSI Inc., Yellow Spring, Ohio, USA[1]). The data on plant height was recorded by uprooting plant from bottom of the water body which represented the length of main shoot. The pH of the water bodies was measured with a hand held portable pH meter (Hanna Instruments, Portugal[1]). The salinity of water was monitored using a salinity refractometer (Atago-10, Japan[1]) following standard method (Biswas, 1993).

RESULTS AND DISCUSSIONS

As observed from the data, out of the seven fields monitored, field nos., 6 and 7 showed good growth of water chestnut crop. Four ponds did not show crop growth at all. The field no. 2 showed very high salinity level of 8.2 ppt at the beginning of the experiment (Table 1) and maintained the high level throughout till December. The pond nos. 1, 3 and 4 also maintained higher level of salinity compared to other ponds. From the beginning itself salinity level in the pond nos. 5,6 and 7 was lowest and it declined further with the onset of monsoon. Initially, there

[1]Does not indicate preferential suggestion for the manufacturer

Table 1. *Water quality parameters at different dates in farmer fields' water bodies*

Parameter	Field / Plot no.																											
	1				2				3				4				5				6				7			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
pH	7.08	6.98	6.9	6.7	7.10	7.02	6.8	6.5	6.98	6.96	7.1	7.1	7.84	7.84	7.2	7.2	7.12	7.06	7.1	6.9	7.14	7.11	6.9	6.8	7.05	6.95	7.2	6.8
Dissolved O_2 (mg/lit) at 30 cm depth	6.3	6.2	6.8	6.1	6.4	5.9	6.0	6.3	6.2	6.2	6.3	8.50	6.3	6.4	6.4	8.50	6.2	6.1	5.5	4.56	6.0	6.1	6.4	5.56	6.4	6.3	5.1	5.12
Dissolved O_2 (mg/lit) at 60 cm depth	5.9	6.0	5.3	5.8	5.3	5.9	6.0	5.9	5.9	6.1	5.9	5.10	5.6	5.9	6.1	5.2	6.0	6.0	4.3	3.53	5.8	5.9	5.1	4.63	5.9	5.9	4.5	2.69
Temperature °C at 30 cm depth	32.6	33.1	31.6	32.1	33.2	32.8	32.1	31.9	33.6	33.0	31.3	32.3	33.9	32.6	31.2	32.0	33.8	33	31.9	32.4	34.0	33.0	31.6	32.1	34.0	33.4	31.5	32.4
Temperature °C at 60 cm depth	32.0	32.0	30.9	30.6	32.1	32.0	31.7	30.5	32.0	32.6	30.5	30.1	31.8	31.4	30.7	30.1	32.5	32.3	31.0	28.6	33.2	31.9	30.4	29.3	32.6	32.4	30.9	29.3
Salinity, ppt	2.5	2.2	2.0	2.3	8.2	9.2	8.0	6	1.6	1.6	1.0	1.2	3.2	3	2.8	2.4	0.8	1.1	0.4	0.5	0.6	1.2	0.2	0.2	0.5	0.4	0	0

A, 14.6.2002; B, 27.6.2002; C, 27.9.2002; D, 28.10.2002

Table 2. Leaf area development (cm²/plant) and total fruit yield (t/ha) in water chestnut in farmers field at Ersama

Parameters	Water body no.		
	5	6	7
Leaf area on 14.6.03	300.54 (±5.57)	360.15 (±13.41)	375.39 (±7.81)
Leaf area on 26.6.03	578.43 (±8.59)	620.68 (±5.59)	631.51 (±7.11)
Leaf area on 26 9.03	1835.12 (±44.71)	2122.10 (±77.74)	1952.56 (±26.72)
Leaf area on 26.10 03	2125.66 (±38.59)	2219.15 (±39.25)	2996.15 (±43.10)
Yield	7.32 (±0.41)	7.56 (±0.24)	8.88 (±0.31)

Values in parantheses are SE±, each is a mean of 3 observations

was no significant variation in dissolved oxygen level and temperature of the water body both at 30 and 60 cm depths. As expected the DO level at deeper level was always lower by 0.2 - 0.5 m gl^{-1} in all the water bodies. However, with the development of canopy DO level decreased significantly in field nos. 5,6 and 7 compared to other water bodies particularly in 7 (Table 1).

At the start of the experiment the leaf area increased slowly as the branching of the plants were limited till second month of the crop (Table 2). Thereafter leaf area increased rapidly with profuse branching of the plants at 3rd and 4th month stage of the crop. The crop started yielding fruits from mid-October till December. For recording fruit yield two sq.meter area in each water body was marked in three places in each field. The cumulative yield for each periodical harvest at an interval of ten days was summed up to find out final yield. The yield in field 7 was found significantly higher compared to other ponds (Table 2).

From above experiment it was apparent that water chestnut could be a viable crop in the coastal waterlogged area mainly in non-saline environment. Salinity does not favour the crop growth and finally afftects yield. However, detailed study may be taken up to find out threshold level of salinity critical for crop growth and yield.

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Session
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Organic System of Rearing Ducks in Post-harvest Paddy Fields in Kerala

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Kuttanad ducks are widely accepted by duck farmers of Kerala because of its excellent egg and meat qualities. The pesticide contamination from both fallen grains and biologicals from the field was below the safe level as indicated by WHO. These results clearly indicated that if scientific interventions are started in these areas for integrated pest management programmes (IPM) using ducks, there are possibilities for lowering the present level of pesticide and herbicide applications with the benefits of reducing costs of fertilizers, pesticides and labour. The ingredients used for the preparation of indigenous medication Madhurakazhayam (*Acorus calamun* L.100 g, *Curcuma longa* 20 g, *Piper nigrum* 20 g, *Borassus flabellifer* 300 g and water 5 l) and Antipyretic mixture (*Piper nigrum* 250g, *Curcuma longa* 2500 g, Calcium hydroxide 750 g, *Azadiracta indica* 1500 g, and *Cocos nucifera* 1000 g) are cheap and locally available. These indigenous medications are very effective to boost the immunity of ducklings without any side effects and leave no residues in duck egg and meat.

The overall results clearly indicated that the present system of rearing ducks in Kerala is a potential method of organic duck production. The socioeconomic profile of farmers is conducive for organic system of duck production as the enterprise is dependent largely upon natural methods of rearing, feeding and management.

***(Key words:** Duck rearing, Organic system, Organic system, Indigenous knowledge, Pesticide residue)*

A unique system of duck rearing is practised in Kerala utilizing the indigenous ducks under foraging system of management. The paddy fields in Kerala after harvest forms a potential and low cost-feed resources for the herded ducks. It is assumed that 5000 layer ducks consume approximately one metric tonne of feed resources from the foraging fields every day. This ecofriendly farming system has been in vogue for more than a century in South Indian States. During the course of their feeding, ducks perform valuable functions such as utilisation of fallen-waste grains, control of pests and enrich fields with manure. Duck rearing provides self-employment, helps in poverty alleviation and nutritional security among farmers (Ravindran, 1983).

The duck population in India (24 million) constitutes 8.5% of the total poultry population and ranks second in position next to chicken. Kerala has a duck population of 1.19 million in a land area of 38863 sq km. Bhat *et al.* (1980) listed 24 breeds and 34 varieties of indigenous ducks in India, but the Kuttanad ducks of Kerala were not included. There are two varieties in Kuttanad ducks namely, Chara and Chemballi (Leo *et al.*, 2003). These varieties are well adapted to the tropical climates and are extensively used by the farmers. Inland freshwater bodies and plenty of canals in the Kuttanad region of Kerala favour large scale duckling production.

In the present context, organic farming and ecological agriculture is gaining importance worldwide. In several countries duck production is integrated with wetland rice farming (Farrell, 1997). In Japan, rice-duck farming practice was promoted by allowing wild ducks into rice fields (Manda, 1992) and this practice was revived to fit into organic farming (Furuno, 1996). In integrated systems, ducks are used for biocontrol of weeds and insect pests, and to control the exotic herbivorous snail populations. Ducks dig up the weed seedling using their feet thereby oxygenating the water and encouraging the roots of the rice plants to grow more efficiently. The present study was carried out to document the existing system of duck rearing in Kerala. The pesticide contamination in the natural feed resources of ducks was also assessed by estimating the pesticide residues in crop contents of foraging ducks.

MATERIALS AND METHODS

Studies were conducted at three major duck rearing centres in Kerala viz., Alappuzha, Thrissur and Palakkad Districts to assess the pattern of duck growing operations in the State. A survey was conducted among progressive farmers in these regions in order to evaluate level of organic components and major constraints involved in the existing duck farming system. Two hundred farmers who were actually engaged in duck rearing were selected for the sample survey. The selection of respondents was made by Accidental Sampling Procedure (ASP) with three criteria viz., literacy of farmers, size of land holdings, and flock size. Primary and secondary data with regard to the extent of the organic methods of duck and rice farming enterprises in the study area were considered for preparing the interview schedule. Literacy level of farmers, experience in duck rearing, flock size, duck variety preference, awareness about the usage of pesticides, impact of pesticide usage with respect to duck foraging, production potential of Kuttanad ducks, role of foraging ducks in biological pest control, and existing farming practices were included in the interview schedule. They were selected to follow a method of Nominal Group Technique (NGT) to collect data on duck farming. After refining the questions, it was pre-tested in a non-study area. The interview schedule comprised both socioeconomic status of farmers and husbandry practices on duck farming. In addition, group discussion, interview, farmers counselling and field visits were carried out to understand the indigenous practices and scientific knowledge adopted in duck rearing systems. The data collected were tabulated in tally sheets, categorized and filled into tables to facilitate interpretation of findings.

In order to assess the pesticide residue in feed materials of foraging ducks in Kerala, ten layer ducks were randomly selected from the field and their crop alongwith contents were removed immediately and preserved in ice and transported to laboratory for detailed analysis. The level of organochlorine residue in crop contents was detected using Gas Liquid Chromatography (GLC) (FDA, 1977, Sherma, 1979). Specific clean up procedures were utilized for complete removal of interfering impurities and extraction of pesticide residues from the collected samples before introduction into the gas liquid chromatograph (GLC).

RESULTS AND DISCUSSION

The results revealed that literacy level of duck farmers were 98 % (only 2 % illiterate) of which only 20 % were having lower primary education and 78 % had primary education. This result concludes that the farmers engaged in duck farming were literate with awareness of advantages of natural methods of farming. More than three-fourth of the farmers were having the experience in duck rearing for 5-30 years. The flock size in 65 % of duck farmers were 1000 to 5000 indicating the heavy flock size in the fields but majority of farmers have land holdings below 20 cents.

Foraging in the fields before the panicle initiation stage in paddy will be of great help to the existing system of duck rearing in the State. This practice would check the common pests and diseases in the paddy fields, thereby it can be utilised for the biological control of pests. This observation was fully endorsed by the rice growing farmers of Kuttanad region and is in agreement with Manda (1992) and Furuno (1996) who reported that duck farming is beneficial in the control of weeds and insect pests. The rice cultivators were also aware about the increased water aeration, soil fertility and control herbs by mulching.

Farmers prefer indigenous varieties of Kuttanad ducks, because they are hardy, acclimatised to the local conditions and are good producers of meat and egg, and this opinion of farmers is in agreement with Jalaludeen *et al.* (2003) and Peethambaran *et al.* (2003). The annual egg production of Kuttanad ducks averaged 180 eggs per duck. Majority of farmers adopted traditional methods of preventive medications and they limit the use of modern medicines. The major indigenous medication practices that are being followed were Madhurakazhayam, the medicated water for baby ducklings, and another traditional antipyretic mixture commonly used for alleviation of fever and respiratory infection in adult birds. The ingredients used for the preparation of indigenous medication Madhurakazhayam (*Acorus calamun L.* 100 g, *Curcuma longa* 20 g, *Piper nigrum* 20 g, *Borassus flabellifer* 300 g and Water 5 l) and Antipyretic mixture (*Piper nigrum* 250g, *Curcuma longa* 2500 g, Calcium hydroxide750 g, *Azadiracta indica* 1500 g, and *Cocos nucifera* 1000 g) are cheap and locally available. These indigenous medications are very effective to boost the immunity of ducklings without any side effects and leave no residues in duck egg and meat.

Table 1. *Organochlorine levels in crop contents of foraging ducks in Palakkad and Thrissur*

Sl. No.	Item	Level (ppm)
1.	α - HCH	0.00082532
2.	β - HCH	0.004217
3.	δ - HCH	0.00124
4.	γ - HCH	0.0016
5.	Total HCH	0.007882
6.	Dicofol	0.021
7.	Alpha endosulphan	0.008

Ninety percent of the duck farmers believe that pesticide application is very high in the paddy fields. Foraging ducks in certain fields were prone to diseases consequent to high application of pesticides in rice fields. More than 74 % of the farmers opined that over-usage of pesticides in the fields is a threat for organic duck rearing. They pointed out that in such fields, populations of fish, crab, earthworms, molluscs, etc. are declining. Foraging in such fields lead to sudden and heavy mortality in ducks. Rice farmers pointed out that the major constraint in extensive duck farming is the large flock size. As voracious feeders, ducks are able to digest almost all the seeds picked from the fields. The level of organochlorine contamination detected in the crop contents collected from foraging layer ducks was within the safe level (Table 1) as indicated by WHO (Saltmarsh, 1998).

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J. Indian Soc. Coastal agric. Res., 22(1&2), 274-284, 2004 **Invited paper**

Fish Feeds and their Quality Attributes with Reference to High Yielding Aquaculture

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To maintain current high growth rate, quality assurances of feed ingredients is of utmost importance. Fish feeding has impact on several quality parameters like w_3 HUFA and vitamin B_{12} in particular. In regard to health and disease resistance, several nutrients and feed additives are known to affect immune response in fish. In this context regionwise resource mapping of feed ingredient availability, development of quality control guidelines and availability of infrastructure for proper processing and storage of feed is important. Establishment of a national facility for testing of feed will help to ensure consistency in feed quality. Appropriate technologies for evaluation of feed ingredient quality, exact formulation and right kind of feed management practices form the prerequisite for getting the best output from feed application in fish production. The quality of feed is a function of how well it meets the nutritional requirements of the cultured fish. This in turn is a function of the nutritional profile of feed and bioavailability of the nutrients. The biological performance of feed may be hindered by the reduced availability of nutrients for lack of proper processing technology. The improved processing technological means for example extrusion cooking clearly indicate the better performance of feed. Application of this technology not only helps in eliminating antinutritional factors, pathogens but also improve starch digestibility and physical properties like water stability, texture of the feed; the utilization of vegetable proteins is also enhanced by extrusion, reducing the impact of feed on ambient water. Therefore, long term sustainability and future aquaculture expansion should probably be aimed at development of farming system, which improves the overall efficiency of resource use and are based upon primary renewable resources. This will be both economically and ecologically viable. Feed formulation and selection of ingredients should be carried out carefully so as to avoid any nutritional or environmental problems. There is still much work to be done on aspects of development of low pollution feeds that will take care of fish growth and health with reduction in the nitrogenous waste production in the ambient water. There are reasons to be optimistic that with the advances of the science of aquaculture nutrition, the quality of farm produce will be tailored in terms of key nutrients like w-3 fatty acids in fillets and hence dietary value addition to human food.

(***Key words:*** *Fish feed, Nutritional requirements, Ingredients in feed preparation, Feed additives, Feed formulation, Quality characteristics and feed specifications, Value addition for quality improvement)*

Indian aquaculture has been maintaining a sustained growth (over 6%) in recent years (Gopakumar, 2003) and is expected to account for the shortfall in aquatic food products resulting from projected population increase by 2020 AD (Dehadrai, 2003). The sector which is a prudent user of primary resources also contributes to a cleaner environment. Aquaculture is predominantly a rural activity and its benefit towards increasing household economy through diversification of income and food provisions hardly needs any emphasis. One of the important challenges therefore is to maintain sustained increase in production. Since feed is the single largest input in aquaculture, nutrition is often put forward as the key for future research to assist in the expansion of aquaculture. Sustainability of aquaculture development is directly related to provision of nutritionally adequate feeds that while improving growth, health and reproduction of species under culture have also little impact on the aquatic environment itself. In India at least 500,000 ha water area is under freshwater aquaculture in which carps are the major components. The important indigenous carps are : *Catla catla*, *Labeo rohita, Labeo calbasu, Labeo fimbriatus, Labeo bata, Labeo gonius, Cirrhinus mrigala, Cirrhinus reba, Cirrhinus cirrhosa, Puntius carnaticus, Puntius dubius* and *Puntius sarana*. The exotic carps include *Cyprinus carpio, Hypophthalmichthys molitrix* and *Ctenopharyngodon idella.*, Besides there are important catfishes like *Clarias batrachus, Heteropneustes fossilis, Wallago attu, Pangasius pangasius, Ompok pabda*; murrels *(Channa sp)*, featherbacks (*Notopterus sp.*) perch (*Anabas sp.*) prawns (*Macrobrachium sp.*), etc. The yield gap for carps in India is wide; 15 tonne^{-1}ha^{-1}yr at the experimental farm level, 10 tonne^{-1}ha^{-1}yr in pilot farms, 6-8 tonne^{-1}ha^{-1}yr in a well managed farm while little more than 2 tonne^{-1}ha^{-1}yr is the national average. At present the quality of cultured fish is variable often including varying survival and growth rates. Adequate consideration of nutrition mainly by provision of supplementary formulated feed for various production stages can bridge this gap. This can as well increase the carrying capacity of culture system and thus enhance fish production. Increasing domestic demand for fish by 2020 AD is projected to be 7.2 million tonne plus 0.6 million tonne for export (Ayyappan and Jena, 1998). To achieve this target, more efficient system of production has to be perfected adding value to the produce and minimizing waste output.

The survival, growth, healthiness and efficient feed utilization of fish depend to a great extent on nutritive value of feed and feeding regime. Optimization of dietary protein level, in particular along with increasing nutrient retention by fish could reduce nitrogen loading and positively influence production cost (Thoman *et al.*, 1999). The benefits of nutrition research culminated into development of high efficiency feeds and is contributing to overall health and productivity (Tripathi *et al.*, 2000). The use of formulated feed balanced in essential amino acids, lipids, carbohydrate, vitamins, trace elements and containing optimum protein : energy balance is an obvious approach to realize full genetic potential of growth of the cultured fish in a given time. From a nutritional perspective efficacy of a feed is evaluated in terms of its (a) biological performance in growth promotion, and (b) economic performance in terms of feed cost per unit production. Experiences have confirmed that the quality of feed is a function of how well it meets nutritional requirements of the cultured fish. This, in turn, is a function of the nutritional profile of the feed and bioavailability of nutrients present in feed ingredients. Feeding fish also involves consideration of dissolved oxygen, temperature and other water quality factors including biotic characteristics. Fish feeds require processing methods that provide special physical properties to facilitate feeding in water to reap the benefit.

Increasing *per capita* fish availability from the present level of 8 kg to 11 kg as recommended by World Health Organisation needs to be targeted. To achieve this goal an increased growth performance and improved efficiency of production in freshwater aquaculture is mandatory. In this context consideration of nutritional profile, feed quality, feeding strategies are crucial. This article highlights these aspects and suggests strategies with regard to fish feed and their quality attributes which can lead to marked improvement in the aquaculture productivity.

Nutritional requirements of Indian carps

There is fairly good amount of information on the nutrition and feeding of Indian major carps based on the studies undertaken both in the laboratory and in the field (Table 1). Wherever there is lack of information the nutrient requirements derived from fish species like common carp *C. carpio* may serve as the basis for formulating effective feed for various growth stages of these species (Kaushik, 1995).

Protein and amino acids : Requirement of protein has been studied in fry and fingerlings of Indian major carps based mainly on weight gain of fish fed purified diets. Under controlled conditions, the optimum dietary crude protein level ranges from 30-40% whereas for grow out stages it is 30-35% and brood fish 35-38%. The digestibility values have been determined for several protein sources of plant and animal origin and found to be generally high (74-94%). Amino acid requirement values for carp are also now known (Ravi and Devaraj, 1991, Ahmed and Khan 2004).

Lipid and fatty acids : In carps fed purified lipid free diets, supplementation of even saturated lipid resulted in positive growth response. Adding sunflower oil or cod liver oil supplying w_6 or w_3 fatty acids respectively resulted in significant improvement in growth and feed efficiency. A mixture of both oils was found to be superior to either lipid source separately (Mukhopadhyay and Rout, 1996). Quantitative lipid requirement ranges between 6-8% for carps. As in other teleosts, the fatty acid composition of body lipid reflects the composition of dietary lipids. In the context of pond culture, it is necessary to understand what changes are induced by the supply of natural w_6 or w_3 sources along with the effects of supplemental feed. For larval stages of all the three Indian major carps, the essentiality of dietary phospholipids is now estabilished (Paul *et al.*, 1999). Optimising lipid nutrition and lipid soluble vitamins especially for the first feeding larvae will provide considerable insight that will allow freshwater aquaculture to progress over the coming years (Watanabe and Kiron, 1994).

Table 1. *Selected nutrient requirements of carps*

Nutrients	Catla	Rohu	Mrigal	Common carp
Amino acids (% protein)				
Arginine	4.8	5.8	5.8	6.2
Histidine	2.5	2.3	3.0	2.9
Lysine	6.2	5.7	7.5	7.0
Isoleucine	2.4	3.0	3.6	3.8
Leucine	3.7	-	6.9	7.2
Methionine	3.6	2.9	1.5	2.7
Valine	3.6	-	4.3	4.5
Phenylalanine	3.7	4.0	8.0	6.5
Threonine	5.0	-	3.9	4.2
Tryptophan	1.0	1.1	-	-
Crude protein (g/kg diet)		300 - 450		
Lipid (g/kg diet)		50 - 80		
Digestibe energy (MJ/kg)		15 - 16		
DP : DE ratio		22		
Essential fatty acids (g/kg)				
18 : 3 w3	1			
18 : 2 w6	1			
Phospholipid (g/kg diet)	40	40	40	
Ascorbic acid (mg/kg)		100		

Source : Mukhopadhyay and Kaushik (2000) International Aqua Feed 4 : 21-24

Carbohydrate : Glucose as such is poorly utilized by fish. This has been reported in several fish species mainly because of low insulin release, absence of glucose transporters and poor regulation of hepatic glucose metabolism (Meton *et al.*, 2003). By the supply of carbohydrate at a dietary level of about 30%, some protein sparing action has been found in all the Indian cyprinids except mrigal which tolerates less carbohydrates than other two major carp species (Das *et al.*, 1991). Indian major carps appear to have amylolytic activity in their digestive tract and are thus capable of digesting complex carbohydrates. Cellulase activity has been reported in intestine of rohu. Thus there is ample scope for better carbohydrate utilization resulting in an energy source comparable with protein and lipid especially through thermal modification of raw dietary carbohydrate. During gelatinisation, carbohydrate granules can be modified in a way which facilitates enzymatic actions and thereby increases the digestibility. Higher carbohydrate digestibility also increases protein sparing effect of feed.

Energy : Chemical energy supplied in food is constantly being converted to free energy to sustain the life processes. Generally protein and lipid are utilized more effectively than carbohydrate as energy source in fish. Studies on energy budgets of diet in a poikilothermic animal like fish is scanty (Ohta and Watanabe, 1996). This may be due to difficulty in determining the metabolisable energy values of diets to quantify energy losses across gills and kidney. A minimum dietary gross energy level of 15 $MJ^{-1}kg$ is considered essential for efficient nutrient utilization in mrigal. For juvenile rohu 15-16 $MJ^{-1}kg$ gross energy and a protein/energy ratio of 22 is reported to be required for optimal growth and feed efficiency. A definite protein sparing effect of lipid has been shown. However a higher supply of non protein energy in the from of lipid above 15% does not appear to induce any further beneficial effect. Given the nature of rapid transition from extensive culture to semi-intensive feed based aquaculture, knowledge on the metabolic utilization of various energy sources is recognized as fundamental in promoting cost effective production in an environmentally sound manner (Watanabe *et al.*, 1987).

Vitamins and minerals : Data on the micronutrient requirements in respect of most of the freshwater species is lacking except for vitamin C, vitamin A, vitamin E, calcium and phosphorus in particular. All these carp species lack l-gulono-γ-lactone oxidase, the terminal enzyme for the conversion of glucose to ascorbic acid and thus depend on dietary supply of vitamin C. It has been shown that catla fry requires ascorbic acid at a dietary level of about 100 $mg^{-1}kg$ diet. Similarly dietary essentiality of ascorbic acid in rohu larvae has been established and quantified (about 1400 $ug^{-1}g$ dry wt) using ascorbic acid enriched zooplankton (Mitra and Mukhopadhyay, 2003). Although other vitamins and minerals have not been adequately studied, for practical purposes data obtained for common carp can be extended to Indian major carps because of the relative phylogenetic closeness of these species and similarities in gross nutritional requirement between different teleosts (Kaushik, 1995).

Ingredients for use in carp feed preparation

Terrestrial plant materials, particularly various oil seed meals, materials of animal origin e.g., fish meal, silkworm pupae, poultry by products, crustacean and molluscan meals are some of the ingredients used for fish feed preparations. Table 2 depicts a list of selected feed ingredients and their proximate composition while Table 3 depicts nutrient digestibility coefficients in some carp species.

Plants sources : Polyculture of freshwater cyprinids as practised today relies heavily on terrestrial plant based agro-byproducts/coproducts rich in carbohydrate. These fishes have better capacity for digestion of complex polysaccharides. All these species have high amylolytic activity in their digestive tract. Some cellulase activity has also been reported in the intestine of rohu in particular. There is ample evidences that dietary digestible carbohydrates improve their protein efficiency ratios (Erfanulla and Jafri, 1995).

There are numerous raw materials of plant origin which can be potentially viable alternatives to replace animal protein source for economic fish production. These are less expensive than those of animal origin and so manufacturers and farmers tend to substitute them for the former to obtain the desired overall nutrient profile of finished aqua feed. They often have a certain binding power and also constitute sources of group B vitamins except of course for vit B_{12}. Their main constituent starch is not always well tolerated by fish and often contain a significant amount of complex membrane carbohydrates (e.g. pectins, hemicellulose, pentosans, cellulose, lignin), which are often indigestible. Lastly they also contain various anti-nutritional factors. Table 4 summarises major anti-nutritional factors commonly encountered in fish feed ingredients.

Oilseed meals : Cakes are coproducts of oil extraction, which supply protein (crude protein : 20 to 40%) although these have less protein than animal ingredients (30-50% protein). Their mineral content is lower but they include a significant quantity of cell wall compounds as well as, frequently, antinutritional factors. Several approaches of inactivation or removal of anti-nutrients have been pursued such as heat treatment, soaking with water, fermentation etc. in order to enhance their nutritive value.

Soybean* (Glycine max) *meal : This leguminous seed has been widely used as a valuable fish feed component due to high protein content, its consistent market availability and price and especially its excellent nutritional value for most farmed fish despite endogenously present anti-nutritional factors. It is rich in protein (40% if it is dehulled, 45% if it is not). Its essential amino acid profile is fairly good despite a low level of methionine. This cake contains some antinutritional substances, in particular antitrypsic factors. Later can be largely destroyed by simple thermal treatment. It is low in cellulose and complex carbohydrate than other oilseed meals, when correctly cooked it constitutes a very important raw material for aquaculture. There are also more purified soya products than meals in the market, these are richer in protein and have lower fibre and other undesirable contents.

Rapeseed (canola) meal/Mustard oil cake : Rape (*Brassica napus and Brassica campestris*) and mustard (*Brassica juncea*) cakes are increasingly used in fish feed preparation. The protein content is about 35% and contain small amount of lysine and methionine and both contain significant amount of fibre; improved varieties contain much less antinutritional factors (like glucosinolates and erucic acid) than the old ones. Solvent extracted meals can be incorporated to about 30% level in carp feed.

Cotton seed meal : Cotton seed meal *(Gossypium hirsatum)* is available in the market but because of its fibre content lysine and calcium deficiency, presence of gossypol and also sterculic

***Table 2.** List of some feed ingredients and their proximate composition*

Name	Dry Matter(%)	Protein (NX 6.25)[1]	Lipid (ether-extract)[1]	Crude Fibre[1]	Ash[1]
Plant Sources					
Rice bran	90.00	10.00	12.00	10.00	5.00
Deoiled rice bran	90.00	12.00	1.00	15.00	12.00
soybean meal	88.00	36.00	8.00	6.00	6.00
Soybean meal, solv ext.	90.00	50.00	1.00	4.00	5.00
Ground nut oil cake	90.00	40.00	5.00	6.00	7.00
Mustard oil cake	90.00	30.00	7.00	6.00	7.00
Sunflower oil cake	90.00	28.00	4.00	16.00	6.00
Rapeseed meal	88.00	30.00	10.00	9.00	8.00
Gingely oil cake	90.00	34.00	7.8	7.9	3.1
Cotton seed oil cake	90.00	37.00	6.00	13.00	6.00
Coconut cake	86.00	23-25	12-13	10-13	8-10
Linseed cake	90.00	28.00	9.50	9.70	5.10
Sesamum cake	88.00	42.00	5.10	12.60	6.50
Deoiled sal seed meal	99.00	11.00	0.67	7.27	76.24
Mohua cake	90.00	15.00	15.00	6.00	10.00
Maize	90.00	9.0	4.00	3.00	3.00
Sorghum	90.00	13.00	2.00	6.00	5.00
Millet	90.00	13.00	2.00	6.00	5.00
Spirulina		50.0	1.0	2.1	11.0
Animal Sources					
Fish meal	88.00	60.00	8.00	3.00	20.00
Meat cum Bone meal	95.40	55.00	4.00	0.00	28.00
Poultry feather meal		88.3	5.4	1.2	2.9
Poultry by-product meal		59.7	13.6	2.1	14.5
Earthworm meal		51.7	3.4	12.8	12.5
Silkworm pupae	90.00	60.00	18.00	5.00	4.00
Prawn head meal	90.00	30.00	10.00	5.00	45.00
Clam meat meal		12	1.00	0.5	82.7
Squid meal		59.64	6-9	0.1-0.5	14-45
Mussel meat meal		45.0	9.0	5.0	26.0
Acetes shrimp	90.00	25.00	6.00	6.00	35.00
Blood meal		76.6	1.1	1.0	3.8

[1]Expressed in percent dry matter basis

acid residues it is not a very sought after raw material. However, because it is rich in protein, it may find use as an ingredient in aquaculture feed as and when new varieties with increased cotton yields and no gossypol residue will be available. For the present 15% solvent extracted cotton seed meal can be used for freshwater fish feed preparation.

Other oilseed meals : Sunflower meal *(Hellanthus annus)* is largely cultivated in India and is low in antinutritional factors like polyphenols and relatively rich in methionine. Crude protein content is about 26%. However, it is deficient in lysine and has a high fibre content, which may be a limiting factor for its use in fish feed formulation.

Table 3. Protein digestibility (%) of common ingredients with respect to three carp species

Ingredients	*Labeo rohita*	*Catla catla*	*Cirrhinus mrigala*
Rice bran (8.0)	89.9	89.9	91.0
Rice polish (8.8)	90.0	89.7	91.2
Wheat bran (10.5)	93.3	9.30	93.1
Raw yellow corn (5.9)	86.0	85.5	85.7
Cooked yellow corn (6.4)	96.1	96.2	95.7
Raw potato starch (6.7)	85.8	83.0	85.3
Cooked potato starch (6.5)	96.8	97.5	97.6
Barley dust (5.2)	83.4	84.4	85.4
Bengal gram dust (9.6)	81.4	82.6	77.7
Soybean husk (6.6)	86.5	86.2	86.6
Lentil husk (11.5)	85.0	83.6	-
Mustard oil cake (37.30)	78.0	-	-
Linseed meal (39.0)	81.5	-	-
Sesame meal (38.2)	76.2	-	-
Soybean meal (49.5)	84.0	-	-
Fish meal (52.4)	80.2	-	-
Silkworm pupae (70.6)	85.2	-	-
Deoiled silk worm pupae (83.3)	83.0	-	-

(Figures in parenthesis indicate crude protein percentage)

Table 4. Major anti-nutrients encountered in some fish feed ingredients

Plant-derived nutrient source	Anti-nutrients present
Soybean meal	Protease inhibitors, lectins, phytic acid, saponins, phytoestrogens, antivitamins glucosinolate.
Ground nut oil cake	Possible mycotoxin (aflatoxin), phytic acid, phytohemagglutin.
Rapeseed meal	Protease inhibitors, glucosinolates, phytic acid, tannins.
Sunflower oil cake	Protease inhibitors, saponins, arginase inhibitor.
Cotton seed meal	Phytic acid, phytoestrogens, gossypol, antivitamins, cyclopropenoic acid.
Mustard oil cake	Glucosinolates, erucic acid.
Sesame oil cake	Phytic acid, protease inhibitors.

Groundnut meal *(Arachis hypogea)* is rich in protein (45% or more) having a high arginine content but are deficient in lysine and methionine. Due to improper storage it may get infested with *Aspergillus flavus* and in turn may get contaminated with aflatoxin. The problem is that it is heat stable and methods of elimination are not easy. The simple method of control is to arrange suitable storage to prevent mould growth. The meal is highly digestible and contains almost no antinutritional factors. It has been continuously in use mixed with rice bran as feed for carps throughout the country.

Sesame cake *(Sesamum indicum)* is an important oil yielding crop in several parts of India and contains about 35% crude protein, 9% oil and 6% crude fibre. Its available lysine and methionine is also fairly well and is rich in Ca & P. This oilcake can be used safely upto 20% level in fish feed.

Palm oil meal *(Elaeis guineenisis)* and copra *(Cocos nucifera)* meals contain about 18% - 20% protein while their fibre contents exceed 50%. They are therefore of little interest to aquaculture except in the local context.

Cereals and by-products : The by-products from cereal grains (rice, wheat, corn, sorghum, etc.) are the foundation of most fish feed in India. Although a number of antinutritional factors are present in grains, phytic acid and hemagglutinins are of main concern to fish feed manufacturers. Since fish lack intestinal phytase, phytic acid (or phytate) which is the storage form of phosphorus in these grains may lower the bioavailability of zinc in particular making it necessary to fortify fish feeds containing such cereal by-products. Recently plant geneticists have developed several varieties of cereal crops with lower phytate content. The protein content generally varies between 10% to 15% and serve as energy sources. They are good sources of group B and E vitamins. Wheat *(Triticum aestivum)* or corn *(Zea mays)* flours are rich in starch (67-72%). In contrast to cakes, cereals are quite low in proteins and also have low EAA contents, particularly lysine. Heat treatments improve starch digestibility which can thus become a significant source of energy. These same starches, as constituents of raw cereals or preferably in cereals which have been heat treated, are also sought after for their physical properties. In the different feed processing (pelleting and especially cooking - extrusion), they have a beneficial action in the same way as purified starches. Wheat bran (the cereal husk) and middlings (intermediate between flour and bran) contain much fibre, but also group B vitamins and vitamin E. If they are finely ground, the middlings constitute good binding agents and are also used as bulk agents. Rice *(Oriza sativa)* bran is widly used in India as a major raw material in fish feed.

Animal protein sources : With regard to animal by products, fish meal and meat cum bone meal are widely used. Fish meal due to its uncomparable nutritional merit is the most sought after protein source in fish feed formulations. Fish meal invariably contains more than 60% protein with 90-95% digestibility. It has high available lysine and methonine content and rich in w_3 fatty acids so essential for growth and health. Fish meals vary considerably in their protein quality and nutrient composition depending on the freshness of the raw material, amount of residual lipid, drying process and temperature and whether the meal has been made from whole fish or waste from some other processing operation. Conditions and length of storage also affect quality (Anderson *et al.*, 1993). The growing sector of aquaculture perhaps cannot continue to rely on finite stock of wild caught fish. The high cost of fish meal can be deterrent to feed manufacture and as such there is a continuous effort to look for alternative protein sources. Meat and bone meal is manufactured/processed using offal products form abattoirs. The quality of meat and bone meals is variable; the ash content reaching 35% in meals made form bony meat. In general they contain 45–60% protein of quite good biological value. The cooking temperature is always very high for health reasons, and so does not allow the production of proteins which are as digestible as those obtained in fish meals. Between 8% and 10% of the product is lipid, including mainly saturated or monounsaturated fatty acids and a minute amount of HUFAs .

Connective tissue meal : These are meals made form collagen, the residue from the manufacture of tallow or lard. Protein content is high (70-80%) with a good essential amino acid profile. These meals differ greatly from the true meals with which they are often mixed, since they have much lower lipid (1-3%) and mineral (10-20%) contents.

Chicken viscera and fish/prawn processing wastes : These meals are made from waste including blood and viscera, constituting a type of meat meal which is very variable in composition. Their essential amino acid content is significant when mixed with plant products. Disposal and under utilization of by-products of fish and chicken processing is a major problem while use of these ingredients in fish feeds through appropriate processing techniques can minimize cost of production and simultaneously check pollution at public places for which safe utilization system needs to be developed for recycling purpose.

Feed additives

Attractants : Apart from nutritional value food detection, feeding stimulation are significant factors in the ultimate feed acceptability. An otherwise nutritionally balanced diet may be marginal in performance due to absence of ingredients which elicit positive stimulatory response in the fish species. The main aim of addition of a feed attractant to a diet is to increase the level of feed intake. Appetite which is *ad libitum* voluntary feed intake is significantly influenced by the type and concentration of attractant. It has been found that satiation level in fish is generally attractant concentration dependent. Lack of consumption of artificial feed in fish can partly be due to a deficiency of feeding stimulants in the feed. Since feeding behaviour is partially controlled by chemical effectors, addition of specific feed attractants may elicit an increase in appetite and subsequently feed intake and growth. In the strict sense, attractants are substances that orient the fish at a distance towards a 'prey'. Attractants play a major role in species in which feeding behavior relies more on olfaction than on vision. Despite the current trend for replacing an increasing part of fish meal with other protein sources, the former is always preponderant in the formulation of most feeds destined for feeding farmed fish. These meals, as well as those of shrimp of squid, are particularly attractive for fish. Addition of attractant substances is already used in the laboratory to promote the ingestion of simplified or purified experimental diets. In production systems, these substances have a role to play in improving feed intake in difficult environment, after stress or when medicinal feeds are being used. Chemical compounds possessing attractant powers can be divided into three main groups: L series amino acids, betaine (or glycine-betaine) and other molecules which gave a pentavalent nitrogen atom; and lastly, the nucleosides and nucleotides (inosine and inosine monophosphate in particular). In practical terms, the two usual sources of natural attractants are first fishmeals (rich in nucleotides) and second, invertebrate meals (shrimp, squid) which are rich in nitrogenous bases. There are certain indigenous plant based materials like fenugreek seeds, roots of certain aquatic plants like murrya etc. which are often used as attractant in carp feed formulations.

Antioxidants : Antioxidants are substances that are easily oxidised and, as a result of this protect other compounds which are sensitive to oxidation. They are used especially to break or at least slow down the chain of reactions involved in peroxidation. This chain starts with the formation of free radicals at the level of the double bonds in fatty acids and ends with the formation of stable aldehyde and ketone type compounds which can be toxic. These reactions do not only occur *in vivo* but also in feeds and they especially affect oils rich in HUFAs. Peroxidation is catalysed by metallic ions such as iron and copper, it damages not only fatty acids but also many other labile nutrients such as vitamin A. Peroxidation is slowed down by several types of molecules that affect the chain of reactions using various mechanisms; sequestering oxygen (ascorbic acid) metal chelators (citric acid, EDTA, amino acids), and proton donors (tocopherols, ethoxyquine, BHA, BHT) and ethoxyquine (dihydroethoxytrimethyl quinoline). It is recommended that antioxidants which are preventive (oxygen sequesters, chelators) and curative (proton donors) should be associated, for example ascorbic acid and alfa-tocopherol, BHA or BHT. Antioxidants are frequently added to some raw materials used in fish nutrition (fish, shrimp or squid meals, or fish oils).

Binding agents : They are almost always more or less complex polysaccharides :

- algal extracts: alginates (which form stable gels in the presence of calcium ions), brown algae , agar- agar.
- terrestrial plant extracts: pectins, arabic gum , auar gum;
- animal extract: chitosans;
- bacterial extracts: xanthan gums;
- others: carboxymethylcellulose and other transformed celluloses; lignosulphites produced by the paper industry, bentonite and other clays.

It may be noted that several ingredients such as molasses, starch (either raw or transformed), wheat gluten, collagen and gelatine, which are sources of carbohydrate or proteins, also have some binding properties.

Probiotics: This involves 'biologically effective microbial supply', made up of several bacteria (*Streptococcus sp*, lactic acid bacteria) or revivable spores, present as they are or on various media (lactoserum, germinating gains, etc.) which act favourably on growth, via mechanisms which are still poorly understood but most probably by modification of the intestinal flora. In fish, clear effects have been observed in various species during the first stages of rearing using live prey.

Water stability of fish feed

Raw materials are first ground and blended to obtain formulated feed mixtures which are subjected to some form of steam pelleting or extrusion method into particles that allow maximum utilization of the feed in the water. The particles should be of high durability to withstand handling, transportation and of good water stability to minimize nutrient disintegration and loss of nutrients upon exposure to water. The duration of pellet water stability is dependent on the time required by the fish or prawn to consume its ration. It is generally known that pellet characteristics such as flowability, sinking velocity, water absorption and water stability are important. Hygienic quality particularly in regard to control of microbial contamination of feed based on enterobacteriaceae and salmonella are important (Thomas and Poel, 1996). Water stability, is affected by the physical properties and composition of the feed mixture and the processing method employed. A number of binding agents are now available any of which may be added to the formulae to reduce the amount of residual fine particles and improve the water stability of pellets.

Nutrient digestibility factor

It may be emphasized that digestibility of ingredients vary depending on physical and nutritional characteristics of raw material; the manufacturing process; the dietary inclusion level of the feed ingredient; the digestive capacity of the fish; the feeding method employed (satiation feeding, restricted feeding, etc.). In view of this it is clear that each ingredient should be considered as being unique and evaluated on it own merit. A variety plant and animal origin ingredients were evaluated for apparent nutrient digestibilities of selected carp species (Table 3). Any factor that reduces the food retention time in the gut affects the nutrient digestibility. It has been reported (Pandian and Vivekanandan, 1985) the gastric evacuation rate increases with proportion of feeding rate. It appears therefore that increase in feeding frequency in adult fish which results in increased passage of dietary material through the digestive tract may cause less material to be digested ultimately resulting in lower protein digestibility values. In view of the difficulties encountered with the quantitative collection of faecal matter within the aquatic environment much more data is required in this subject area before confidence can be given to the digestibility coefficient obtained.

Carp feed formulations

Indian major carp species readily accept formulated feed and thus supplementary feeding has been a common practice in carp polyculture. Application of data obtained under laboratory conditions on the "nutrient requirement of fish" to "what is needed for pond culture" is often difficult unless proper consideration is given to the fluctuating nutrient availability in a dynamically complex pond ecosystem (Mukhopadhyay and Kaushik, 2001). On-farm field trials on the effectiveness of several formulated feeds were undertaken over the years to indicate the most appropriate once. Feeds were developed (Table 5) with regard to feeding behaviour, known dietary requirements and cost effectiveness. A specification of carp feed is shown in Table 6.

Table 5. *Formulated feeds (%) for various growth stages of carp (in pelleted form)*

Ingredients	Fry	Fingerlings	Juveniles	Brood stock
Rice bran	20	40	38	30
Ground nut oil cake	38	20	35	35
Roasted soybean meal	20	25	20	20
Fish meal	17	10	5	10
Vitamin-Mineral premix	2	2	2	2.0
Vegetable oil	2.7	3	-	2.7
Fish oil	0.3	-	/0	0.3

Fry- 25-40 mm, fingerlings- 40-100 mm, Juvenile/adult > 100 mm

Table 6. *Specification for carp feed*

Fish size	Feed form	Protein (% min)	Lipid (% min)	Fibre (% max.)	Moisture (% max.)
Spawn/fry	Fine to course powder	36	8	6	10
Fingerling	Crumbles; 1 mm pellet	30	6	9	10
Juvenile/adult	2-3 mm pellets	30	5	10	10
Broodstock	3-5 mm pellets	32	7	8	10

Table 7. *Quality of some ingredients (%) for carp feed formulations*

Ingredients	Protein (N x 6.25)	Fat (ether extract)	Crude Fibre	Total Ash	Moisture
Fish meal	>50	<10	<2	<30	<10
Meat and bone meal	>40	<14	<2	<33	<10
Soybean meal	>36	<7	<8	<8	<13
Ground nut oilcake	>40	<10	<8	<13	<11
Fine rice bran	>10	<16	<8	<10	<11
Rice bran (oil extracted)	>12	<3	<12	<14	<13
Corn meal	>8	<3	<2	<2	<13
(Fish oil)	>5 meq/kg (Peroxide value)				

Quality characteristics and specifications of carp feed

There is a vast array of terrestrial agricultural by-products which can be used as feed ingredients. Fish feed manufacturing involves the selection of raw materials and formulation followed by processing. For fish feed manufacture raw materials are ground, weighed and blended to obtain mash feeds which are subjected to steam and/or water conditioning before pelletization. The composition of pellets obtained by carefully blending the ingredients remain more or less constant. Imbalance in formulation or presence of toxin etc. in the ingredient can severely affect fish health (Viola, 1990). Raw materials based on adequate nutrient profile, digestibility and biological value, palatability and absence of anti nutrients can reduce the feed wastages and hence water pollution to ensure optimization of resource utilization (Mukhopadhyay *et al.*, 2004). The feeds are defined according to certain specification with regard to nutritive composition based on specified descriptions for nutritional, hygienic and physical quality. Together, these specifications require knowledge of a vast number of different properties of ingredients to optimise processing while maintaining or controlling nutritional quality for a given feed form. Quality of feed and its ingredients include combination of physical, chemical, biological, sensorial and sanitary features. This is directly reflected in the actual performance of fish. A good quality feed with low FCR not only gives better growth but also can greatly minimize nitrogen and phosphorus loading to the environment. Among the most common chemical analysis we have proximate composition, free fatty acids, total volatile nitrogen etc. to evaluate quality. Other chemical analyses such as histamine, antioxidant and peroxide value are also very useful when properly applied. Toxicity of rancid oil may severely affect fish health status unless there is adequate levels of vitamin E and C. Microbial degradation of ingredients of animal origin may result in the production of toxic biogenic amines. Among the physical factors bulk density, water absorption index, flow properties are important. At the end it is the presence of cost effective bioavailable nutrients, improved performance in terms of average daily gain and lower feed conversion, reduced total nitrogen excretion which are the prime factors for consideration. Thus raw material quality (freshness in particular) processing conditions (mainly drying process), length and condition of storage are issues which affect the final quality. Certain quality characteristics for carp feed ingredients are shown in Table 7.

Value addition for improvement in farmed fish quality

There is a large amount of scientific literature on the merits of fish eating on human health (supply of protein of high biological value, high level of n-3 poly unsaturated fatty acids, supply of vitamins like cyanocobalamine and minerals calcium and phosphorus). It is also now known that one can tailor aquaculture product quality through proper application of nutritional principles. For example even in a semiintensive system it is possible to modify the fatty acid composition of fish (and hence its dietary value as human food) through small changes in feed mixtures (presence or absence of oilseed cake, rice bran which is deoiled or not). In contrast to protein, lipid composition of fish is not genetically determined but depends largely on dietary fatty acid profile. There are several such examples with many fish species including carp. Recent data have shown that a small addition of an oil mixture to a common feed mixture can even increase the reproductive performance and improve the quality of juveniles of Indian major carp (Nandi *et al.*, 2001).

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Opportunities and Constraints in Enhancing Coastal Productivity and Livelihood through Mariculture and Value Addition

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India is the second largest aquaculture producer with 2.03 MT annual production contributing to 6.2 % of global aquaculture production. However, mariculture of any other species as a commercial enterprise is yet to establish along the Indian coasts. Currently value addition through mariculture is carried out in case of shrimp processing and packaging as well as crab and lobster fattening. Small quantities of clams, oysters and mussels are also value added for internal and export markets. However, the bulk of the products are traded in fresh condition. Thus there exists great scope both for increased production as well as value addition in mariculture.

With the advent of the shrimps *P.monodon* and *P. indicus* hatchery techniques developed by the scientists of the CMFRI, producing larvae in the hatchery became a reality opening up the great potential of shrimp culture in India. Production of marine organisms through culture in nearshore coastal waters and land based ponds holding saline waters have resulted in considerable quantities and generated significant foreign exchange in the country through exports. Integrated mariculture through social action is the need of the hour.

There are number of prospects for value addition in this sector. The identified opportunities for value addition are Cage culture and trade of live fish, Fattening and trade of live crab, Fattening and trade of live lobster, Depuration and trade of live mussels, clams and oysters, Value addition of fin fish for local market, Value addition of dry, smoked and salted fish. Moreover, value addition through by-products like pickles, surimi, trade of breaded and battered fish for fast food joints, canteen and bakeries, aquarium fish breeding and trade, tourism and value addition are also discussed. Inspite of the large opportunities available for value addition through mariculture, the opportunities have not yet been well utilized. There are numerous technological, economic, social and legal issues, which are to be solved before the potentials are fully realized.

***(Key words :** Mariculture, Value addition, Social action, Constraints)*

India is the second largest aquaculture producer with about 2.03 mmt annual production contributing to 6.2 % of global aquacultural production. Coastal aquaculture in India has been focusing around the much sought after shrimp species such as *Penaeus monodon* and *P. indicus.* However, mariculture of any other species as a commercial enterprise is yet to establish along the Indian coasts although as a livelihood opportunity bivalve culture has been making great strides along the south west coast during the past few years. Currently value addition through mariculture is carried out in the case of shrimp processing and packaging as well as crab and lobster fattening. Small quantities of clams, oysters and mussels are also value added for internal and export markets. However, the bulk of the produce are traded in fresh condition. Thus, there exists great scope both for increased production as well as value addition in mariculture.

Present status

Although attempts to initiate mariculture activities started in India over 50 years back with the initial attempts for growing finfish and seaweeds, no significant advancement resulted till about ten years back. With the advent of the shrimps *P. monodon* and *P. indicus* hatchery techniques developed by the scientists of the CMFRI, producing larvae in the hatchery became a reality opening up the great potential of shrimp culture in India. The initial success resulted in an unregulated growth in the industry and subsequent collapse due to poor management practices. Table 1 gives an account of the mariculture potential in India.

India being a tropical country, the marine biodiversity is one of the highest. However, the biodiversity utilization index of India is one of the lowest (0.13) indicating the poor utilization of the resource for culture. The marine organisms of aquacultural importance are listed in Table 2.

Mariculture production

Production of marine organisms through culture in nearshore coastal waters and land based ponds holding saline waters have resulted in considerable quantities and generated significant foreign

Table 1. *Open water coastal aquaculture potential in India*

Location	Potential cultivable area (m ha)	Current cultivable area (ha)	Annual production (tons)
Open sea	1.8	20	2000
Bays	10700	-	-
Estuaries	2050	5	800
Island lagoons	35,000	-	-

Table 2. *Marine organisms of aquacultural potential*

Species	Hatchery	Rearing
Penaeus monodon	√√√	√√√
P.semisulcatus	√√√	√√√
P. indicus	√√√	√√√
Scylla serrata	√	√√√
Portunus pelagicus	√√	√√
Panulirus. ornatus	√	√
P. homarus	√	√
P.polyphagus	√	√
Thenus orientalis	√	√
Perna viridis	√√√	√√√
Pinctada fucata	√√√	√√√
Crassostrea madrasensis	√√√	√√√
Anadara granosa	√√√	√√√
Meretrix casta	√√√	√√√
M. meretrix	√√√	√√√
Paphia malabarica	√√√	√√√
Trochus radiata	√√√	√√√
Xancuspyrum	√√√	√√√
Sepia pharonis	√	√
Loligo duvaucelli	√	√
Mugil cepahlus	√	√
Lizaparsia	√	√
L. mocrolepis	√	√
Valamugil seheli	√	√
Ckanos chanos	√	√
Etroplus suratensis	√	√
Epinephelus tauvina	√	√
E.dusumieri	√	√
Lethrinus spp	√	√
Lates calcarifer	√	√
Gracilaria edulis	√√	√√
Gelidiella acerosa	√√	√√
Sargassum spp	√√	√√
Ulva spp	√√	√√
Euchaema spp	√√	√√
Holothuria scabra	√√	√√

√ techniques under development, √√ techniques developed, √√√ techniques commercialized

exchange in the country through exports. Increased demand for shrimp in global market, successful demonstration of semi intensive shrimp culture, establishment of commercial hatcheries along the east coast and ever increasing demand for shrimp in international markets have resulted in increasing the farmed shrimp production from around 40, 000 tons in 1991 to 82, 850 tons in 1995-95, and a subsequent decline to about 70,000 tons in 1996 and a recovery in recent years to over 100,000 tons. Table 3 provides details of the shrimp production through mariculture and exports from India.

Table 3. *Production and export of cultured shrimp from India*

Year	Culture production mt	Export mt	Value in millions INR
1990	35500	23075	3674
1991	40000	26000	5447.6
1992	47000	30550	7662.5
1993	62000	40300	12889.3
1993	82500	53853	18662.3
1995	70573	47992	15316.9
1996	70686	45945	16425.6
1997	666868	43454	20860
1998	82634	53712	25110
1999	86000	54000	27820
2000	113700	65894	38700
2001	127170	74826	35450
2002	145770	80997	37940

Although there are several problems facing the shrimp farming industry, concerted efforts by research, development, social action, precautions, better management, involvement of industrial houses and social awareness have resulted ensuring some degree of sustainability in the farming systems in the country. The products from the farming are value added by the industrial houses and packaged for various export markets. The major products which are exported as value added are: Headless Frozen Shrimp, FROZEN fish, Frozen Squid, Frozen Cuttlefish, Frozen Lobsters, Chilled marine products, Live fish, Dried Fish products, others. The details for the year 1999 are given below in Table 4.

Integrated mariculture through social action

In the coastal lowlands (*Pokkali* in Kerala, *Khar* in Goa, *Khazan* in Karnataka, *Bheri* in West Bengal) there have been traditional practices of shrimp farming during the year alternating with the rice crop. Since these are fragmented small private holdings belonging to poor classes, farming practices of a·'.vanced nature are not practical. Group farming ,proach which relies on synchronized farming operations and collective management. During the late 1990s, CMFRI introduced the action plan for group farming in the coastal *pokkali* fields of Kerala which was a great success. In recent years through its Institute Village Linkage Programme (IVLP), group faming of the shrimp is carried out to improve the rural economy.

Table 4. *Value added marine products of exports from India*

Item	Quantity (tons)	Value (million INR)
Frozen shrimp	103070	33623.8
Frozen fish	126474	5257.8
Frozen squid	34451	2878.8
Frozen cuttlefish	33771	2852.5
Frozen lobsters	1364	661.5
Chilled items	2793	360.1
Lie fish and shellfish	1733	389.8
Dried fish	5661	343.0
Others	17887	207.3
TOTAL	327205	47573.9

Another example is the example set by the women self help groups (WSHGs) of southern Kerala. The WSHGs in the Dhalavapuram area of southern Kerala are actively involved in the mariculture of edible oysters to supplement the family income b· using the low cost technology developed by the CMFRI. The annual production through mariculture of edible oysters have reached about 800 tons. The ·roducts are value added by boiling, and shucking before trading for freezing and export.

Great strides have been made by the mussel farmers of Kerala who have taken up the CMFRI technology for adoption through numerous WSHGs of north Kerala. The rope method of culture is followed. Techniques for seed collection, seed rope preparation, lay out of culture ropes, husbandry and harvesting practices have been carried out under the technical guidance of CMFRI and the annual production has reached about 2000 tons. Each mussel culture rope yields about 13 kg of mussels per meter of rope length. Value addition is through depuration and sale staggered sale of cleaned mussels through mobiie vans moving along the highway in the afternoons.

Juveniles of the crab *Scylla serrata* and the lobster *Panulirus* spp through fattening has become a common avocation along the east and south west coasts of Tamil Nadu. The small sized juveniles have no market value. However, after a few months of fattening in captivity through intensive supplementary feeding they reach commercial size fetching very high values in the export market for live fish. The value addition has become very popular as the governmental agencies have come forward to provide massive grants and subsidies for promoting this activity. However, such massive operations are resource unfriendly and therefore should not be encouraged.

Prospects of value addition

There are a number of opportunities for value addition of marine products in the coastal villages which will provide added income as well as employment and livelihood opportunities. There is need to sensitize the coastal community on these opportunities and carry out a detailed participatory intervention planning before entering into entrepreneurship activity . Such an approach will expose the end users to app possibilities and provide them an opportunity to select the activities for which they have the interest, time, resource and market. The following identified opportunities are briefly described.

Cage culture and trade of live fish

Small sized finfishes of high value can be collected from the wild and retained in cages in the sea or bays and fed with supplementary feed till they attain market size. There is great demand and high price for live fishes in the internal and export markets which could be utilized while harvesting and marketing. Harvest could be on demand in order to ensure high returns.

Fattening and trade of live crab

Juvenile crab abundant in the estuaries could be collected and kept in submerged cages. The crabs can be fed with trash fish daily till they attain marketable size. Fully grown live crab fetches >Rs. 200 per kg live weight.

Flattening and trade of live lobster

Juvenile lobsters which are entang··d in the nets are used for this activity as fis·.·.· are reluctant to return them to sea. They are kept in submerged traps and fed daily with live feed of clams and mussels. Market sized lobsters provide >Rs.1000 per kg live weight.

Depuration and trade of live mussels, clams and oysters

Presently cultured mussels and oysters and clams are marketed fresh. It is a common practice abroad to depurate them before marketing in order to remove sand grains, fecal matter, detritus, pseudofaeces, bacterial load etc. Portable depuration systems could be fabricated for use in retail shops or seafood restaurants

Value addition of fin fish for local market

Excellent working models have come up through out Kerala for vending value added fresh fish through supermarkets and other outlets. Fresh fish are cleaned, filleted and displayed over ice in highly sanitized and hygienic display counters as done abroad. They are weighed and cleaned in the presence of customers by professionally trained persons and cut as per the specifications of the consumers, packaged and handed over in a few minutes. The stalls are air conditioned and all operations are visible, professional and hygienic. Even ready to fry/ cook fish is available in cling film packaged containers. These have become very popular among the elite consumers. This is an excellent example of value addition in the sale offish which can be further popularized in other areas.

Value addition of dry, smoked and salted fish

Hygienically prepared and dried fish are packaged in clean attractive packets and sold through supermarkets. Since the products are very clean and professionally prepared, they command higher prices and better market acceptability. Numerous women groups are carrying out the value addition and sale in the south Indian states. The ATIC of CMFRI also is trading the products made by the WSHGs of the Elamkunnapuzha village.

Value addition through by-products like pickles, surimi

Low value marine fish is value added by converting them in to byproducts like pickles, surimi etc which have high consumer demand. Some kind of technological interventions are needed, as also equipments for processing and packaging. TIP AC of the Department of Science and Technology, Govt. of India has attractive schemes for empowering NGOs with the required inputs including capital. Many low value fish could be better utilized through value addition by making use of these opportunities.

Trade of breaded and battered fish for fast food joints, canteens, bakeries

Preparation of breaded and battered fish products and sale of them to bakeries, eat outs, fast food restaurants, canteens provide an excellent opportunity. These are to be carried out on a day to day basis after carrying out a market analysis and obtaining the required training for the product development.

Aquarium fish breeding and trade

Aquarium fish breeding, holding, trade and all related activities are also an activity of value addition and livelihood which are available to the coastal communities. Tremendous scope exists and there have been several success stories by small entrepreneurs who have gained the training from CMFRI.

Tourism and value addition

There are a number of tourism related activities like sports fishing, live fish capture, preparation of freshly caught fish from the wild etc. which are all activities related to tourism. There is also demand for live oysters, crab, lobsters by tourists. Value addition by catering to the specific needs of the tourism sector is an increasingly popular activity in the southern states of India which are becoming centers for international tourism.

Constraints for development

In spite of the large opportunities available for value addition through mariculture, harvest and sale, the opportunities have not been well utilized. There are numerous technological, economic, social and legal issues which are to be solved before the potentials are fully realized. Technologies for several species are not fully developed. In certain cases, the technologies are highly specialized. Infrastructural and financial constraints are also hindrances. The inability of the rural folk in accessing credit is another constraint. Lack of forward and backward linkages, coupled with several social and economic reasons prevent these opportunities from being realized fully. Maricultural and leasing rights, common property utilization, environmental concerns, poaching, lack of insurance, lack of buy back arrangements, poor marketing channels, role of middlemen, are all issues to be sorted out for better realization of the existing opportunities. Concerted action by development agencies are required for enabling the maricultural opportunities realize its full potential at the community level as an avenue for employment, livelihood and value addition.

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Evaluation of Production Performance of Indian Major Carps-Seabass Polyculture Technology in Rainfed Surface Dugout pond

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An experiment on the polyculture of Indian major carp with Seabass *L. calcarifer* was carried out to evaluate the production performance of carp - Seabass culture in the Khar Land Region of Raigad district of Maharashtra. The main objective was to observe the seed stocking rate and different sizes of the seed at the time of stocking and it's influence on the growth and production. The experiment was undertaken in the seasonal surface dugout pond of (0.02 ha) for three years (1999 - 2002). It was observed that when Seabass seed (2.8 - 3.9 cm) was stocked with large size fingerlings of Indian major carp (6.0 - 12.0 cm) the production (196.250 kg) and survival (66.86%) of carp was increased to maximum extent. However, growth and survival of Seabass varied according to stocking rate and size of seed. Thus polyculture can be undertaken for enhancing total fish production and nutritional status of rainfed pond owners, if semi-fingerlings of Seabass are stocked with advanced fingerlings of carp.

(***Key words:*** *Polyculture technology, Rainfed dugout pond*)

Seabass (*Lates calcarifer*) is an important local food fish because of its tasty and nutritious meat. It is an expensive fish compared with other species. At present, the supply from capture fishery is insufficient due to large demands. Therefore, the intensive promotion of seabass culture can help to meet this objective. It is euryhaline species and can be cultured in freshwater, brackish water and seawater. The seed of seabass is abundant in mangrove areas during the early part of the rainy season. However, there is size variation in nature. The seabass being cannibalistic in nature prey upon the small size seed which results into very low survival percentage. Further, seabass prefers live food organisms. This research station has therefore conducted trials on culture of seabass along with Tilapia (*O. mossambicus*). As tilapia is prolific breeder and young ones of it acts as forage to seabass, the culture technique was developed. However, production of seabass was low due to cannibalistic behavior and lack of sufficient live food organism. The trials were later on conducted to observe the performance of Indian major carps when cultured with seabass .

The Fishery Faculty of Dr. B.S. Konkan Krishi Vidyapeeth had undertaken the survey of traditional polyculture of seabass with tilapia and carps (Belsare, *et al.*, 1987, Shirgur, 1990) There was very few literature or no literature on culture of only Seabass or carps along with seabass (Singh *et al.*, 1990 a,b, Singh and Shirgur, 1994, Singh and Mehta, 1997, Shingare *et al.*, 1996). The main objective was to observe growth performance of carps along with seabass in rainfed ponds in Konkan region of Maharashtra.

MATERIALS AND METHODS

The experiment was conducted in 0.02 ha water spread area in rainfed seasonal surface dugout pond at Khar Land Research Station, Panvel, Dist. Raigad in Maharashtra. Experiment was conducted for three years from 1999-2002. The seed of seabass were collected from the creeks. The carp seed reared at this farm was used for the experiment. During first year stunted fingerlings were used. The tilapia seed were collected from the village ponds. Being prolific breeder acting as forage to seabass , tilapia were released one month before the stocking of seabass.

The supplementary feed such as deoiled cake of groundnut rice bran was provided to carps and tilapia. The chemical fertilizers such as single superphosphate and urea were applied only once before stocking of seed. The hydrobiological parameters were recorded.

The details such as seed stocking, harvesting, survival percentage, total production, hydrobiological parameters etc. are recorded.

RESULTS AND DISCUSSION

During the year 1999-2000, the stunted fingerlings of carps with size range of 6.0-12 cm were stocked @ 1750 ha^{-1}. The seabass @ 3410 ha^{-1}. with size range of 2.8 - 3.9 cm were stocked. The seed of tilapia were stocked one month before @ 8000 no ha^{-1} with size range of 3.2 - 4.5 cm. During 2000-2001 and 2001-2002, seabass @ 5300 and 1885, carps @ 1000 and tilapia @ 6000 and 3000 ha^{-1}, respectively were stocked. The size of carps was 3.5 - 5.8 cm. The size of seabass was smaller (1.5 - 2.0 cm) during 2000-2001 and bigger (4.0 - 5.1 cm) during 2001-2002. The size of tilapia was in the range of 2.8 - 4.0 cm (Table 1).

Table 1. *Details of stocking of fish seed*

Particulars	Month of stocking		
	1999-2000 Aug-Sept	2000-2001 July-Aug	2001-2002 July-Aug
Seabass			
a) Nos.	3410	5300	1885
b) Size range (cm)	2.8-3.9	1.5-2.0	4.0-5.1
c) Av. size (cm)	3.30	1.75	4.60
Catla			
a) Nos.	1000	500	500
b) Size range (cm)	6.0-12.0	3.5-5.2	4.2-5.8
c) Av. size (cm)	8.82	4.50	5.10
Rohu			
a) Nos.	750	500	500
b) Size range (cm)	6.5-12.0	3.2-4.5	4.0-5.4
c) Av. size (cm)	8.10	3.65	4.5
Tilapia			
a) Nos.	8000	6000	3000
b) Size range (cm)	3.2-4.5	2.8-4.0	2.5-3.5
c) Av. size (cm)	3.90	3.60	2.85

The survival percentage of seabass for successive three years was 11.58%, 14.52% and 18.30%, respectively. There was increase in survival percentage according to size and stocking density. The survival percentage of *catla* and *rohu* during 1999-2000 was higher (62.5% and 72.66%, respectively) in case of stunted fingerlings while it was reduced to 46% and 65%, respectively in 2000-2001 and 30% and 35%, respectively in 2001-2002. The average growth of seabass, *catla* and *rohu* was 419 g, 925 g and 739 g, respectively during 1999-2000. There was decrease in growth during next two successive years. The growth of seabass, *catla* and *rohu* during 2000-2001 was 279 g, 889 g, 438 g, respectively. While during 2000-2002, it was 397 g, 666 g and 400 g, respectively. The total fish production during 1999-2000 was highest. The production of seabass, *catla* and *rohu* during 1999-2000 was 165.500 kg, 578.200 kg and 403 kg ha^{-1}, respectively. While during next successive year carp production was reduced. During 2000-2001, production of seabass, *catla* and *rohu* was 215.00 kg, 204.500 kg and 142.500 kg ha^{-1}, respectively. While during last years, it was 137.150 kg, 100 kg and 70 kg ha^{-1}, respectively. The culture period for three years was 7 ½ months (Table 2).

From the harvesting data it was observed that production of carps was highest when size of carp was larger than seabass. It revealed that using stunted fingerlings of carps, which showed fast growth compared to fingerlings, could increase production. Further, stocking density of stunted fingerlings (1750 no ha^{-1}) also enhanced the production. During 2000-2001, the small size seed of carps resulted in low survival and production. The stocking density was also less. During last year (2001-2002), the same trend was observed. It showed that the low survival was due to predation of carps by seabass. The growth of carps was also slow due to stocking of small size seed of same season. Inspite of higher stocking density production of tilapia during first year was less compared to next successive years. It may be due to predation by seabass. The low survival and variation in growth of seabass indicates that there is cannibalistic behavior. The presence of bigger size seabass prevented smaller ones from feeding and competition for feed, which resulted in starvation and high rate of mortality.

The hydrobiological parameters for three years such as water temperature, pH, transparency, dissolved oxygen, salinity were in the range of 25.8-29.8°C, 8.10 - 8.35, 17.5 - 21.5 cm, 4.0 - 4.6 mg l^{-1} and 0 - 1.75 ppt, respectively. The low transparency throughout culture period was due to turbid water. The turbidity was due to heavy clay content. The water level in rainy season was 1.0-2.0 m. However, it was highly reduced upto 0.6 m after rainy season. (Table 3).

James and Marichamy (1986) and Khamris and Hanafi (1986) have observed the growth variation in the range of 65-1350 g at Tuticorin and 13.1-960 g in Malaysia. The polyculture of Seabass with *Chanos chanos* (milk fish) showed fast growth (Danakusumati and Ismail *et al.*, 1986). Fortes (1985) reported that percentage of young tilapia was decreased from 8.3 to 1.8 % as seabass number

Table 2. Details of harvesting

Particulars	1999-2000	2000-2001	2001-2002
Seabass			
a) Nos.	395	770	345
b) Size range (cm)	24-80	22.3-35.2	23-38.5
c) Weight range (g)	200-4100	170-550	200-750
d) Av. weight (g)	419	279	397
Catla			
a) Nos	625	230	150
b) Size range (cm)	38-45	34.5-42.5	35-42
c) Weight range (g)	850-1800	650-1250	400-1100
d) Av. weight (g)	925	889	666
Rohu			
a) Nos.	545	325	175
b) Size range (cm)	36.5-42	28.5-36.5	29-35.5
c) Weight range (g)	550-1200	270-650	300-550
d) Av. weight (g)	739	438	400
Tilapia			
a) Nos.	340	470	160
b) Size range (cm)	22-27.5	18-25.5	23.5-30.1
c) Weight range (g)	200-400	150-285	225-450
d) Av. weight (g)	237	199	273
Culture duration (months)	7.5	7.5	8
Percentage survival			
a) Seabass	11.58	14.52	18.30
b) Catla	62.50	46.00	30.00
c) Rohu	72.66	65.00	35.00
Total weight harvested (kg)			
a) Seabass	165.500	215.00	137.150
b) Catla	578.250	204.500	100.00
c) Rohu	403.00	142.500	70.00
d) Tilapia	80.500	93.500	43.750
Water depth (m)			
a) During rainy season	1.0-2.0	1.2 -2.5	1.4-2.7
b) After rainy season	0.6-0.8	0.7-0.9	0.9-1.2

***Table 3.** Hydrobiological parameters*

Particulars	1999-2000	2000-2001	2001-2002
Water temperature (°C)	25.8	29.8	27.6
pH	8.35	8.80	8.10
Water transparency (cm)	20	17.5	21.5
Dissolved oxygen (mg/l)	4.6	4.0	4.4
Salinity (ppt)	1.75	0.5	-

increased from 500 to 1000 per ha. Pillay (1954) observed average growth of seabass upto 25 cm after six months culture period. Shingare *et al.* (1996) studied the effect of survival and growth, however survival and production was very low. Singh *et al.* (2001) reported the production of 400-600 kg ha^{-1} under polyculture system.

CONCLUSIONS

It can be concluded from the present studies that culture of stunted fingerlings of carps can be undertaken along with seabass. However, small size or equal size seed of carps should not be stocked. The stocking density of stunted fingerlings should be about 2000 nos ha^{-1}. However, further research in respect of stocking capacity of carps is needed. To avoid cannibalism, competition for feed and low survival of seabass, stocking density of tilapia preferably adults should be increased for better growth and survival and water level upto 1.5 m should be maintained. The species used under this culture are having different feeding habits, therefore culture of these species is a profitable business for coastal farmers to increase overall fish production.

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Evaluation of *Ghery* Prawn Culture in Chilika Lagoon with Special Reference to Social Issues

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Chilika lagoon, a unique coastal wetland and a Ramsar site situated in the state of Orissa, India, is a hotspot of aquatic biodiversity and supports rich fisheries resources. The ecosystem known for its unique ecological characters and steady source of fisheries has been threatened in the face of continued anthropogenic activities and natural upheavals. Apart from natural changes, large scale operation of *Ghery* prawn culture in the lagoon has been identified as the major human induced activity largely contributing to the economical through sociohostile situation since late eighties. *Ghery* operation by local non-fishermen community and outsiders has been the root cause of perpetual hostile environment finally resulting in economic deprivation of traditional fishing communities. Two types of prawn culture *gheries* (mud-walled and net walled) are constructed in the lagoon ranging from 2.0-130 ha in area. These cover a total lagoon area of more than 10,000 ha at present, although aquaculture in Chilika area up to one kilometer from the high water line has been banned by the Supreme Court since December 1996. Average stocking density of *Penaeus monodon*, survival and yield range from 2-3 m^{-2}, 30-40% and 300-396 kg ha^{-1}, respectively under these *ghery* culture system. Net profit ranges from Rs. 0.082-0.091 million ha^{-1}. Present status of *ghery* prawn culture in Chilika lagoon, prognostication of threat to the fragile ecosystems, sociopolitical issues relating to prawn culture *gheries*, and some suggested ameliorative measures are discussed in details.

(Key words: *Ghery prawn culture, Hydrological intervention, Ecorestorative measures, Social conflict)*

Chilika lagoon in Orissa, the largest coastal wetland ecosystem in the subcontinent and a much focused Ramsar site is a hotspot of biodiversity including fish germplasm. It supports rich fishery resources to provide food and livelihood security to more than 0.15 million impoverished fishers in its periphery and island villages. The ecosystem known for its unique ecological characters has been threatened in the face of continued anthropogenic activities and natural upheavals. Apart from natural changes like rapid siltation, shifting of lagoon mouth, explosive fresh water weed growth, continuous decrease in salinity regime, etc., large scale operation of prawn culture *gheries* in the lagoon has been identified as the major human induced activity largely contributing to the degradation of the ecosystem. Two types of prawn *gheries* are constructed in the Chilka region; one is made of earthen dikes and another one is by bamboo/casuarina polls. The enclosed water area of each unit ranges from 2.0 – 130 ha.

The Chilika Development authority (CDA), with the financial assistance from the Tenth and Eleventh Finance Commission, carried out hydrological intervention to rejuvenate the ecosystem during 2000. As part of the intervention, a new mouth were opened which is nearer to the main water body of the lagoon and the outer channel was desilted for effective exchange of water. In view of the current ecorestorative measures undertaken by CDA, the present study was carried out to evaluate the operation of *ghery* prawn culture in Chilika lagoon, its adverse impacts on ecosystem, and related sociopolitical issues.

MATERIALS AND METHODS

The present study was conducted in the northern central and southern sectors of the Chilika lagoon during February-April, 2002. Construction of prawn *gheries* (large piece of enclosed water body) is done either by earthen dikes or by enclosures with synthetic filament net in the inner Chilika (islands and channel networks of Krishna Prasad *tehsil*), outer Chilika (main open water body), and peripheral areas. Two types of prawn *gheries* are constructed in the Chilika lagoon; one is made of earthen dikes/mud walls in the shallow areas and the other is made of tough filament netting walls erected by long bamboo/casuarina poles (4.5-4.8m long) and supported by strong buttresses. Height of mud walls and filament nets (16 meshes per sq.cm) ranged from 0.8-1.8m and 2.5-2.8m, respectively above the water surface. The enclosed water area of each unit ranged from 2.0-130 ha. Two numbers of mud-walled and two numbers of net walled prawn culture *gheries* from each of the three sectors (total of 12 *gheries*) were selected for the study. Total enclosed water spread areas of mud-walled and net-walled *gheries* were 11.6 ha and 68.36 ha, respectively. Prawn culture data (crop details) were collected from the *ghery* operators. Stocking of seed and harvesting operations were observed to record data. Water quality parameters of the enclosed water bodies of both types of prawn culture *gheries* were studied following standard methods (APHA, 1989). Information related to aspects were collected from fishermen and non-fishermen through interactive discussion.

RESULTS AND DISCUSSION

Operation of prawn gheries

Large sized *gheries* constructed in outer Chilika have double net walls (inner net 16 meshes per sq.cm and the outer net bar mesh size is 0.6 cm). The traditional enclosures 'Jano' is used for capturing the trapped and held fish stock (Nermark, 1989) and the *ghery* is used for selective culturing of 'Bagda' (*P. monodon*). Some of the fishery cooperatives also constructed *gheries* by converting their capture fishery sources taken on lease from Government. In general, the large sized prawn *gheries* in outer Chilika lagoon (net enclosures) are large sized wet pens where selective stocking of black tiger shrimp (*P. monodon*) is resorted to without fertilization and supplementary feeding.

Present status

By August, 1993, the total conversion of capture fishery sources (fishing grounds) into prawn culture *gheries* stood at 3380 ha (Anon., 1993), which increased explosively to 24,616 ha (26.60% of total water spread area of the lagoon) by August, 1995 (Mohanty, 1995). The encroachment of lagoon area to expand prawn *gheries* continued beyond 1995, which after partial demolition/eviction by local administration, was estimated at 10200 ha during 2002. Western fringe areas of the lagoon within Khurda district boundary were almost cleared of the unauthorized prawn *gheries* by the local administration and there was partial removal of *gheries* in the lagoon area within Puri district. Almost all *gheries* are operating in the southern sector. Presently, mud-walled *gheries* cover about 2650 ha (26%) and the net-walled *gheries* cover about 3950 ha (74%), which mostly fall within the district boundaries of Puri and Ganjam districts.

With a view to reducing tension and to preventing illegal expansion of prawn *gheries*, the state government imposed ban on aquaculture in the Chilika lagoon and also banned granting and renewal of lease for culture sources during 1999. So far, almost all the prawn *gheries* in Chilika under Khurda district have been removed, while prawn *gheries* in Puri (Krushna Prasad *tehsil*) and most of the *gheries* in Ganjam district covering about 10,200 ha are still in operation (Fig. 1) in total violation of Hon'ble Supreme Court Order and State Government order.

Unresolved social issues

The non-fishermen and others forcibly occupied many of the traditional fishery sources, reducing open water areas for capture fishing operation. The situation led to decreased catch from the capture fishery which affected the per capita income of fishermen. In general, continuation of such banned prawn culture *ghery* operation in Chilika has been the root cause of perpetural social conflicts and suffering of traditional fishermen.

Yield and return

Two different management practices for mud walled peripheral *gheries* and filament double net walled *gheries* inside the lagoon water body and channels were followed by the operators, and yield and return from these two types of prawn *gheries* are furnished in Table 1. Water quality parameters of prawn *gheries* during prawn culture operation and open Chilika outside the *gheries* are presented in Table 2. Higher values of BOD, N, P, NH_3 and TSS and lower values of dissolved oxygen inside the *gheries* in comparison to the water quality parameters of the open Chilika indicate that the water inside the *ghery* gets deteriorated during prawn culture operation, and often localized pollution also takes place.

Based on the average culture performance as shown in Table 1, the prawn seed (post-larvae) requirement for the present *ghery* areas of 10,200 ha is estimated at 230.52 millions, which is mostly collected from the wild (outer channel of Chilika lagoon and nearby Rushikulya estuary). Recently some prawn *ghery* operators have stocked their *gheries* with hatchery seeds procured from Andhra Pradesh. Total annual yield of tiger prawn (*P. monodon*) from 10,200 ha on the basis of average yield works out to 3314.59 mt. This production is not reflected in the official shrimp production of the state as the Supreme Court has banned aquaculture in Chilika Lake.

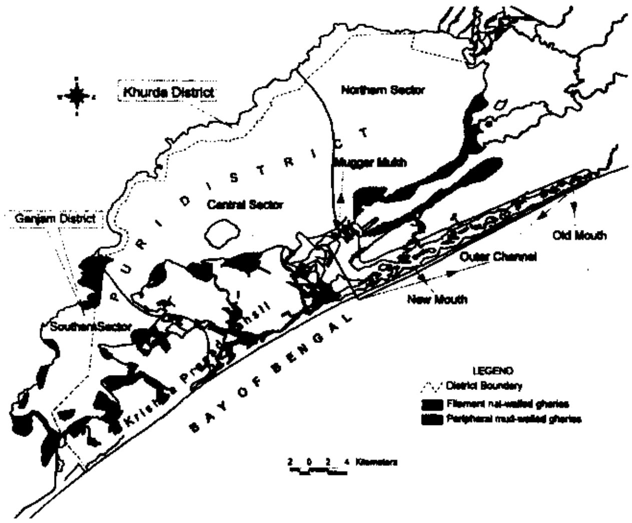

Fig. 1. *Map of Chilika Lagoon showing Prawn Gheries (2001-2002)*

Adverse impact on the lake ecosystem

While Chilika lagoon continued to face serious threats from both natural (siltation, decline in the salinity regime, alarming growth of weeds, shifting of mouth, etc.) and anthropogenic pressure (deforestation and degradation of catchments, increased agriculture activity in the fringe and island areas, human settlement in accreted land masses, release of waste water from processing and ice plants, excessive exploitation/extraction of bioresources etc.) resulting in its inclusion in the Montreux Record in 1993 (Pattnaik, 2001, Mohanty *et al.*, 2001 and Mohanty, 2002), large scale irrational expansion of prawn *gheries* covering more than 26 percent of the lagoons water spread area in 1995 carried out in unscientific manners by over-greedy people further damaged the already stressed ecosystem of the lagoon. The ecoinimical shrimp aquaculture carried out in prawn *gheries* can be understood from the following delineated points:

- Irrational coverage of water area exerts considerable impact on water flow and cause sedimentation of large denser particles in the immediate vicinity of *gheries* and thereby disrupting benthic communities.
- The low oxygen values inside the *gheries* due to decaying vegetation increases heavy detrital load which becomes a source of pollution.
- During heavy inflow of river runoff into the brackishwater lagoon in monsoon metabolites may decompose at the bottom under the influence of haloclines resulting in oxygen depletion below critical level affecting the organisms inside the *ghery* and in its vicinity.
- Earthen diked and net enclosure *gheries* in the shallow areas with bottom vegetation have damaged the spawning and nursery grounds of several resident fish and prawn species.

Table 1. *Operational details of prawn* gheries

Particular	Mudwalled *ghery*	Filament net walled *ghery*
Construction areas in the lagoon	Periphery	Open water and channels in the outer and inner Chilika.
Unit area (ha)	2.0 - 10.0	10.0 - 130.0
Av. cost of construction (Rs./ha)	20,000	22,000
Species cultured	P. monodon	P.monodon
Av. stocking density (per ha)	30,000	20,000
Av. survival (%)	40%	30.0
Lime application (kg/ha)	100.0 (Sporadic)	Nil
Fertilization	Nil	Nil
Supplementary feeding (kg/ha)	270.00 (Av.)	Nil
Av. growth (ABW)	33g	40g
Yield (kg/ha)	396.00	300.0
Av. operating cost (Rs/ha)	28,000	17,000
Av. gross return (Rs/ha)	118,800	99,000
Net profit (Rs/ha)	90,800	82,000

Table 2. *Average values of water quality parameters inside and outside the prawn culture* gheries *in Chilika lagoon during February, 2002.*

Parameter	Mud-walled *ghery*		Net-walled *ghery*	
	Inside	Outside	Inside	Outside
pH	6.8	7.1	7.2	7.4
Total suspended solid (ppm)	198	173	179	168
Dissolved oxygen (ppm)	4.3	5.5	5.7	6.2
Temp. (°C)	28.2	28.1	27.6	27.8
Total alkalinity (ppm)	106	62	82	69
Nitrite-N (ppm)	0.063	0.054	0.03	0.01
Nitrate-N (ppm)	0.49	0.28	0.21	0.11
Ammonia (ppm)	1.02	0.26	0.52	0.03
BOD (ppm)	4.01	2.46	1.98	0.67
COD (ppm)	38.01	21.06	17.87	14.89
Transparency (ppm)	31.3	56.8	60.4	63.7

- Net walled *gheries* constructed in the continuous water channels between Mahasa-Berhampur and Alanda-Patna island villages along the eastern side of the inner Chilika have completely destroyed the potential habitats of mud crab (*Scylla* sp.) with *Halophila* bed.
- Fringe areas covered with earthen diked prawn *gheries* reduce flood cushioning area and contributed to the damage of shoreline configuration.
- Smaller mud-walled prawn *ghery* units in the peripheral areas use artificial palletized feed for fattening of prawn during the last month of rearing (250-270 kg ha^{-1}) and bailout the waste water into the lagoon water after harvest which causes siltation and eutrophication in the immediate vicinity.
- Prawn culture in the net walled *gheries* inside the lagoon may affect the nutrient status of the ecosystem and reduced capture fishing areas, pushing the traditional fishermen into economic distress.
- Increased stocking demand of *P. monodon* seed has tremendous adverse impact on the wild seed resources of Chilika lagoon and coastal culture prawn fishery.
- Blockage of natural water channels in the inner Chilika (Krishna Prasad *Tehsil*) due to *ghery* construction has been affecting the original ecology of the inner Chilika and seaward breeding migration of prized fishes like mullets (*Mugil cephalus* and *Liza macrolepis*), seabass, etc. and lakeward movement of their seed resulting in poor fishery and recruitment failure.
- Stocking of WSD virus infected hatchery produced shrimp seed (procured from Andhra Pradesh) in some *gheries* during 2002-03 has been an environmental threat to the ecosystem and prawn stock.

Suggested ameliorative measures

Keeping in view the larger contribution of prawn *gheries* to the ecodegradation and the significant extent of damage to the social harmony among the communities living in and around the Chilika lagoon, some social measures are suggested to get the benefit of ecorestoration and to establish peace in Chilika. The suggestions are :

- State Administration to regulate fishing in the Chilika lake for conservation of its fisheries under Orissa Marine Fisheries Regulation Act (OMFRA) and Rules, 1982 strictly.
- Inner Chilika channels should be freed from net walled and mud walled *gheries* to restore free flow of water and movement of fish, prawn and crab from outer channel to the outer Chilika in the southern sector and to facilitate seaward breeding migration of mullets and other economic fishes.

- All capture fishery sources ('prawn' and 'non-prawn' sources) except for 'Bahani' net fishing areas should be physically demarcated by using GPS and fixing concrete poles on four directions to help prevent usurption of traditional capture sources for illegal *ghery* construction.
- Government policy for leasing of Chilika fishery sources needs radical change after careful analysis of entire gamut of issues/problems relating to prawn *gheries*.
- Regular programme for capacity building among stakeholders in wise use of bioresources in dynamic aquatic habitat and their effective participation in the restoration process should be organized.
- NGO's and CBO's should play their vital tactful roles to prevent such banned aquaculture activity in Chilika, if necessary.

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Water Productivity and Economic Evaluation of Aquaculture-based Integrated Farming System Approach in Waterlogged Ecosystem

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An integrated farming system was evaluated in farmer's field at Khentalo of Cuttack district, Orissa. Out of 2.47 ha waterlogged area, 1.64 ha was converted into a growout pond for fish and prawn culture while vegetable, flower and fruits were grown on 0.83 ha of raised embankment all around the pond since 1989. Poultry sheds were also constructed for rearing 4000 birds in such a way that their droppings could fall into pond as organic manure and feed for fish. The average productivity of lowland high yielding paddy was 3.5 t ha^{-1} as compared to 8.1 t ha^{-1} per annum of fish and prawn production. Gross and net returns from fish and prawn culture alone during 2002 were Rs. 6,17,160 (Rs. 3,76,317 per ha) and Rs. 3,31,065 (Rs. 2,01,868 per ha), respectively. This accounted for Rs. 14.00 per m^3 of water productivity in the pond system alone. The integrated farming system gave highest water productivity followed by vegetable and irrigated paddy. The gross and net returns from the whole system of 2.47 ha during the year 2002 were Rs. 6,51,110 (Rs. 2,63,607 per ha) and Rs. 3,62,515 (Rs. 1,46, 767 per ha), respectively. The farmer initially invested Rs. 1,23,910 in 1988 towards construction of the pond plus infrastructure and earned a net return of Rs. 40,554 per ha of whole system in 1989, which gradually increased up to Rs. 1,32,894 per ha in 1997. He again invested Rs. 1,30,000 towards stone pitching in 1998 and Rs. 3,20,000 towards poultry shed, and the net return (after adjusting investment) was Rs. 2,17,600 (Rs. 88,097 per ha) during 1998 and a net loss was Rs. 1,16,900 during supercyclone year in 1999. The net return per ha again increased steadily after cyclone from Rs. 27,465 in 2000 to Rs. 1,37,894 in 2001 reaching upto Rs. 1,46,767 (35 times higher than the paddy cropping) in 2002. Revival of poultry component, introduction of rice-fish integration and addition of milch cattle in the system would make it more profitable and more sustainable utilizing surface and ground water of the waterlogged area. This is going to be a replicable integrated farming model for the coastal Orissa. It may also be replicated in irrigated alluvial land of other regions.

(***Key words:*** *Integrated farming system, Water productivity, Waterlogged ecosystem, Aquaculture*)

Orissa state derives its livelihood, food, nutritional and environmental services from 0.70 M ha of upland area and 0.92 M ha of alluvial plains including 0.08 M ha of waterlogged soils. Inspite of 1482 mm of average rainfall, Orissa's rice productivity in 2000-2001 was 1127 kg ha^{-1} compared to 1540 kg ha^{-1} of Bihar and 3346 kg ha^{-1} of Punjab (Samra *et al.*, 2003). Even though water is abundant in this state, highest poverty ratio is still a unique situation. Similar is the case in many other eastern India states. In most of the waterlogged fertile alluvium soils of eastern India, water stagnates above ground for nearly six months in a year and only one anaerobic paddy crop is raised. Monocultures are risky and farmers are growing anaerobic rice with 50% probability of crop failures and 40% probability of harvesting less than 1 ton per ha. These threats of waterlogging, high rainfall and excessive ground water resources can be converted into poverty alleviating opportunities in many parts of eastern India. Diversification of rice monoculture into aquaculture-based integrated farming system in this scenario is not only environmentally sustainable but also an economically viable and risk avoiding strategy that ensures flow of income throughout the year. In these systems, marginal lands/ wet lands are generally brought into productive use, where pond serves as a focal point for direct or indirect links between other components (Mohanty, 2003). Keeping all these aspects in view, an aquaculture-based integrated farming system developed at farmer's field was evaluated for its productivity, sustainability and profitability.

MATERIALS AND METHODS

An on-farm aquaculture-based integrated farming system model was developed in waterlogged fields at Khentalo of Nischintakoili Block in the district of Cuttack, Orissa, since 1989. Out of 2.47 ha of low productive swampy lowland, a fishpond was constructed in 1.64 ha and the dugout earth was put on the *bund* (0.83 ha) to raise it for horticultural crops. The main pond of 1.64 ha was constructed with an initial investment of Rs. 1,23,910.

The pond system has three small nursery ponds (total 0.2 ha) for rearing of fry (0.3–0.5 g) to advanced fingerling stage (100–160 g) of Indian major carps for subsequent stocking in the main growout pond.

Prior to stocking, the main pond was treated following the standard pond preparation procedures such as drying, ploughing, liming (@ 200 kg ha^{-1} as basal), application of fresh cow dung (@ 7000 kg ha^{-1} as basal) and SSP (@ 25 kg ha^{-1} as basal). *Mahua* oil cake (also acts as a manuring substance) @ 250 ppm was applied during pond preparation to eradicate predatory/unwanted species. Stocking of the main growout pond (1.64 ha) starts in the month of January. The fishes are reared up to the month of May before harvesting. The pond was restocked in June and was harvested at the end of November. So altogether two crops are taken in a single calendar year. During November-December the pond was drained out. The pond preparation for the next year crop was carried out during the 45 day-gap between November and January. The three nursery ponds provided the required fingerlings for both the crops. The size of supplied fingerlings from nursery ponds for stocking in main pond ranged between 100-110 g for first crop during January and 140-160 g for second crop during June.

During stocking, a density of 7500 fingerlings per ha was maintained in the main pond with a species composition of 30:40:15:15 (*Catla catla: Labeo rohita: Cirrhinus mrigala: Cyprinus carpio*). In addition to this, prawn post-larvae of *Macrobrachium rosenbergii* (PL_{15-20}) were also stocked in the main pond for polyculture with Indian major carps @ 15000 ha^{-1}. High energy pelleted feed was given twice (1:1) a day (morning and evening) @ 2.5% of mean body weight throughout the culture period. Since cowdung was given as basal and poultry manure was supplied on daily basis, urea was not applied to the pond ecosystem for fertilization purpose. Weekly observations on soil and water quality were recorded using standard methods (APHA, 1989, Biswas, 1993). Periodic liming @ 25 kg ha^{-1} was carried out at every 15 days interval to maintain desired water pH and plankton density. Further, to maintain a cleaner aquatic environment, regular water exchange was carried out which corresponds to 2 - 3% day^{-1}. Crop performance, fish/prawn growth parameters, yield, survival rate, performance index, condition factor and feed conversion ratio were estimated using standard methods (Mohanty, 1999). Weekly rainfall, surface ponding and water table of the study site were monitored at regular interval.

In the initial years, seasonal vegetables, papaya and banana on the *bund* were planted along with mango, teak, areca nut and coconut. Different kinds of fruit trees in limited number like guava, pomegranate, sapota, litchi, jamun (hybrid) were also grown. In the western part of the tank, stone lining was done to construct 16 numbers of poultry houses (250 birds/shed) of 24 m^2 area in each in the year 1999. Apart from 16 numbers of on-pond poultry houses, the farmer constructed two more poultry houses (1000 birds/shed) adjacent to the pond dyke of 100 m^2 each to meet poultry manure requirement of his crops. So total capacity of birds at a time was 4000. This activity was started taking a loan of Rs. 6,00,000 from nationalized bank, out of which Rs. 1,20,000 was subsidised. The water productivity of different farming system was estimated as the ratio of output in terms of rupees to the volume of water used for the year 2002.

RESULTS AND DISCUSSION

Hydrology

The average annual rainfall of Khentalo for last 12 years (1991-2002) was 1476 mm and the monsoon (June to October) rainfall was 1249 mm, which accounts for 84% of annual rainfall. On an average the water level appeared above surface from 3rd week of June, reached maximum during first week of August, started receding after that and finally remained above ground for nearly six months in a year. Water table depth below ground level varied from 5 cm to 167 cm during post monsoon period (December to June). The steep rise and fall in water table was probably due to its drainage into river Mahanadi and Paika during low flow period and quick recharge of ground water during high flow period. Under this situation pond got enough water through subsurface inflow during July-October and needed ground water wells for filling the tank for first crop season of the year.

Water and soil quality in relation to fish production

Water and soil quality variables generally determine the production potentiality of the water body for any aquaculture system, as several biotic and abiotic factors play a key role in enhancement of productivity. Poor growth performance of fish/ prawn usually takes place at pH < 6.5, dissolved oxygen < 4 ppm, temperature < 20°C and transparency < 15 cm, while higher values of total alkalinity (>90 ppm) indicate a better productive ecosystem. Further, increase in plankton density reflects higher nutrient status and productivity of water body (Mohanty and Mishra, 2003, Mohanty *et al.*, 2003). However, the average recorded various hydrological parameters of the study site (growout pond) ranged between 7.29 $\pm$ 1.17 (pH), 5.7 $\pm$ 2.8 ppm (dissolved oxygen), 112 $\pm$ 31 ppm (total alkalinity), 221 $\pm$ 59 ppm (TSS), 4.2-6.1 ppm (dissolved organic matter), 0.033 $\pm$ 0.007 ppm (nitrite-N), 0.025 $\pm$ 0.008 (nitrate-N), 31 $\pm$ 11 cm (transparency), 6.5 $\pm$ 2.8 ppm (CO_2) and 0.18 $\pm$ 0.04 ppm (ammonia). The recorded minimum and maximum values of various pond water quality parameters even after dilution with groundwater were within or nearly the optimum range for fish/ prawn culture. The area with respect to soil type falls under alluvial zone. The average texture of the soil was clay having acidic pH (5.53) and the composition of sand, silt and clay was 36.6, 19.0 and 44.4%, respectively.

Aquaculture performance

Every year, growth pattern of cultured fish species in the first and second crop was totally different in this system. In the first crop (January - May), average daily growth (ADG) was minimum in the first month and gradually improved in subsequent months while the trend was totally reverse in the second crop during June - mid November (Fig. 1). However, as the stocking size in both the crops ranged between 100-160 g the survival rate, ponderal index, condition factor, yield and performance index of both the crops did not differ significantly. In both the cases in a year, average growth of cultured species ranged between 500-550 g with a survival rate of 92-95%. The average yield per crop was achieved between 3.6–3.9 t ha^{-1}, which corresponds to average yield of 7.5 t ha^{-1} yr^{-1}. In the initial years, the feed conversion ratio (FCR) was high (1:2.2) as the pond was newly excavated and there were no poultry units over the pond. However, after development of muck and introduction of poultry, the feed input decreased by 35-40% and FCR improved significantly (average 1:1.45).

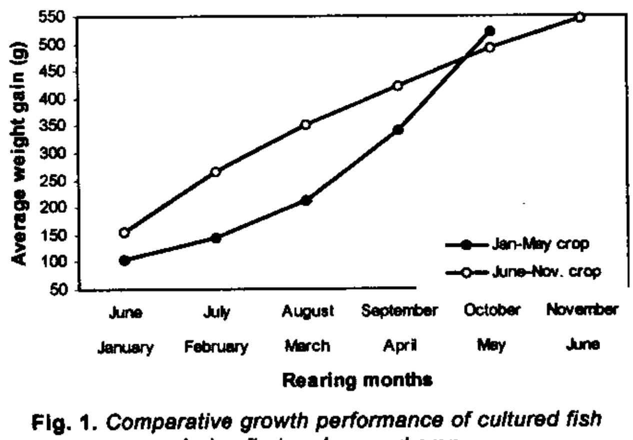

Fig. 1. *Comparative growth performance of cultured fish during first and second crop*

As in case of fish, prawns were not grown twice a year and were stocked only once during the first crop and was harvested in the month of November (8-9 months). During this period, on an average, 34-39% of the stocked material was harvested, with an average mean body weight of 72 g. Poor survival rate of prawn was probably due to smaller size at the time of stocking, cannibalism and heterogeneous individual growth (HIG) of male and female morphotypes. In general, *M. rosenbergii* is known to exhibit a complex social organizational hierarchy. The predominance of a definite social hierarchy among the male morphotypes increases the differential growth pattern within the population. The three main male morphotypes (stunted male-SM, orange clawed male- OCM and blue clawed male- BCM) and two main female morphotypes (virgin female, VF and berried female, BF) were usually found in the harvested biomass with the mean body weight ranging from 20g - 220 g size. Once a set of prawn reaches the terminal morphotype, it inhibits the transformation of other morphotypes to successive stages. This was probably the reason of wide range variation in growth pattern among different morphotypes. The percentage contribution of different male morphotypes noted under this system ranged between 45% (SM), 8% (OCM) and 47% (BCM), while among female morphotypes VF and BF contributed 80% and 20%, respectively. Similarly, average weight distribution of SM, OCM, BCM, VF and BF ranged between 28-32, 35-45, 140-155, 35-42 and 43-49 g, respectively. This corresponds to an average prawn yield of 640 kg ha^{-1} in addition to 7.5 t ha^{-1} yr^{-1} of fish production. Thus the total biomass production in terms of fish and prawn corresponded to 8.10 t ha^{-1} yr^{-1}. The annual operational cost and net return for the year 2002 of the pond system (1.64 ha) was evaluated and presented in Table 1.

Poultry system and *bund* plantation

In 1999, about 4000 birds were reared in each batch and a marginal profit of Rs. 2 per bird was obtained. But due to supercyclone (October 1999) more than 50% of bird died and the farmer incurred a heavy loss. This prohibited the farmer for continuing with poultry. The other important factors for discontinuation of poultry were requirement of more attention, high maintenance and feed cost in comparison to fish culture.

Table 1. Annual operational cost and net return of the 1.64 ha pond system (year 2002)

Input material	Quantity	Total input cost (Rs.)
Cost of fingerling production for stocking @ Rs. 2.00 per fingerling	12,285 x 2 time =24,570 nos.	49,140
Cost of prawn seed @ Rs.0.5 per post-larva	40,950 x 1 time = 40,950	20,475
Cost of ploughing by tractor @ Rs. 200 per hour	20 hours	4,000
Cost of cowdung @ Rs. 400 per ton	12 ton	4,800
Cost of lime @ Rs.4 per kg	320 kg	1,280
Cost of pellet feed @ Rs.8.50 per kg	18.4 ton	1,56,400
Water exchange @ Rs.50 per hour of pumping	300 hours	15,000
Labour cost @ Rs. 50 per man day	350 man days	17,500
Cost of pond draining @ Rs.50 per hour	5 pumps x 10 hour per day x 7 days = 350 hour	17,500

Total input cost = Rs. 2,86,095
Selling of fish: 12,285 kg @Rs. 40 per kg = Rs. 4,91,400
Selling of prawn: 1,048 kg @Rs.120 per kg = Rs. 1,25,760
Gross return = Rs. 6,17,160 (Rs. 3,76,371 per ha)
Net return from the system of 1.64 ha (gross return – input cost) = Rs. 3,31,065
Net return per ha = Rs. 2,03,107

In the initial years vegetables were also grown on the *bund* as fruit and other trees were small with limited canopy. The total returns from vegetables alone were to the tune of Rs. 1,10,400 (Rs.1,33,012 per ha) in the first year and as the trees grew it came down to Rs. 23,000 (Rs 27,710 per ha) in the year 2002. Before cyclone the system had 365 coconut trees, 3000 arecanut tree, 100 teak plants and 100 mango plants. Revenue from selling tender coconut (green) and ripe coconut was Rs. 1,05,000 (Rs. 80,000 from green and Rs. 25,000 from mature fruit). But after cyclone (1999) the system was left with 39 coconut trees, 490 arecanut plant, 10 mango trees and only 3 numbers of teak tree. As a result of cyclone the farmer not only suffered loss due to damage to tree but also majority of fish population died due to pollution of pond water.

The detailed yearwise input and returns from the pond as well as *bund* system (Integrated farming system) are presented in Table 2. The system suffered loss only in the year 1999 to the tune of Rs 1,16,900 due to devastating supercyclone. Further, the cyclone impact affected the net return in the subsequent year 2000 in which the net return was only Rs. 67,840. The net return was Rs. 1,00,170 in the first year operation of the system, which has enhanced to the maximum of Rs. 3,62,515 in the year 2002.

System's water productivity and rice equivalent yield

The water productivity of the system was estimated as the ratio of pond output in terms of rupees to the volume of pond water for the year 2002. The total volume of water available in the pond assuming average depth of 1.5 m was 24,570 m^3. Annual water exchange was about 19449 m^3. The total returns from the pond system alone was Rs.6,17,160 in the year 2002. This corresponds to a water productivity of Rs. 14.02 m^{-3}. The average rice yield of lowland high yielding variety paddy was 3.5 t ha^{-1} (Rs. 17,500 per hectare), while average fish and prawn production from 1 ha pond area was 8.1 t ha^{-1} (fish equivalent of 9.42 t ha^{-1}). Hence the rice equivalent yield of the pond system was found to be about 75 t ha^{-1} during the year 2002. The gross and net water productivity of different cropping system were estimated for the area as presented in Fig. 2. The integrated farming system gave highest water productivity followed by vegetable and irrigated paddy.

Income other than IFS

Beside the IFS the farmer has 3.6 ha of land out of which 2.4 ha was cultivated for paddy and rest for sugarcane crop under waterlogged situation. The average earning from the rest of the system other than IFS was Rs. 30,000. From sugarcane total earning was Rs. 20,000 (Rs. 16,666 per ha) and from paddy it was Rs. 10,000 (Rs. 4,166 per ha) per annum.

Table 2. *Details of yearwise expenditure and return of the integrated farming system (1.64 ha pond + 0.83 ha* bund*)*

Year	A: Input cost (Rs)							B: Gross return (Rs)					Net	Net
	Infra-structure	Horticul-ture/ vegetable seed, etc. *	Fish and prawn seed	Fish feed	Labour	Miscl. **	Total in rupees	Fruits & Vegetable	Fish & prawn	Coconut	Poultry ***	Total in rupees	Return in rupees (B-A)	Return in Rs / ha
1988	1,23,910 ****	-	-	-	-	20,000	143910	-	-	-	-	-	-	
1989	-	12600	12000	28730	14000	13000	80330	110400	70100	-	-	180500	100170	40,554
1990	-	12000	14700	29750	14000	13500	83950	114000	88000	-	-	202000	118050	47,793
1991	-	12000	16400	31200	14000	14800	88400	98600	96750	-	-	195350	106050	42,935
1992	-	10400	18000	36900	17500	14500	97300	44000	172800	30000	-	246800	149500	60,526
1993	-	8700	23000	42850	17500	16000	108050	42800	199000	45000	-	286800	178750	72,368
1994	-	8900	28300	48700	17500	19000	122400	46000	269200	48500	-	363700	241300	97,692
1995	-	7500	30100	54225	21000	30500	143325	52100	329700	59000	-	440800	297475	1,20435
1996	-	3200	33200	64650	21000	28600	150650	47200	345000	76900	-	469100	318450	1,28,927
1997	-	2850	35500	81000	24500	29000	172850	35450	372400	93250	-	501100	328250	1,32,894
1998	130000 *****	2900	48900	86800	28000	23000	319600	48300	383900	105000	-	537200	217600	88,097
1999	320000 ******	3000	53100	69500	28000	380000	753600	14000	218200	80500	324000	636700	(-) 116900	(-) 47,327
2000	-	2660	42200	92000	17500	31000	185360	1300	249500	2400	-	253200	67840	27,165
2001	-	2550	58700	106000	17500	34550	219300	12900	541000	6000	-	559900	340600	1,37,894
2002	-	2500	69615	156400	17500	42580	288595	23000	617160	10950	-	651110	362515	1,46,767
Grand Total on 15 year basis							**29,57,620**					**55,24,260**	**25,66,640**	**10,39,125**

* Horticulture including banana, papaya, pineapple, mango, arecanut etc. ; ** Miscellaneous includes lime, fertilizer, cowdung, pumping, irrigation system, masonry work, etc.; *** Poultry was added in the year 1999; **** Rs.123910 was invested towards pond excavation; ***** Rs.130000 was invested towards stone lining; ****** Rs.320000 was invested towards poultry component. **Average net return per ha per year on 15 year basis from IFS = Rs. 69,275**

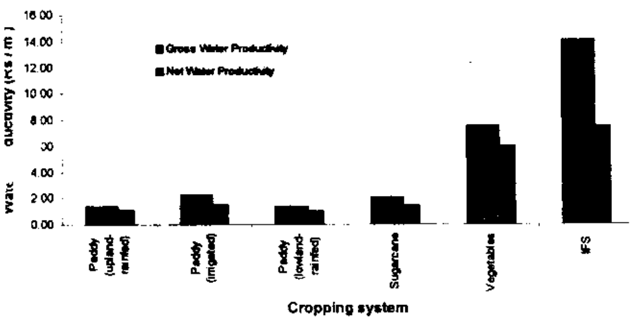

Fig. 2. *Comparative net and gross water productivity of different cropping system*

CONCLUSIONS

Despite the devastating effect of supercyclone in 1999, the project, without any compensatory financial assistance from other sources, remained viable as evident from Table 2. This has not only enhanced the social and financial status of the farmer but also maintained the sustainability of the system gradually over a period of time. It thus has served as an example of a successful agricultural enterprise though integrated farming system approach with right kind of scientific approach driven by market demand. Viewed from a broader perspective, the system allows farmers to diversify their production and enables them to fully utilize their farm labour, especially during the periods of low labour demand and offseason. Thus, the system results in maximum utilization of farm resources. Such IFS approach in small units may provide answer to enterprising farmers in competitive agribusiness environment in future.

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Impact of Aquaculture on Coastal Agriculture System in Pichavaram, Tamil Nadu

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Soil and water samples were collected from aquaculture ponds and nearby agriculture fields to assess the impact of development of aquaculture. Conversion of lands from agriculture lands to aquaculture was noticed. Soil pH does not vary much and electrical conductivity was high in aquaculture ponds (11.23 to 12.72 dS m^{-1}) than agriculture fields (7.17 to 7.82 dS m^{-1}). Water salinity was high in aquaculture ponds. Soil organic carbon and total phosphorus in water did not vary much. Though there was no adverse impact, suggestions were given for long term sustainability.

*(**Key words**: Conversion of agriculture land for aquaculture, Impact on soil & water properties)*

Aquaculture, a system of cultivating the aquatic organisms under controlled environmental conditions, becomes more remunerative than agriculture and other livestock industry. In recent years, aquaculture has been attracting heavy investment due to the availability of sound technologies and limitless potential for export especially shrimp. Due to high profit, economic viability of the industry, low labour requirement, suitable soil and environmental conditions and encouraging market for products, aquaculture industry has expanded in very short duration and is probably the fastest growing food industry in the world.

The aquafarming activities were initially started in the coastal fallow lands close to the estuarine and creeks. But due to the ever increasing demand for shrimps in the international market, people were tempted to increase the shrimp farming activities which gradually moved towards interior and neighbouring paddy fields, salt pans, tidal and inter tidal mud flats and mangrove areas. In less than 10 years, about 85,000 ha of land have been developed for this purpose in India. Consequently during last few years aquaculture farms are encroaching upon the agricultural lands at a very fast rate in the coastal belts of India (Bandyopadhyay, 1998).

The growth of shrimp farming in Thailand, Indonesia, Philippines and India has caused some changes in the land use, particularly reduction in the agricultural land. The seepage and discharge of water from shrimp farms appears to have caused salinisation of soil and water, leading to reduction in rice yields and abandonment of some paddy lands. Many rice growers in Thailand have shifted from rice cultivation to shrimp culture (NACA, 1994). In India conversion of agricultural lands came up as a contentious issue in some areas. In Andhra Pradesh itself, more than 50,000 ha of agricultural lands have been converted for aquaculture purpose. Apart from the conversion, this has raised many environmental issues like salinisation of nearby agricultural lands and water resources. This paper attempts to find the extent of conversion of agriculture land for aquaculture and its impact on soil and water quality in agricultural lands.

MATERIALS AND METHODS

The study was carried out in and around the Pichavaram in Cuddalore district of Tamil Nadu. Paddy is the major crop. The extent of change in agriculture land for aquaculture was assessed from the detailed survey. To assess the impact of aquaculture on agriculture system soil and water samples were collected in three aquaculture farm ponds and nearby agricultural fields for two seasons. Soil samples were analysed for pH, electrical conductivity and organic carbon and water samples were analysed for pH, salinity, dissolved oxygen and total phosphorus as per the standard procedures (Piper, 1966, APHA, 1995).

RESULTS AND DISCUSSION

Aquaculture was started after 1980 in this area and increased to around 300 ha. The study shows that the agricultural lands have been converted into shrimp farms in the area. In most of the coastal states in India, the extent of different habitats used

Table 1. *Soil and water quality in aquaculture ponds and agriculture fields*

	Parameters	Summer		Winter	
		Aquaculture pond	Agriculture field	Aquaculture pond	Agriculture field
Soil	PH	8.07	7.82	7.97	7.78
	Electrical conductivity dS m^{-1}	12.72	7.82	11.23	7.17
	Organic carbon (%)	0.92	0.68	0.81	0.57
Water	PH	7.65	7.18	7.11	7.42
	Salinity (ppt)	29.12	26.03	20.12	9.5
	Dissolved oxygen (mg/l)	4.17	3.82	4.72	4.35
	Total phosphorus (ppm)	0.034	0.021	0.041	0.005

for shrimp farming is not documented and revenue records are not updated. Revenue generation, non-availability of water and poor crop yield are the main reasons for this conversion. Earlier estimates revealed that 12.5–15% of the farms are constructed in lands earlier classified as agriculture land (CIFE/CIBA, 1997).

Soil pH ranged from 7.97 to 8.07 and 7.78 to 7.82 in pond and agricultural field, respectively. There was no significant difference in soil and water pH between shrimp pond and agriculture field. Electrical conductivity values were high in aquaculture ponds (11.23 dS m^{-1} to 12.72 dS m^{-1}) compared to agriculture field. Organic carbon values did not vary much between aquacultural ponds compared to agricultural fields. Water salinity was low in winter compared to summer in aquacultural ponds and agricultural fields. Dissolved oxygen was high in farm ponds compared to agriculture lands. Total phosphorus did not vary much between aquaculture ponds compared to agricultural fields (Table 1).

Though the soil and water quality was not affected, the conversion of agriculture land to aquaculture may affect the long term sustainability of environment. Honourable Supreme Court imposed the ban on conversion of agriculture land. Clearance from the district authorities indicating that the farm is not constructed on agricultural land is mandatory for obtaining license from aquaculture authority. Though the agriculture fields and aquaculture farms are in close proximity without any problem, there is a necessity for buffer zone for long term sustainability.

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Observations on Fishery of Windowpane Oyster in North Konkan Coast of Maharashtra

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The windowpane *Placuna placenta* produces seed pearls which are porcelaneous and translucent. Due to very small and irregular size, these are used for their traditional medicinal properties and not considered as gems. However, local village women use it as jewellery. Along the North coast of Maharashtra, the natural beds, windowpane oyster, locally known as "Chandra", are available in Raigad district. These beds are exploited by fishermen and after removal of pearl, the shells are sold to private firms for production of lime and calcium powder. The survey undertaken showed that during 3-4 months period, the income per head per day and for season was Rs. 195/- and Rs. 16,575/-, respectively.

(Key words: Windowpane oyster, Pearl culture, Economics*)*

The windowpane oyster, *Placuna placenta* produces seed pearls which are porcelaneous and translucent. These are used for their medicinal properties and are not considered as gems (Joseph and Kripa, 2001). But some village women use it as a pearl for beautification purpose. Because of tiny and irregular size, this oyster has not gained much importance as pearl (Victor *et al.*, 2003). Some natural beds of windowpane oyster are observed in North Konkan coast of Mahrarashtra. The fishermen of nearby villages are employed to collect the oysters and are able to get employment and profitable income from the capture fisheries (Velvizhi and Selvam, 2003).

The study was undertaken to know the natural availability of windowpane oyster and socioeconomics status of the fishermen involved in capture fishery of windowpane oyster.

MATERIAL AND METHODS

The survey was undertaken at Morebae in Uran *tehsil* of Raigad district which is in North Konkan coastal Zone of Maharashtra. Under this survey, total 20 boat owners were interviewed personally by the authors with the help of questionnaires prepared for the survey. On this basis information was collected and economics of windowpane oyster fishery was worked out.

RESULTS AND DISCUSSION

The fishermen collected the windowpane oysters from February to June with the help of hands or by hand nets. About 80 to 90 boats were going daily for collection. The fuel requirement per boat was about 5 litre day^{-1} amounting Rs.135/-. Total 7-8 villages were engaged in this business namely, Morebae, Wahal, Bamanwadi, Kopar, Shivaji Nagar, etc. Out of these villages 90% fishermen were engaged from Morebae village. The collection of 9 gunny bags (20 to 30 baskets) of oysters per day was done by 2-3 fishermen with the help of boat. One bamboo basket contains about 150 to 200 oyster shells (Table 1).

After transportation of this oyster to landing center, the fisherwomen were engaged in the processing of oyster for pearls. The fleshly portion from oyster was removed and boiled in water for about 15 to 20 minutes. After boiling, flesh was packed in clothes and these clothes were buried in the soil upto 1 to 2 feet depth for four days. During this period, the flesh was decomposed and only pearls remained. The sand and other foreign materials were removed by magnetic stone to get clear pearl. Later on these pearls were washed and sun dried.

From Table 2, it is clear that through this business, fishermen are able to get profit of Rs. 195/- per day per person and Rs. 16,575/- per season per person. The profit per boat per day was Rs. 585/- and profit per boat per season was Rs. 49,725/-.

The survey was undertaken for the complete season from Feb. 2003 to June 2003. It was noticed that these natural beds were found after a gap of 3-5 years. The disappearance of these beds for long time may be due urbanizations and industrial development in this area which resulted in imbalance of nature. A decade ago, the natural

Table 1. Observations on fishery of windowpane oyster

1	Fishing Season	-	Feb 2003 to June 2003
2	No. of fishing boats day	-	80 to 90
3	No. of villages engaged in fishing	-	7 to 8
4	Village with maximum percentage of active fishermen	-	Morebal (90%)
5	Method of fishing	-	Hand picking and with the help of hand nets.
6	Daily oyster collection / boat	-	20 to 30 bamboo basket
7	No. of oysters / basket	-	150 to 200
8	Quantity of pearls obtained /day /boat	-	4 to 5 g
9	Production of oyster shells /boat	-	7 gunny bags
10	No. of bamboo basket /gunny bags	-	4 to 5

Table 2. Economics of windowpane oyster

A)	**Expenditure:**	
1.	No. of fishing boats / day	80
2.	No. of Fishermen engaged / boat	3
3.	Quantity of diesel and charges / boat	5 lit and Rs. 135/-
4.	Expenditure /Fishermen/boat/day	Rs. 45/-
5.	Expenditure for 3 months (85 days)	Rs. 11, 475/-
6.	Expenditure /season /person	Rs. 3,825/-
B)	**Daily Income :**	
1.	Income of 4 to 5 g pearl / boat @ Rs.60/- per g	Rs. 300/-
2.	Income of pearl obtained (340 g) from 80 boats	Rs. 20,400/-
3.	Sale of oystershells/boat (@Rs.60/- per gunny bag) (7 gunny bags / boat and 4 to 5 bamboo basket /gunny bag)	Rs. 1420/-
4.	Sale of oystershells of 80 boats (560 gunny bags)	Rs. 33, 600/-
5.	Income per person (Shell + pearl)	Rs. 240/-
6.	Income per boat (Shell + pearl)	Rs. 720/-
7.	Income per person in a season (for 3 months/85 days)	Rs. 20, 400/-
8.	Income per boat /season (for 3 months / 85 days)	Rs. 61, 200/-
C)	**Profit :**	
1.	Profit / person /day	Rs. 195
2.	Profit /boat /day	Rs. 585/-
3.	Profit /person /season	Rs. 16,575/-
4.	Profit / boat / season	Rs. 49,725/-

oyster beds were observed every year in Vashi estuary. The poor fishermen in this area are getting profit from this fishery of about 16,575/- per season per person. Thus, they are able to improve their socioeconomic status (Velvizi and Selvam, 2003).

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Preliminary Studies on Use of Fish Culture in Rainfed Pond Water for Seed Production of Freshwater Prawn, *M. rosenbergii* in Backyard Hatchery

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Generally, clear freshwater is mixed with seawater to prepare required saline water for production of seed of fresh water prawn, *Macrobrachium rosenbergii*. However, due to scarcity of clear fresh water, this research station tried to make the use of fresh water from rainfed fish culture pond which was highly turbid (87 mg l^{-1}). Water was filtered through irrigation filter having mesh size of 0.1 mm. After filtered turbidity was reduced to 57 mg l^{-1} the water parameters were recorded during the experimental period. Live feed (*Artemia naupilia*) and wet feed prepared artificially were given during larval rearing period. The first PL was observed on 21st day and total cycle was completed in 40 days with 32 percent survival.

(**Key words**: *Freshwater prawn, Seed production, Rainfed pond, Fish culture*)

Marine shimp farming gets affected due to viral disease problem in recent years (Mohanta and Rao, 2000). Due to that many farmers are attracted towards culture of Giant freshwater prawn, *M. rosenbergii.* However, the seed availability is the major problem in culture. To run the hatchery there is requirement of 60-70% of freshwater and the remaining is seawater to maintain larval culture medium of 12-14 ppt salinity. Most of these hatchery owners use clear freshwater, having no or less turbidity (Reddy, 1997). Due to scarcity of clear freshwater in coastal part, it is necessary to know the use of rainfed fish pond water for hatchery. In Raigad district most of the ponds are rainfed having high turbidity due to colloidal particles. In these ponds fish culture are carried out. In the coastal belt there is ample supply of marine water from estuary but there is lack of freshwater. Therefore, with the use of surface dugout pond water it may be possible to harness rainwater during monsoon season. This stored water can be useful to run the backyard hatchery in coastal area.

Therefore, the study was undertaken to know the effect of rainfed fish culture pond water for seed production of Giant freshwater prawn, *M. rosenbergii*, so that it can be helpful to run backyard hatchery.

MATERIALS AND METHODS

In the present study larval rearing was conducted in two different fresh water sources i.e., clear tapwater and pond water in experimental plastic pools with capacity of 500 litre. The water parameters of different water sources are shown in Table 1.The pond water was filtered through irrigation filter having fine mesh. Freshly hatched prawn larvae (stage I) were estimated and supplemented to the larval rearing tanks. Moderate continuous aeration was provided to all the rearing pools using compressor. Salinity of water were maintained to 12-14 ppt throughout the rearing period by using different fresh water sources. Effective larval medium were 400 l in each pool with a stocking density of 75 nos. of (Stage I) larvae per litre. Daily siphoning of molted shells and 50% water exchange were made throughout the larval cycle. *Artemia nauplii* were fed twice a day and libitum upto IV stage in both the pools. After IVth stage, prepared wet feed once in a day at morning after passing through sieve and *Artemia nauplii* at evening were provided.

RESULTS AND DISCUSSION

The details of larval rearing are presented in Table 2 and it is found from the table that there is no much difference in larval survival percentage. Appearance of first PL was observed at 21 days in clear water larval rearing medium, where as in pond water pools it appeared at 26 days. Larval rearing cycle was completed in 40 days in clear water and in pond water it was extended upto 45 days. Total number of PL produced has also not much different i.e., 9801 in clear water and 8500 in pond water. Larval survival was found 32.67% in clear water,

Table 1. Particulars of water parameters in different source of water

Parameters	Pond water (freshwater source)	Pond water after filtrations	Seawater	Clear tapwater (freshwater source)
EC (dS/m)	0.26	0.26	32	0.1
pH	7.51	7.56	7.57	7.00
Eh	023	023	023	023
Salinity (ppt)	0	0	31	0
Hardness ppm)	35	30	650	5
Alkalinity (ppm)	110	100	240	100
Turbidity (ppm)	87	50	5	Nil
Transparency	10	30	95	100
Temp. (°C)	26.5 - 28.0	26.5 - 28.5	26.5-28.5	26.5-28.5
DO (ppm)	4.2-5.6	4.3 - 5.8	4.6 to 6.2	7.2 - 8.2

Table 2. Details of larval rearing

Particulars	Pond water after filtrations (experimental)	Clear tapwater (control)
Salinity (%)	12-14	12-14
Water temp (°C)	26.5 to 28.5	26.5 to 28.5
Capacity of plastic pools (l)	500	500
Effective larval medium (l)	400	400
Stocking rate (No. of larvae/L)	75	75
NO. of larvae (stage 1) stocked	30,000	30,000
Quantity of water exchanged	50%	50%
Feed	*Artemia nauplii* (upto IV stage)	*Artemia nauplii* (upto IV stage)
Prepared feed	Wet feed (From V stage)	Wet feed (from V stage)
Appearance of first PL. (days)	26	21
Larval rearing cycle (days)	45	40
No. of PL produced	8500	9801
No. of PL /l.	21	24
Larval survival (%)	28.33	32.67

whereas in pond water it was 28.33%. The details of water quality parameters in larval rearing medium are presented in Table 3. The dissolved oxygen and pH were higher in clear water larvae rearing medium as compared to pond water larval rearing medium. Whereas hardness, alkalinity, NH_3 -N, NO_2-N and NO_3-N were higher in pond water larval rearing medium as this water was too much turbid.

Optimum water quality management is a pre-requisite for success of any prawn hatchery. Water is the main source to carry diseases to the larvae. Therefore it is very important to maintain water quality (Reddy, 1997). Ideal range of turbidity of water is less than 30 mg l^{-1} with a transparency of 20-35 cm (Reddy and Chandra Prakash, 1999). Sebastian (1996) suggested that the use of open wells or bore wells as a freshwater source for hatchery and also suggested 100 ppm alum treatment for turbidity of suspended particles. The present investigations revealed that use of surface dugout fish culture pond water can be used for seed production of *M. rosenbergii* by filtering this water through irrigation filter and thus saves the expenditure. Rao (2000) reported that poor growth

Table 3. *Details of water quality parameters in larval rearing medium*

Parameters	Pond water	Clear water
Water temp °C	26.5 to 28.5	26.5 to 28.5
Salinity $\%_0$	12-14	12-14
pH	7.6 - 8.2	7.7 - 8.3
DO (ppm)	3.8 - 5.4	4.3 - 5.9
Hardness mg/l	1128 - 1584	1110 - 1426
Alkalinity	160-180	120-140
NH_3 -N (mg at N/l)	2.89 - 6.18	1.69 to 5.98
NO_2 -N (mg at N/l)	0.75 - 6.20	0.99 - 6.80
NO_3 -N (mg at N/l)	23.82 - 52.30	18.30 - 40.52

performance of *Rohu* and *Mrigal* was observed in turbid tanks of Karnataka having less transparency of 15.0 to 6.0.

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Session
On
Forest plantation as wind breaks and for ecology and economic upliftment

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Advances in Mangrove Research : Soil-Plant-Climate Interactions in Mangroves

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Mangrove forests are affected by edaphic, climatic and hydrological parameters but very limited information is available on these aspects. Mangroves grow well in silty clay soil. Coarse textured soil is not suitable for the growth of mangroves. Extremes of salinity are not desirable for optimum growth of mangroves, and so also the extremes of temperature. Rainfall is beneficial for the growth and establishment of mangroves. Changes in microclimatic in mangrove is also affected by tidal action. Tidal amplitude also affects mangrove establishment and development. Rise in sea level will also affect the mangrove forest.

*(**Key words**: Mangroves, Soil-plant-climate interactions)*

Mangrove forests are a complex ecosystem composed of various inter-related elements in the land-sea interface zone and linked with other natural systems in the coastal region such as corals, sea grasses, coastal fisheries and beach vegetation. The ecosystem influences climate, prevents coastal erosion, contributes to land accretion and acts as a buffer zone in cyclone prone areas. It also supports human population living in and dependent on this ecosystem for centuries (Vannucci, 1986).

Mangrove forests are susceptible to changes in climatic, edaphic and hydrological conditions. The effects of these environmental factors determine the extent and distribution of mangroves (Rao, 1986).

Among climatic factors, temperature, rainfall and wind have the most significant influence on the composition and quality of mangrove vegetation (Hong, 1991).

Soils

Research on mangrove soils has been very limited. Soils in mangrove areas are formed by alluvium from rivers and by the sediments from the sea. Mangrove soils are rich in nutrients such as magnesium, sodium, phosphorous and potassium. The physical and chemical characteristics of the soil depend on the source of alluvium and sediments, which in turn influence mangrove distribution.

Mangroves grow well on silty clay soils (Bandyopadhyay, 1995), which are prevalent along the coastline, estuaries and closed gulfs of Vietnam. However, in the northern part of Vietnam, mangroves grow on mudflats where the alluvium originates from lateritic hill soils; and consequently the trees remain small.

Hong (1992) investigated the growth of *R. stylosa* and *Kandelia candel* planted on sandy clay mud flats and observed that the growth rate of mangrove seedlings is low due to poor soil texture and severe climatic condition. Here, *Kandelia candel* showed highest growth rate.

Hong (1991) recorded certain changes as a result of rehabilitation of mangrove forest. The substrate has been gradually transformed into loam and the pH value has subsequently increased indicating a reduction of soil acidity. There had also been a steady increase in litter production in those areas resulting in the increase of commercially important species of fish, shrimps and other aquatic animals. Under intense sunlight, high temperature, high evaporation rate and insufficient tidal activity, the bare soil has been oxidized to acid sulphate soil in Mekong delta and attempts to cultivate coconuts have failed after a period of three years due to degraded soil of the area (Hong and San, 1993).

Sharp differences in textural composition have been noticed (Bandyopadhyay, 1995) among stressed islands (Harinbari and Sagar islands) and unstressed islands (Prentice and Lothian) in Sundarbans. Prentice and Lothian are completely inundated during high tide and deposition of alluvium takes place continuously with the resultant increase in silt and clay factions. But Harinbari and Sagar islands remained uninundated during high tide and silt deposition did not occur. Accordingly, water holding capacity was low. This resulted in the differential growth of mangrove forest.

Hardjowigeno (1986) reported that the dominant mangrove soils in Indonesia are fine textured, saline, unripe and contained sulfidic material in different amounts and depth, and observed dominance of *R. mucronata* in deep muddy soils, *R. aptculata* in shallow muddy soils, *R. stylosa* in sandy coral soils and *R. mucronata* in soils having 30 to 50 cm peat.

In Bangladesh, Siddiqui and Khan (1990) observed poor survival and growth of *Heriteria fomes, Xylocarpus mekengensts, Brugeria* and *Ceriops decandra* on newly accreted soils. Hassan (1986) claimed that soil texture, pH, salinity, bulk density and other soil characteristics are not responsible for the variation of growth of planted mangroves trees as most of those characteristics are more or less similar along the coastal belt of Bangladesh. Das (1971) reported that both *Sonneratia* and *Avicennia* are pioneer tree species for coastal region in low and high saline areas, respectively.

Six soil types have been identified as being closely associated with mangroves in Fiji (Lal, 1990). The 'dogo' clay soils and the generallay acidic "tiri" soils which have no structure, porly drained and possess high level of exchangeable sodium and sulphides, generally support healthy growth of *R.samoensis, R.stylosa, B.gymnorhiza* in the project areas.

Salinity

The salinity of the soil depends on salinity of the tidal water, tidal height, rainfall, elevation of the area, proximity to creeks, proximity to fresh water inflow, depth to water table, texture of the soil, presence of vegetation, etc. In Sundarbans, the salinity of the soil profile is less near the inner estuaries where there is fresh water in flow (Bandyopadhyay, 1995). The magnitudes of fresh water input controls the salinity regime. Seedlings of *S. alba* were grown for three months in nutrient solutions containing 0%, 25% and 100% seawater. Plants grow poorly in both 0% and 100% seawater treatments. Growth was greatly stimulated in 25% and 50% seawater treatments. Root length however increased gradually with increasing salinity with 100% seawater producing the longest roots (Samarakoon and Jayawickrema, 1986).

In Bangladesh Siddiqui and Khan (1990) reported satisfactory survival performance of *S. apetala* all along the coastal belt, but growth was higher with lower salinity and growth rate and declined at places with higher salinity. In case of *Avicennia offoicianlis,* higher growth was reported at Char Kukri with a water salinity of 16 ppt during the dry season, but growth of *S. apetala* was higher with lower salinity (5 to 15 ppt) and growth was lower with salinity (15-25 ppt). *Xylocarpus mekongenis* occurs in moderately and strongly saline zones in Sundarbans (Choudhury, 1971). In case of *Brugniera* growth was high in 15-25 ppt and lower in 25-35 ppt. *E. agallocha* is one of the dominant species in slightly and moderately saline zones. It had stunted growth and was absent in greater part of strongly saline areas.

Mangroves develop well in places such as Ca Mau Cape (Vietnam) where mean salt concentration is 22-26 ppt. High salt concentrations of 33-36 ppt diminishes the size and number of species as is evident on Quang Minh Coast in Vietnam. Mangrove species such as *A. alba, A. marina, R. mucronate* and *R. stylosa* can adjust to different salinity levels and can tolerate high salinity during dry season and low salinity during the rainy season. However, *Nypa fruticians* can grow only in brackish environment with a salinity of 5-15 ppt and will dry when planted in very saline coastal areas (Hong and San, 1993).

Rainfall

Mangroves require a certain amount of fresh water for optimum growth. Rain regulates salt concentration in soil and plants and provides an extra source of fresh water. South West monsoons from the Indian ocean bring heavy rains to S.E. Asia during the summer months. Consequently, the most dense mangrove forest are found in this region.

Surface water salinity in mangrove areas is greatly affected by seasonal rainfall and evaporation. Heavy rainfall in wet season is said to be the main factor causing low salinities of 0,5 to 1.0 ppt in the Red River estuary and also in Mekong delta (Hong and San, 1993).

Tides

Tides affect vegetation along with the structure and salinity of the soil. Diurnal tides are less favourable for the growth of mangroves especially those which have no pneumatophores, since the period of inundation is doubled requiring a high storage of oxygen in roots. Mangrove forests of Southern Vietnam, which are affected by semi-diurnal tides develop much better than those in the north (Hong and San, 1993).

Tidal amplitude also affects mangrove development. Large amplitudes and high velocities of tides widen the channels and cause erosion in mangrove areas, thereby minimizing mangrove seed and propagule settlement. Moreover in low amplitudes there is title transportation of seedlings and sediment.

Changes in microclimate in mangroves is also affected by tidal action.

Temperature

Extremes of temperature affect the growth of mangrove vegetation, though climate is basically decided by factors in global scale, however, it is important for mangroves at the regional scale.

A great number of seedlings of *R. stylosa* were killed below 5°C and all seedlings killed below 3°C in *kharif* in Saudi Arabia, although *A. marina* was not killed at 3°C. Here, all plants were less than one year old. However, there was less damage from temperature higher than 5°C to *R. stylosa* and *A. marina*, *A. marina* has more tolerance to high temperature than *R.stylosa* (Kogo, 1986). It was further observed that strong solar radiation damaged the young seedling and propagules, particularly of *R. stylosa*. Comparative germination test at Khafji showed 100% germination in shaded plots, whereas 50% damage was recorded in open areas.

Reduction in number of species, and the height and size of trees at low temperatures wee noted. It was reported that in January, 1961 a number of leaves of *Brugaria gymnorhiza* dried and dropped, when the temperature went down to 0°C in Vietnam. In April, 1990 at Duyen Hai district when the air temperature went upto 40°C physical activities of *R. apiculate* were minimized (Hong, 1991). Similarly, it was found that a number of *Avicennia* propagules died 48 hours after exposure to high temperature of 39-40°C.

Sea level rise

A rise in sea level will affect the mangrove forest. It will accelerate the speed or coastal erosion. Strong waves deposit sand and sediment in mangrove areas, covering pneumatophores and killing trees. No detailed study has been done so far on the effect of sea level rise on mangrove forests.

CONCLUSIONS

Attention is necessary on systematic study under controlled condition on the effect of different soil parameters and climatic factors on different aspects of mangrove growth and establishment.

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Advances in Coastal Zone Research: A Note on Technological Improvement in Mangrove Research

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The paper discusses two significant areas of application of technological advancement. In one, it suggests the use of remote sensing technique in fields like coastal geomorphological changes, sediment discharge, movement, detection and monitoring of cyclones, sea-surface temperture, ocean current and mangrove environment. In another area, the paper suggests application of biotechnological tools and tissue culture for vegetative propagation in mangroves.

(***Key words:*** *Mangroves, Remote sensing, Vegetative propagation, Tissue culture)*

In a significant application, remote sensing technique is finding ever increasing applications in fields like coastal geomorphological changes, sediment discharge, movement, detection and monitoring of cyclones, sea-surface temperature, ocean current and mangrove environment. Orbital remote sensing data provide synoptic, multispectral repetitive coverage which are very useful in the observation of various biological and non-biological factors and interactions between them. Department of Ocean Development funded programme on Marine Remote Sensing Satellite Information Services (MARSIS) focused on the monitoring of coastal ocean resources through remote sensing. National Mangroves Committee of India recommended the Nationwide mapping of mangroves-areas, preferably by remote sensing techniques with land surveys and time series data to asses the rate of degradation of mangrove resources.

The spectral reflectance of different mangrove species is found to be useful to assess plant health and local environments. The red edge (0.68 to 0.76 mm) is wider in all mangrove species but it does not have a sharp red edge like other vegetation. This significant feature could be used in identifying mangrove forests from other vegetation.

Remote sensing data have been increasingly used for mapping mangrove wetlands for the reasons:

a) Provides quick and repetitive survey of large area.

b) Provides images with different spatial resolutions for different degree of details.

c) Provides accessibility to inaccessible sites.

d) Provides faster and accurate digital classification with limited ground verifications.

e) Provides temporal land cover pattern during different seasons, and

f) Provides portability to GI systems.

A nationwide mapping/inventory programme for coastal wetlands has been launched in India by Ministry of Environment and Forests with the participation of Space Application Centre (SAC) and other state remote sensing agencies to prepare coastal wetland maps on 1:250000 scale using TM satellite and LISS-II data. Based on ground truthing, the use of optical sensor data in demarcating the mangrove areas is established. Especially the visual interpretation of IRS LISS II is found to be more suitable to demarcate both dense and less dense mangrove areas. The advancement of agriculture activities and the converted mangrove areas clearly appeared on satellite image in case of Mahanadi delta.

Since coastal areas are very much prone to have cloud cover during most part of the year, the use of optical sensors data is very much restricted. But with the advent of Synthetic Aperture Radar (SAR) all weather monitoring of forests, agricultural crops on a repetitive basis are possible. Mapping of mangroves and coral reefs in South Andaman islands using SPOT, Lands at MSS, TM LISS-II and SAR X band images indicates that SAR data is useful to mangroves since it has tonal variations from evergreen forests but not suitable to map coral reefs due to high moisture content.

In another significant application area for vegetative propagation in mangroves, vast areas of costal wetlands potential for mangrove growth could be covered with mangrove vegetation but large scale planting materials necessary for this could only be possible through -

- Vegetative propagation
- Tissue culture technique

Moreover, mangrove planting season may not coincide with the reproductive season of mangrove plants and in such situations it is suggested :

- Vegetative propagation methods like stem cutting, propagule cutting and air layering offer the advantages of mass multiplication of superior clones and trees
- Endangered species can be easily multiplied through vegetative propagation
- Propagation of sterile hybrids is possible mainly through vegetative propagation
- Advances in the area of biotechnology and tissue culture offer unique opportunity for generation of large scale planting materials as and when required

Moreover, with the application of molecular tools it is also possible to monitor the genotypic changes and ensure true clonal propagation of the desired material.

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Plant Diversity in the Sundarbans Mangorve Forest of West Bengal

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Mangrove plants on the estuarine mouths, delta lands, and coastal intertidal zones of the Sundarbans are interesting for their unique halophytic adaptation and step by step succession. This ecosystem is important for overall protection of the coastal areas from severe natural calamities and also for having important economic potentialities. This silted up delta land is also fertile for aquaculture and agriculture. For these unique potentialities, large group of rural people were settled in these coastal areas for their easy livelihood since the last two centuries. As such, the important roles of these mangroves and uniqueness were studied and highlighted in this paper.

*(**Keywords** : Sundarbans mangroves, Plant diversity, Aquaculture)*

The mighty river Ganga originating from the ice melting mountain peaks of the Great Himalayas meets the Bay of Bengal as Bhagirathi - Hugli river in West Bengal (India) and Padma-Meghna River in Bangladesh. These vast rivers traverse several hundred kilometers of diverse ecological niches in the hill tracts of the Great Himalayas. The confluence of the mighty river Ganga is popularly known as lower Ganga delta, which gradually accreted or silted up due to continuous silt deposition on seaboard. In this zone dense mangrove forest was developed gradually, which is popularly known as Sundarbans. Alongwith these mangroves, several species of the mangrove dwelling fauna have also settled, acclimatized and became dominant. Besides these unique floral successions in the intertidal lands, good number of algae, fungus, and aquatic-terrestrial-amphibian-avian fauna are found as common dwellers in the estuarine rivers, canals, creeks and wetland. These mangrove forests, estuaries rivers and mangrove reclaimed area cover about 9630 km^2 within India (Naskar and Guha Bakshi, 1987).

Geographical areas and boundaries of the Indian Sundarbans mangal

Six major tidal rivers *viz.*, Baratala (Muriganga), Saptamukhi, Thakuran/ Jamira, Matla, Goasaba, Raimangal-Herobhanga or Harinbhanga flow from north to south and meet the Bay. Most of these rivers in the Indian Sundarbans have silted up as the upstream connections with the mother river Ganga have choked. Besides these, the large scale human interaction and deforestation activities *vis-à-vis* reclamation and renovation of the mangrove forest land resulted in silt deposition on these river beds. Furthermore, good number of broad to narrow rivers, rivulets, tidal canals and creeks *viz.*, Bidya, Raimangal, Kalindi, Kartal, Hogol, Jamuna, Ichhamati, Gomor, and Ajmalmari formed a close network system. During high tide and sea surges most of these coastal zones, islands and delta lands in particular get inundated or flooded with saline seawater. In these saline zones, the mangrove trees, shrubs and the halophytic shrubs, herbs and climbers mostly grow naturally and step by step naturalizsed (Mac Nae, 1968). Indian Sundarbans spread over within the latitude 21°31′ N and 22°30′ N and longitude between 88°10′ E and 89°51′ E (Naskar, 2004).

MATERIALS AND METHODS

Field surveys were conducted by country boat and motor lunch in and around Sundarbans Tiger Reserve, and beyond the western part of the Matla river. Total 112 plant species of mangroves and mangrove associate were collected and identified and also their soil conservation role investigated on these intertidal zones. The fisheries potentialities on these estuarine rivers and agricultural possibilities on these mangrove reclaimed delta lands were also assessed based on critical field studies. In the present treaties, halophytes, the special type of xerophilous plants and their adaptations are discussed with special reference to Indian Sundarbans.

RESULTS AND DISCUSSION

Broad characteristic features of the halophytes and their salt tolerance mechanism

These halophytic plants normally have succulent foliages with dominant water storage tissues; their leaves are usually small to medium, evergreen, leathery with thick cuticle layer and with dominant well developed palisade tissues. As these group of plants grow on the salt dominant soil and saline water mixed substrate these plants adapt best in saline environment by some specific techniques viz., or osmo-regulatory mechanisms for overcoming the toxic effect of salt. These specific and specialised mechanisms are (i) salt extrusion, (ii) salt exclusion and (iii) salt accumulation (Scholander *et al.*, 1962, Naskar, 2004). The ultra-structure of the epidermis and endodermis of capillary rootlets may be the most important sites for the ultra-filtration mechanism for the halophytes in general and mangrove plants in particular and these structural modifications make them fit to grow in the saline seawater. Scholander *et al.* (1962) have mentioned that mangroves and the halophytic plants are either salt secretors or salt extruders (Table 1).

Joshi *et al.* (1975) have highlighted that *Avicennia* spp. are the most efficient salt extruding species; as such, *Avicennia marina* and other species can grow in high saline condition. Salt exclusion processes are effective salt free selection mechanism; it may be performed due to the presence of ultra-filtration mechanism in their roots; by these ultra-filtration mechanism, water is absorbed by halophytic plants after filtering out the salt ion *and* these halophytic plants or mangrove species sometime deposit sodium and chloride ions in their stem barks and pneumatophores, knee roots or older leaves. Due to their salt accumulation abilities, these halophytic groups of plants bear succulent leaves. Joshi *et al.* (1975) have mentioned that the old senescent leaves of the halophytic/ mangrove plant species contain sodium and chloride ions, but potassium and phosphate ions are withdrawn prior to leaf senescent. By this process and mechanism the excess salts are usually removed out from the metabolic tissues. The deciduous species exclude salt by annual leaf fall, prior to new growing foliages and flower initiation.

These mangrove plants normally form aerophores or air-breathing roots, known as pneumatophores, pneumatothods of *Phoenix paludosa*, root-knees and others; these aerial roots perform effective root zone respiration in this anoxic waterlogged, compact intertidal soil. Besides these air-breathing roots, supporting stilt roots, prop-roots, root-buttresses, plank-roots are the other characteristic features of these major mangrove species alongwith salt tolerance mechanism and root zone respiratory functions, these aerial roots also provide mechanical support. These dominant mangrove species are the trees or shrubs and mostly have their unique viviparous, crypto-viviparous or pseudo-viviparous germination mechanism. But most other halophytic herbaceous plant species lack all these characteristic features of true or major mangrove species. Other than these mangroves or halophytic plants, no other plants can grow in these intertidal coastal/ delta regions. Furthermore, several groups of the halophytic plants generally have no such well developed aerial roots, the viviparous or crypto-viviparous germination mechanism; these characteristic features alongwith few other characters of true mangroves differentiate them from the vast group of other halophytic plants. These coastal mangroves and halophytic plants may also supply and provide nutrients to these coastal soil and water phases and enrich productivity of this ecosystem. On the basis of their detailed characteristic features and habitats in these saline areas, halophytic plants and the mangroves are categorised as i) major components or elements of mangroves, ii) minor components or elements of mangroves, iii) mangrove associates or back mangroves and iv) mangrove habitat weed flora (Tomlinson, 1986). Mangroves are basically trees or shrubs and most of these herbaceous flora in the saline habitats are known as 'halophytic flora', but these are not mangroves in its true sense.

Uniqueness of the Sundarbans *Mangals*

The Sundarbans *mangals* within the boundary of Bangladesh and India are unique with following features.

- This mangrove zones have the habitats for highest bio-diversity, unique with flora and fauna;
- Sundarbans mangal is the only marshy mangrove habitat Tiger land of the World;
- Tidal amplitude and fluctuations of the Sundarbans mangal is very high, up to 6m- 7m MSL;
- Floral successions in the Sundarbans mangal are also unique diversity;
- Sundarbans mangal support coastal fisheries throughout the east coast of Indian,
- Sundarbans mangal acts as the sink for mega - metropolitan pollutants;
- For all these reason, Sundarbans mangal was included in the 'World Heritage' list by IUCN.

Sl. No.	Scientific Name of the Plants	Halophytic characters adapted by the plants				
		Leaf	Stem	Root	Rep. Part	Remarks
III.	**Back Mangrove Plant Species of the Indian Sundarbans**					
43	*Derris indica* (Lamk.) Bennet	+	-	-	+	These back mangroves generally grow in mangrove adjacent area; occasionally inundated
44	*Derris scandens* Benth.	+	+	+	+	
45	*Derris trifoliata* Lour.	+	+	+	+	
46	*Caesalpinia crista* Linn.	+	+	+	+	
47	*Caesalpinia bonduc* (Linn.) Roxb.	+	+	+	+	
48	*Sarcolobus globosus* Wall.	++	+	+	+	
49	*Sarcolobus carinatus* Wall.	+	+	+	+	
50	*Dolichandrone spathacea* (Linn.f.) Schum	-	-	-	-	
51	*Cerbera odollam* Gaertner	+	+	+	+	
52	*Barringtonia racemosa* Roxb.	-	-	-	-	
53	*Capparis zeylanica* Linn.	-	-	-	-	
54	*Crataeva roxburghii* R. Brown	-	-	-	-	
55	*Opuntia dillenii* (Ker. Gawler) Haw.	-	-	-	-	
56	*Salacia chinensis* Linn.	-	-	-	-	
57	*Pandanus tectorius* Soland ex Parkins.	-	-	-	-	
58	*Barringtonia acutangula* (Linn.) Lour.	-	-	-	-	
59	*Solanum trilobatum* Linn.	-	-	-	-	
60	*Solanum surattense* Burn.f.	-	-	-	-	
61	*Diospyros ferrea* (Willd.) Roxb.	-	-	-	-	
62	*Dodonaea viscosa* (Linn.) Jacq	-	-	-	-	
63	*Allophyllus cobbe* (Linn.) Blume	-	-	-	-	
64	*Calophyllum inophyllum* Linn.	-	-	-	-	
65	*Manilkara hexandra* (Roxb.) Dub.	-	-	-	-	
IV.	**Weeds flora and other plant species of the Indian Sundarbans**					
66	*Crotalaria juncea* Linn.	-	-	-	-	These species have no morphological features like that of the mangroves but they can grow in the moderate saline soil and water condition; these species grow step by step and settled within the mangrove forest areas, normally beyond the frequently tidal inundated zones.
67	*Canavalia cathartica* Thour.	-	-	-	-	
68	*Pentatropis capensis* (Linn.f.) Bullock	-	-	-	-	
69	*Tylophora tenuis* Blume	-	-	-	-	
70	*Finlaysonia obovata* Wall.	-	-	-	-	
71	*Hoya parasitica* Wall.	-	-	-	-	
72	*Premna corymbosa* Rottle & Willd.	-	-	-	-	
73	*Vitex negundo* Linn.	-	-	-	-	
74	*Sesuvium portulacastrum* Linn.	+	+	-	-	
75	*Trianthema portulacastrum* Linn.	-	-	-	-	
76	*Trianthema triaquetra* Rottl. & Willd.	-	-	-	-	
77	*Heliotrophium curassavicum* Linn.	+	+	-	-	
78	*Suaeda nudiflora* Moq.	+	+	-	-	
79	*Suaeda maritima* Dumort.	+	+	-	-	
80	*Salicornia brachiata* Roxb.	+	+	-	-	

Contd.

Sl. No.	Scientific Name of the Plants	Halophytic characters adapted by the plants				
		Leaf	Stem	Root	Rep. Part	Remarks
81	*Ruppia maritima* Linn.	-	-	-	-	
82	*Ipomoea pes-caprae* (Linn.) Sweet	+	-	-	-	
83	*Hewittia sublobata* Linn.	-	-	-	-	
84	*Cryptocoryne ciliata* Fisch. (Roxb.)	+	-	-	-	
85	*Crinum defixum* Ker.	+	-	-	-	
86	*Viscum orientale* Willd.	-	-	-	-	
87	*Viscum monoicum* Roxb.	-	-	-	-	
88	*Macrosolen cochinchinensis* Van.-tiegn.	-	-	-	-	
89	*Dendropthoe falcata* (Linn.f) Etting.	-	-	-	-	
90	*Cassytha filiformis* Linn.	-	-	-	-	
91	*Cuscuta reflexa* Roxb.	-	-	-	-	
92	*Alternanthera paronychiodes* St.	-	-	-	-	
93	*Scirpus littoralis* Schrad.	-	-	-	-	
94	*Fimbristylys complanata* (Retz.) Link.	-	-	-	-	
95	*Cyperus exaltatus* Retz.	-	-	-	-	
96	*Cyperus tagetiformis* Roxb.	-	-	-	-	
97	*Porteresia coarctata* (Roxb.) Takeoka	+	+	+	-	
98	*Myriostachya wightiana* Hook.f.	-	-	-	-	
99	*Phragmites karka* Trib. ex Steud.	-	-	-	-	
100	*Aeluropus lagopoides* Trin. ex. Thw.	-	-	-	-	
101	*Acrostichum aureum* Linn.	+	+	+	-	
102	*Drynaria quercifolia* (Linn.) J. Smith	-	-	-	-	
103	*Pyrrosia lanceolata* (Linn.) Farwell	-	-	-	-	
104	*Stenoclaena palustris* (Burn.) Bedd.	-	-	-	-	

Several non-mangroves, non-halophytic plant species were introduced inside these inter-tidal and above - tidal mangrove forest by human beings, birds or other animals or by naturally grow within in these Sundarbans mangrove forest areas. All these species were not mentioned here as these are not truly naturalised, nor the common flora of this halophytic mangrove environment and habitat of the Sundarbans.

V.	**Not mangroves nor halophytes but established within the Sundarbans mangrove areas**					
105	*Borassus flabellifer* Linn.	-	-	-	-	Not mangroves nor halophytic, but occasionally found in coastal mangrove areas.
106	*Saccharum spontaneum* Linn.	-	-	-	-	
107	*Erythrina fusca* Lour.	-	-	-	-	
108	*Terminalia catappa* Linn.	-	-	-	+	
109	*Launea coromandelica* Hook.f.	-	-	-	-	
110	*Tinospora cordifolia* Miers.	-	-	-	-	
111	*Excoecaria indica* (Willd.) Muell.	-	-	-	-	
112	*Tamarix troupii* Hole	-	-	-	-	

'+++' denote maximum mangrove characters present, '++' denote medium mangrove characters present, '+' denote minimum mangrove characters present , '-' denote absence of mangrove characters

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Roles Played by the River Flat Plants in the Iintertidal Zones at Gosaba Block of Sundarbans, West Bengal

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Floristic components on the river flat land and intertidal river bank in and round the Gosaba block of Sundarbans were collected and identified. Succession along with the important roles played by these mangroves were investigated.

(***Key words***: *Mangorves, Diversity, Economic potentials*)

The dominant and important rivers in the east of the Gosaba block in Sundarbans is the branch of Raimangal, the river Bidya almost bisect the Gosaba block to east and west. Few other minor rivers within and in the periphery of the Gosaba block are Durga Duani, Kartal, Sarala, Gomar, Sajna, Didhyadhari, Pathankhali, Melmel. All these rivers or tidal canals and creeks intersect the total Gosaba block into several islands. As such, this block is disconnected from the mainland. For these reasons this block is the real backward rural area of Sundarbans having immense problems.

Most of these mangrove forest reclaimed villages, agricultural land and brackish water fisheries under the Gosaba Block have been developed and renovated for the human habitation and other purposes. As such the common economic crop plants, tree species and the non-halophytic weed flora along with the mangroves and other halophytic herbs and shrubs were gradually naturalized beyond the frequent tidal inundated and saline zone (Naskar, 1993). Under these circumstances, there developed a mixed vegetation, both man made and naturalized (Naskar, 1993).

The river bank have been protected from tidal inundation by erecting earthen dykes and the mangrove forest areas were cleared gradually for renovating the agricultural field, brackish-water fisheries and human habitation (Naskar and Guha Bakshi, 1987). Gradually the farmer and fisherman communities are settled there and step by step develop these areas as busy human settlement areas (Anon., 2003). Some sign of the earlier natural vegetation still exists in and around several river flat areas of the present day's Gosaba Block and some of the river flat areas are also protected by mangrove plantation during the recent time (Banerjee, 1964).

Most of these island and Gram Panchayat areas were under the dense mangrove forest only about 80-90 years back and some of these Gram Panchayat areas were only reclaimed 40 - 50 year back or later. Till date, 2438.42 ha natural mangrove forest areas are present within the boundary of the Gosaba Block, on the riversides and elsewhere (Anon., 2003).

MATERIALS AND METHODS

Field survey were conducted by country boat in and around the Gosaba block; the river flat natural mangroves and mangrove associated plant species were collected and identified.

RESULTS AND DISCUSSION

The common and frequent mangrove and other plant species in and around the Gosaba blocks are *Avicennia marina* (Forsk.) Vierh, *A. alba* Blume, *A. officinalis* L., *Excoecaria agallocha* L., *Bruguiera gymnorhiza* (L.) Lamk., *Ceriops decandra* (Griff.) Ding Hou, *Aegiceras corniculatum* (L.) Blasco and *Aegialitis rotundifolia* Roxb.; the species, *Phoenix paludosa* Roxb. is also the common mangrove habitat palm and the mangrove associated species are *Sarcolobus globosus* Wall., *Acanthus ilicifolius* L., *Clerodendron inerme* (L,) Gaertn. f.; the common grass species is *Porteresia coarctata* (Roxb.) Takeoka; while the herbaceous species are *Suaeda maritima* Dumort., *Heliotropium curassavicum* L., *Pentatropis capensis* (Linn.f) Bullock. All these mangroves and halophytic plant species were collected, identified and studied along with their succession pattern and soil binding roles played.

Beside these, the sporadic distribution of other true mangroves and the mangrove associated species collected are *Rhizophora mucronata* Lamk., *Sonneratia apetala* Buch. - Ham., *Xylocarpus granatum* Koenig., *Hibiscus tiliaceus* L., *Thespesia* *populnea* (L.) Soland. ex Corr., *Tamarix gallica* L., *Solanum trilobatum* L., *Crinum defixum* Ker-Gawler, *Barringtonia acutangula* (L.) Gaertn.f., *Caesalpinia crista* L., *C. bonduc* (L.) Roxb. *Scirpus littoralis* Schrad., *Viscum orientale* Willd. (Parasite), *Cuscuta reflexa* Roxb. (Parasite). Some of these species grow beyond the tidal inundated areas.

As these mangroves and mangrove associated plants protect the river dykes and provide organic matter to the soil and water phases; these plants were identified as most important. In course of time and along with the development of human settlement, several non-mangrove plants were also introduced by the newly settlers for their day to day need and choice. As such, here a new mixed vegetation of diverse flora were developed artificially and all these also naturalised. During the recent time some of the quick growing exotic tree species were also introduced in this previously mangrove dominated forest area.

Critical field studies and assessment o both the natural and the introduced flora of this Gosaba block of theSundarbans are felt as the urgent need. That research studies and findings may be the important data base for future land use and also for undertaking the conservation policies and measure for the floral diversity maintenance, identification of the role of natural habitat, its effect on the delta land conservation, protection and overall sustainability.

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Session
On
Technology transfer and changing socio-economic scenario for coastal agroecosystem

Socioeconomic Aspects of Transfer of Technology in Coastal Agroecosystems

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Agricultural technologies are developed with huge investments and based on strenuous research efforts of the scientific community. Unless the fruits of these efforts are reaching the farmers at appropriate time, the ultimate objective of performing agricultural research will not be met with. Coastal agroecosystem with varied resource potential needs to have long term vision oriented strategies for technology development and dissemination. The major aspects of them includes a) the aim of the applied research is expected to be oriented towards the major problems faced by the farmers, b) the technology development process needs to include the farmers at all the stages of development. After they are being developed, their testing and integration with the farming system needs to be done effectively, c) there are multiple ways and means for technology dissemination and diffusion. The mass media and farmers themselves could strengthen its role in these processes. To conclude, technology transfer in agriculture is a continuous process and the same needs to keep pace with the other scientific development.

*(**Key words** : Technology transfer, Socioeconomic issues, Technology evolution, Participatory approach, Technology testing & integration, Technology diffusion)*

Coastal agroecosystem with its wide variability in different components of production systems plays a prominent role in Indian agriculture. This agroecosystem extends to nine states viz., Gujarat, Maharashtra, Goa, Karnataka, Kerala, Tamil Nadu, Andhra Pradesh, Orissa and West Bengal and Union Territory of Pondicherry, besides islands of Lakshadweep and Andaman and Nicobar Islands. The sustained development of the system is more important as it produces wide range of annuals, biennials, perennials, animals and fishery based products. One of the characteristic features of this production system is the predominance of small and marginal farmers with an average land holding size of less than 0.02 ha in states like Kerala to about 1.5 ha in states like Andhra Pradesh. The ecosystem is blessed with high rainfall zones in the West Coast and irrigated farming in the East Coast. Consequently, this zone falls under the medium to high productive zones for various crops. Though crop husbandry predominates the agrarian scenario in general, fisheries and animal husbandry are effectively integrated with it. This system is also prone to high degree of natural disasters like cyclones in the East Coast. The socio-economic profile of coastal agroecosystems has wide degree of variations with increasing level of urban population. The paradigm shift of the agricultural labour from farming to non-farming is another characteristic feature of the coastal agroecosystem. In the background this paper discusses the socioeconomic aspects of transfer of technology in coastal agroecosystem.

Technology spread among resource-poor farmers

During the past fifty years, agricultural development policies have been remarkably successful by emphasizing external inputs as the means to increase production. This has led to growth in the consumption of pesticides, inorganic fertilizers, animal feed stuffs and tractors and other machineries. Consequently, we have achieved outstanding agricultural progress in the recent years. However, there has been little effect of green revolution technologies in most of the holdings of the resource-poor farmers. New technologies rarely spread beyond the large/resourceful farmers and the aggregate impact remains small. But it is the declared intention of the Government in our country to increase production from these holdings as well, both to improve the standard of living of these hitherto neglected sector of farmers and also to make a greater contribution to our country's increasing needs. Where extension does reach them, the approach has been to attempt the transfer of technologies proven to work on research stations rather than on farmers' fields. Consequently, new technologies rarely spread beyond the large farmers and the aggregate impact remains small. This lack of progress by resource-poor farmers is a feature of agricultural development in many countries and it has been argued that it is largely due to its inappropriateness of the transfer of technology (TOT) approach used in many research and development programmes.

Technology evolution

Indian agriculture predominated by small and marginal farmers, faces stupendous challenges in the present century. The challenges to be faced in the agricultural sector of the country are more daunting to the National Agricultural Research System (NARS), which has to be revitalized and integrated for the solution of location-specific problems of increasing and sustaining the productivity of the natural resource base. This would demand a relook into the present strategy being followed by the NARS of the country.

Indian Council of Agricultural Research (ICAR) is the apex body of India's agricultural research programmes including its allied disciplines such as horticulture, animal husbandry, agricultural engineering, fisheries, forestry etc. ICAR takes the major policy decisions on agriculture and its allied disciplines and also implement various research programmes mainly based on commodity lines. At present, agriculture remains as a "State Subject" in Indian administration procedure and the respective state governments' deals this subject with the help of the State Agricultural Universities and the State Department of Agriculture and allied disciplines. There are also other institutions such as National Bank for Agriculture and Rural Development (NABARD), needs to get themselves actively involve in the developmental aspects of agriculture.

Agricultural research, organized traditionally along disciplinary or commodity lines and without adequate involvement of the clients lacked the farming system perspective as they are mostly conducted in research stations under conditions that are not representative of farmers' fields. They often focus on increasing the productivity of the farms by generating new technologies without a proper understanding of the existing farming systems, resulting in low adoption rate of the evolved technologies.

Agricultural researchers, having a good idea of the constraints pertaining to their field of specialization use them for research problem definition. By this, they often fail to observe that any change caused by the introduction of a new technology will not only affect the component being studied, but the entire farming system within which the component is embedded. Agricultural research in India often aims to increase the productivity of crops without paying much attention to the economic viability of those technologies under farmer's field condition. In contrast, farmers are more interested in raising profits, which need not be necessarily through increase in productivity. Hence for better adoption of research results by the farmers, in addition to productivity, more attention is required on the socioeconomic aspects of the evolved technologies. The first step for this is to perform a SWOT analysis about the evolved technologies. This could be well understood through SWOT analysis of the system.

Strengths, Weakness, Opportunities and Threats of coconut sector in India

Strengths

- Coconut has wider adaptability to ecosystems
- Established management practices for sustained yield levels are available
- Time tested and proven technologies for adoption at farmers' level with scope for inter/multi/mixed crops
- Innumerable products/byproducts of high economic value
- High employment opportunities for women, deprived and youth
- High potential for export of products and earnings in international markets
- Health promoting food products and eco-friendly non-food items
- Great stake for agro-industries and community development

Weakness

- System dynamics in coconut-based farming is a long run process
- The research results and their benefits cannot be realized in short run as in the case of annual crops
- Diseconomies in scale of production and marketing at farm level
- The agronomic and plant protection practices for the crop demands special type of skilled labour
- Mechanization is not possible to the desired level due to predominance of marginal farms
- Predominance of rainfed farming in major growing areas like Kerala
- Lack of organized marketing based on cooperative norms
- Insufficiency in agro-based industries
- Unexploited potential of human resources for small/medium scale industries.

Opportunities

- Evaluation of the largest number of germplasm for a given purpose/utilization
- Enhancement of knowledge through intensive training programmes
- Greater scope for adoption of technologies with refinement
- Involvement of community level approach for augmenting farm income
- Potential source for women empowerment through self-help groups
- Restructuring the market base linkages with agro-corporations/industries
- Excellent scope for product diversification and addition of high value to products

Threats

- Decline in farm income imposed due to various factors - market price, infestation by pests/ diseases, adverse weather
- Neglect of the garden leading to poor yield levels
- Increase in unemployment of youth and women
- Non-competitiveness at global level
- Decline in general price level for coconut products at international level

Considering the above facts, perspective planning of research and development including the transfer of technology needs to reorient their mandate. Based on socioeconomic aspects, the major characteristic features in coastal agriculture as a whole could be explained as :

- Predominance of small and marginal farmers, who in general are risk averters in nature but faces high degree of production and price risks
- Farming systems approach – better resource use efficiency
- Less marketable surplus
- Market reforms involving farmers
- On-farm processing
- Categorization of technologies
- Prioritization of technologies
- Identification of problems
- Striking the crux among the problems

A farming system is a complex, interrelated matrix of soils, plants, animals, power, implements, labour, capital and other inputs controlled in part by farming families and influenced to varying degrees by political, economic, institutional and social forces that operate at many levels. The combined effect of these factors is often location-specific and there are many reasons behind their internal relations. In short, farming system is a highly heterogeneous and complex phenomenon.

Small and marginal farmers, who are more risk-averse than large farmers, are expected to adopt higher degree of farm diversification or intensification for protection against production and economic risks. This means that these farmers can make use of the production complementarities to reap the benefits of synergism through appropriate choice of crop combinations or other economic activities. This would help them to achieve maximum resource use efficiency through i) intensive use of land, ii) optimum use of time, iii) benefits from additional enterprises, iv) reuse of farm wastes and byproducts, v) rational use of farm family labour, and vi) integration of farm and non farm activities. While evolving technology and disseminating them, the researchers need to consider the following.

Transfer of technology

a) *Aim of applied research*

Research refers to science and it seeks new knowledge by abstracting the models with multiple assumptions. New knowledge, of itself, has no value to farmers, until it is put into a technology. Farmers cannot use science. They need technology.

Applied research like agricultural research, adopts various principles and theories of science in genetics and plant breeding, crop management, plant physiology, biochemistry, entomology, pathology, engineering, etc. to achieve their respective mandates, which are often centered on increasing the production by achieving higher productivity. To meet these goals, researchers of individual disciplines apply various scientific theories in their experiments and try to prove or disprove their hypotheses. But, this process may lead to evolution of a technology keeping other factors as constant. The same technology when is being exposed to the real world conditions under farmer's conditions, may or may not be successful depending on the relevance of the assumptions made at the time of technology evolution. In nut shell, applied research efforts need to give more stress not only on the scientific theory, but also the end point of application of these theories should lead to evolving a new technology.

A new technology in any branch of agricultural science is warranted provided the existing technology has become invalid due to system dynamics of one or more factors of the production system, as well as the clients loses their credibility on its technical feasibility and economic viability. The existing technology can also be replaced, if the new technology shifts the production function to an elevated level by realizing better input-output coefficients.

b) *Participatory technology development*

Technology generation is a process, which integrates knowledge, technology, and other traditional values like folk wisdom into a form which serves to meet the objectives even in uncontrolled conditions for wider range of end users. The role of technology generation is to produce new technology alternatives.

Social scientists perceive that while researchers aim for increase in productivity, farmers who are undertaking the farming as a livelihood aim for maximizing their profitability. Hence the process of technology development and its dissemination needs to begin after thoroughly understanding the existing farming system considering its agroclimatic, edaphic, biotic, abiotic and socioeconomic conditions and also the pros and cons of the existing technology, which may need an alternative.

The linear model of technology development, which assumes that research, first generates knowledge, which is then transferred by extension and finally utilized by farmers is more successful in western countries, wherein the research situations are comparatively similar to that of the experimental stations. However in reality, there are many differences between the Research Station and the farmer's fields (Table 1).

Table 1. *Major differences between the environment of the research station and farmers fields*

Particulars	Research Station	Farmers field
Experimental results	Often evolved under homogeneous conditions	Heterogeneity is the rule
Farming environment	Ideal conditions prevail	Heterogeneous
Factors of production	Controlled	Subject to time, production and price risks
Land	Usually large and in general land is not a major constraint for conducting the experiments	In India more than 80 percent of the farmers are small and marginal and are having land area of less than one hectare
Source of investment	Based on budget allocation from the sponsoring organization	Mainly from farm business income
Capital	Often unlimited	Often limited in case of small and medium farms and adequate in case of medium and large farms
Irrigation facilities	Not a serious constraint	Serious constraint during summer months
Infra-structure	Often well developed	Often limited in case of small and medium farms and adequate to unlimited in case of medium and large farms
Labour	Permanent labour and casual labour available in time	Mostly dependent on hired and family labour
Marketing	Bulk and generally on contract basis	Often staggered and less marketed surplus and mostly to village traders
Effect of production and price risks	Less impact	More impact
Concept of resource recycling	Often in theory	Often put into practice
Support from institutional agencies	Not required	Often needed
Socioeconomic factors	Often have less impact	Often have more impact

The present mode of technology development in India is a unidirectional flow of knowledge from National Agricultural Research System (NARS) to subject matter specialists, to extension workers, to contact farmers and from them to follower farmers. The linear model does not include farmers as an essential component in technology development process, but make them as passive receptors and users. In this situation, if the new technologies are appropriate and fit in a particular farmer's conditions or needs, then they stand a good chance of being adopted. But if they do not fit and if farmers are unable to make changes, then they have only one choice. They have to adapt to the technology or reject it entirely.

The alternative to overcome the present malady is to seek and encourage the involvement of farmers in adapting technologies to their conditions. This constitutes a radical reversal of the normal mode of research and technology generation, because it requires interactive participation between professionals and farmers. Participatory Technology Development (PTD) is a process in which the knowledge and research capacities of farmers are joined with those of scientific institutions, while at the same time strengthening local capacities to experiment and innovate. Farmers are encouraged to generate and evaluate indigenous technologies and to choose and adapt external ones on the basis of their own knowledge and value systems.

Though PTD has its own limitations based on group behavior and individual farmer's perception of the problem, his attitude, level of knowledge and resource environment etc., at present social scientists consider this as one among the best tools for problem identification and technology transfer. A sincere involvement of the end users would always help to undertake mid term review in the technology generation process, which would ultimately end in better rate of adoption. In this process, there is ample scope for evolving alternative technologies or other options for a particular technology.

c) *Technology testing and adaptation*

Research results based on field experiments in the research institutes, need not suit to the needs of the farmers or some refinement on these findings would enhance the adoption rate of the recommended technologies. The reasons are obvious since there are many differences in the place where the technologies have originated from the place where they are going to be adopted. Hence for realizing better rate of adoption of the technologies, the researchers should understand these differences and needs to refine and assess their technology.

Technology testing and adaptation can be performed through assessment and refinement, which paves way for achieving effective operational linkages between scientific institutions and the farmers for technology integration and optimization. This would meet the growing demands of different production systems to increase productivity, augment income and improve the quality of life of rural people.

Technology transfer, to be effective, must be preceded and succeeded by technology assessment. How reliable is the assessment can be judged by the effectiveness of transfer of a given technology. Technology assessment and transfer are complementary to each other. Technology transfer must be based on needs and capabilities of agroecological settings, resources endowments, agro-production distribution systems and farm household. The ultimate aim of researchers, extension personnel and developmental agencies is to empower the farmer with the appropriate knowledge, technique and skills so as to enhance the capability to judiciously exploit the natural resources and family labour for sustainable agriculture and rural development. Further, the feedback received from the past extension programmes was inadequate to reset the research and transfer of technology agenda on a large scale.

d) *Technology integration*

Technology integration fits a new technology into current farming systems. It has three dimensions:

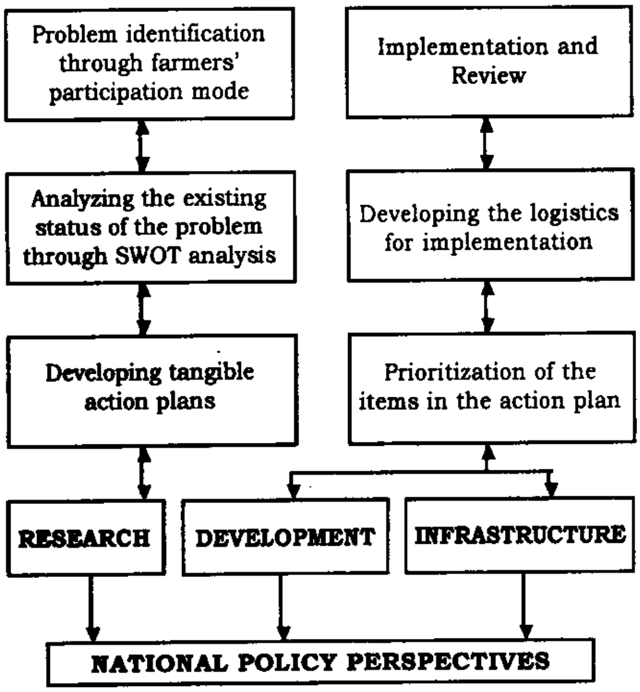
a. One pertains directly to the system of production. Integration is facilitated by knowledge of the farmer client and is also facilitated by research on related problems and by extension instruction to farmers on its use. As with testing, integration is essential. The farmer must do it. If he has to do it without research and extension help, it will be inefficient and slow.

b. A second dimension is integration with the market, both input and product. Much agricultural technology is embodied in a commodity. If that commodity is not available and cannot be made available, a new technology cannot be adapted, no matter what its merit. Integration involves market action to make inputs available or research-extension activity adapted to the lack of input. On the product side, if there is inadequate market, farmers cannot integrate the technology into their systems of production.

c. The third dimension is integration with national policies. National policy often works through product and input markets and sets conditions the farmer must adapt to. These conditions affect the ways he can deal with new technology. If policies are not adequate and cannot be changed, the conditions they create must be adapted to.

To be more precise, technology integration is the process of synergizing the technology with the farming system, infrastructural facilities and with the national policy perspectives. The success of the technology mainly depends on this stage. In this process, effective coordination is needed among the research institutes, development departments and the farmers. Technology integration need not to be restricted to the national or state levels, but to be expanded upto a minimum of districts. The steps involved in this process may be explained as in the flow chart

FLOW CHART ON TECHNOLOGY DEVELOPMENT PROCESS



e) *Technology dissemination*

This process involves informing farmers about a new technology and helping them to integrate them into their farming systems. The extension demonstration is one of the most effective ways of doing dissemination. It may not be as much a 'demonstration' as it is a means by which the farmer's own experimental process is facilitated. Farmers will not adopt a practice until they have either experimented with it in their own system or have seen it perform in a system almost like theirs. The demonstration facilitates this process and is literally an 'on-farm trial'. As technology becomes more complex, more assistance is needed from extension to help farmers fit it into there systems. The role of mass media is vital in this process. With the advancement in the field of Information Technology, diffusion process has become easy and economical.

f) *Technology diffusion*

Technology diffusion and adoption are primarily centered on the farmer. Farmers themselves, through their kinship groups and other social systems, constitute a powerful force for technology diffusion. Extension is most effective when it takes advantage of and encourages the farmer dynamics.

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Technology Generation for Coastal Agroecosystem through Production System Research - NATP Contribution

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One of the objectives of the NATP component is to provide research support to the agroecosystem in order to raise efficiency, responsibility and relevance of the system for an integrated and balanced agricultural growth. It has the overall responsibility of managing the Production System Research Projects of the coastal region. The research projects under this ecosystem have been broadly categorized into Agri-horti and fisheries/ livestock, each having five thematic areas. From this Directorate, 38 PSR projects were sanctioned under various thematic areas viz., Integrated Pest Management, Integrated Nutrient Management, Natural Resource Management, Post-harvest and Value Addition & Socioeconomics. These projects cover 24 ICAR institutes and 12 State Agricultural Universities in 9 Coastal States and 2 Union Territories. After 3 years of project implementation, several technologies were developed. Important technologies developed are refined IPM technology for management of rhinoceros beetle, red palm weevil, eriophyid mite and basal stem rot of coconut. Integrated nutrient management practices have been developed for coconut, rice based cropping system, oil palm and cashew. Soil and water conservation measures for different plantation-based cropping system and efficient water harvesting and water management measures suitable to different locations of Western Ghats were developed. Several value added products have been developed from tuber crops, spices and oil palm. Fisheries project have developed value added products from low cost fishes. This paper discusses the methodology of operation of production system research projects, technologies developed, etc.

(**Key words:** *Technology generation, Production system research, National resource management, Integrated pest management, Post-harvest technologies, Agri-horti production system, Fishery production system, Value addition*)

The Coastal Agroecosystem of our country is recognised as one of the five important ecosystems. It comprises of hinterland, which has a varied geometric and topographical features of mountains valleys, coastal plains, riverine systems, climatic conditions, different soils and water bodies, vegetations ranging from rich tropical rain forests to coastal mangroves and a wide range of crops that are cultivated in this region. Agriculture, horticulture, agroforestry and silviculture are the various activities practiced in this ecosystem. The agroclimatic conditions of the coastal zones are congenial for growing horticultural crops like mango, cashew, pineapple, banana, plantation crops like rubber, pepper, coconut, arecanut, tea, cocoa, oil palm, etc. and tree spices. This is the only system where agriculture and aquaculture coexists. India has a vast potential for marine fisheries development with 2.02km^2 area of exclusive economic zone along the coast line. Besides, about 1 million hectare of brackishwater area in the form of estuaries for brackishwater, fish and prawn farming is available. The region occupies commendable position in the export of horticultural produce, spices and marine products to the international market. It supports the livelihood of several million people whose socioeconomic conditions are very much dependent on the system.

Problems and prospects

Coastal region suffers from problems of water scarcity, soil erosion and depletion of biological diversity and possible threat of rise in sea level due to global warming. The coastal areas suffer both in monsoon and post monsoon seasons. In monsoon season, excess rainwater, prolonged water stagnation, high water table, high humidity, impeded drainage and lose of nutrients are some of the common unfavourable factors. In the post-monsoon season, high salinity of soil and ground water and also scarcity of fresh water limit crop productivity. The production is further constrained by extensive occurrence of problem soils such as saline soils, clayey soils, eroded soils, pest and disease problems, etc. Over and above this, natural calamities like cyclones, currents and tides are a common feature of these areas. Anthropogenic pressure, unfavourable environmental changes are also adding to the problems. The picture of fisheries and livestock enterprises are no different from agriculture. Degradation of aquatic life with newly emerging diseases pose threat to aquatic enterprises. The present productivity level of the livestock in the coastal regions is poor mainly due to poor genetic base and lack of management practices. All these call for an integrated coastal systems management strategy, based on the technologies to improve the overall productivity of the systems, thereby augmenting the quality of life of the people.

The overall responsibilities of management of the Coastal Production System Research projects lie with the Director of Coastal Agroecosystem. A total of 38 projects in Production System Research are being implemented under this Directorate. The problem areas under Agri-Horti and Fisheries projects have been divided under various thematic areas such as Integrated Pest Management, Integrated Nutrient Management, Natural Resource Management, Value Addition and Post-harvest technology and Socioeconomics. These projects cover all the 9 states of coastal region and the two union territories viz., Andaman and Nicobar Islands and Lakshwadeep. A total of 169 subprojects have been sanctioned covering 24 ICAR institutes and 12 State Agricultural Universities.

The technologies generated in this project are as follows :

Integrated nutrient management

Agri-horti

A coconut-based farming system comprising coconut, fodder grass, banana, pepper, mulberry, diary, poultry and pisciculture was developed at CPCRI, Kasaragod. The output obtained was 23535 coconuts, 11445 l of milk, 645 kg of broiler birds, 173 kg fish, 17.3 kg of silk worm cocoon, 3477 quail eggs and 87 kg of banana. Thus, the total revenue obtained from the system was Rs. 2,51,311. The net return obtained from the system was Rs.73,142 per annum. Studies on intercropping during juvenile phase of oil palm revealed that, crops like maize, tobacco, chilies, bhendi, ridged gourd, napier grass, colocasia and banana can be grown successfully under West Godavari conditions. A maximum return of Rs. 20,000/- was obtained with seed maize. Under Gujarat conditions crops like banana, spider lily and turmeric were found successful and profitably grown. For the management of salt affected soils in the coastal region of West Bengal application of leaves of locally available trees to soil @ 5 t ha^{-1} along with inorganic N fertilizer and application of city compost was found superior. For the coastal soils of Andhra Pradesh and Tamil Nadu application of Gliricidia @ 5 t ha^{-1} along with inorganic N fertilizer and leaves of *Derris indica* were found appropriate, respectively. At Puttur (Karnataka), turmeric was found to be the best intercrop in cashew recording 3.35 t h^{-1} or rhizomes fetching a total gross income of Rs. 67,000 h^{-1}. GCH-6 and CCH-5 varieties of castor were found to be promising for cultivation under saline soil conditions of Gujarat. The highest yield of 1647 kg ha^{-1} was obtained with GCH-6 and was at par with GCH-5 which yielded 1572 kg ha^{-1}. Experiments on banana indicated that covering the bunches with polysleeves with ventilation resulted in uniform and attractive light green colour with least blemishes in fruits compared to uncovered bunches. A small test consignment (3 boxes each 14 kg) sent to Iran revealed that the fruit quality matched with international standard. *Desi* cotton hybrids G.Cot. DH7 and G.Cot. DH9 were identified as high yielders in the coastal areas of Gujarat (14-25 q ha^{-1}), Karnataka (8-10 q ha^{-1}), Tamil Nadu (7 q ha^{-1}) and Andhra Pradesh (6-7 q ha^{-1}). Cotton cv. LRA 5166 was found to be the best suited to coastal areas of Sundarbans in West Bengal. In production of quality planting material by rapid propagation technique, three node cassava mini-setts transplanted at closer spacing was found to produce best results. In the case of Amorphophallus 300 g, Colocasia 20 g and in Xanthosoma, 40 g minisetts gave a better trend in planting material production at Trivandrum, Kerala.

Fisheries

A farmer friendly polymerase chain reaction (PCR) package has been developed for identification of the white spot virus infection in shrimps. A pellet feed (3 to 5 mm dia) containing 40% protein has been successfully developed for raising juvenile mud crabs *(Scylla tranquebarica)*, with locally available ingredients (fish meal, squid meal, shrimp head meal, clam meal, soy flour, wheat flour, fish oil and vitamin mix), a specially formulated mineral mix and guar gum as binder. This achievement has been made for the first time in this country and is being further tested. A longitudinal shell cutting machine has been designed and fabricated for cutting of irregular shaped molluscan shells with reciprocating cutting mechanism in pearl culture. A cutting machine has been designed and developed, working on the principle of high-speed rotary motion for making cubical shaped shell beads of various sizes.

A low cost unconventional pig feed has been identified using locally available fed resources like hotel wastes, groundnut cake, rice bran, cashew apple etc. A starter feed for ducklings was prepared and the know-how of feed formula was transferred to a private firm in Kerala for large-scale production.

A video film named "Duck Production in Kerala" which was produced in English during the year 2000-2001 was translated into Malayalam, edited and modified to suit the local farmers. A vaccine has been developed for the control of duck pasteurollosis disease. A mussel seedling device that can be easily operated by two people was designed and fabricated and found to be efficient in terms of labour and time.

Natural resource management

Agri-horti

Contour bund + Vegetative barrier (pine apple) recorded the minimum runoff as well as soil loss in the first year in multi-tier production system at Ooty. Half moon terraces and continuous contour trenches with vegetative barier *(Vetiveria zizaniodes + Stylocanthes scabra)* as conservation measures are giving better performance of cashew in Goa region. Contour staggered trenches as a conservation measure in pineapple/french bean/ginger performed better as compared to control in Cardamom plantation at Appangala, Karnataka. Catch pit with pineapple border strip as a bioengineering measure in coconut plantation recorded lesser runoff and soil loss at Kasaragod, Kerala. At Jagsi site in Saffidon block on Sonepat district, a skimming-cum-recharging structure has been designed at a downstream location prone to runoff flooding. At Bapatla an improved subsurface skimming system called improved "doruvu" technology has been installed at about 50 sites. Three skimming wells have been installed in an area of 12 acres belonging to 13 farmers on a community basis. Radial collector type skimming structures are installed in Vettandudi village and Therkkupoigainallur village. At Aruppukkotai a percolation pond of 3010 m^3 capacity has been constructed to study the effect of recharge through 6 bore wells in inland saline regions. In the supercyclone affected areas of Orissa, early rice cv. Vandana has been identified for the coastal pre-cyclone period and winter potato cv. Kufri Chandrakukhi has been identified for cultivation in coastal rice fallow and homestead lands after cyclone.

Fisheries

Field trips were made for coral resources survey in Van Theevu coral bed in Tuticorin. Both live and dead corals of *Acropora humilis, Favia pallida, Montipora digita, Hydnophora grandis, Platygyra lamellina, Montipora foliosa, Porites somaliensis and Goniastrea incrustans* were collected and are being analysed for chemical compositions. Afforestation has been undertaken to reclaim the mangrove of Kerala by planting the *Rhizophora* sp.

Integrated pest management

Agri-horti

A biointensive feasible and refined IPM technology has been developed for the control of Rhinoceros beetle in plantation crops which includes (1) release of baculovirus, (2) application of *Metarhizium anisopliae,* (3) Use of pheromone lure. Mass trapping of red palm weevil population using pheromone traps and root feeding with neem formulation and leaf axil filling with neem oily/ hydrocarpus cake has been found effective for the control of Red Palm Weevil in coconut. New methodologies for the estimation of live eriophid mite population using "template carding" and total mite population by 'water wash count method' were developed. Three formulations of fungal pathogen *Hisutella thompsinii* based myco acaricided viz., Mycohit powder, Mycohit LG 20 and Mycohit OS have been developed for the biological control of coconut eriophid mite. In the case of coconut, an antiserum was produced from the Ganoderma protein isolated form Mudhalipatti sisolate for diagnosis of basal stem rot disease. DAS-ELISA was performed to confirm the antigen-antibody reaction at different concentrations of antiserum.

Among the fifteen plant extracts tested against Ganoderma infecting Arecanut, garlic extract (10%) completely inhibited the growth of the pathogen followed by *Peperomia pellucida, Musa paradisiacal* (Variety Kadali), *Spilanthes acmella* and *Ocimum sanctum.* A wide genetic variability was revealed in the fingerprinting study by RAPD, from the very high number of polymorphic bands amongst the isolates of Ganoderma (94.6% polymorphism). AFLP was conducted to confirm the RAPD results. This is the first report of AFLP in *Ganoderma.*

Post-harvest technology and value addition

Agri-horti

A mobile starch extraction unit was fabricated and demonstrated for extraction of starch from tuber crops like cassava, sweet potato, etc. Fermentation conditions were standardized for production of Citric acid and Glutamic acid from cassava starch factory residues. Bioactive properties of Amorphophallus, Curcuma and Chinese Potato were established. A low cost technology was developed for storage of fresh and dry ginger without loss of quality. Preparation of white pepper by microbial fermentation was also standardized. A decorticator was developed and fabricated for the extraction of fibre from oil palm empty fruit bunches. Beta-carotene and other pigments were extracted from crude palm oil. An arecanut sprayer with long lance and nozzle has been developed, which can be used to spray up to a height of 50 feet. A manually operated coconut splitting device has been developed. A sheller was designed and fabricated for separating the kernel from the partially dried coconut cups (moisture content more than 20%).

Fisheries

Battered and breaded products were developed from low cost fishes and their commercial production was started. Neutraceutical products were developed from low cost fishes and their commercial production was started. Neutraceutical products like dicalcium phosphate and fish calcium has been prepared from cuttle bone and backbone of tuna fish. Value added products like battered and breaded, smoked mussel were prepared form green mussel.

Livestock feed were formulated using fish ensilage as the chief protein source and rice bran, jowar, coconut cake and wheat bran was the other carbohydrate sources.

Socioeconomics

Secondary data on land use pattern, rainfall pattern, area, irrigated area, production and yield of major crops, livestock, population census and agriculture machinery and implements were collected at district/taluk/block/level for the past 10 years at Tamil Nadu, Andhra Pradesh, Kerala, Maharashtra.

CONCLUSIONS

Agriculture has been the oldest and everlasting profession of humankind. Over millions of years farmers of the world identified suitable crops, developed cultivation technologies, moulded farming systems to suit their needs and traded their produce. With the advent of green revolution the dream of food sufficiency came true and presently keeps pace with the population growth. However, widespread evidences are there on production problems, environmental degradation, soil erosion, squandering of water resources, heavy use of pesticides resulting in pest resistance and over exploitation of fishery resources. The present agricultural scenario calls for an alternate approach to undertake accelerated broad level growth not only in food production but also in natural resources management through a strategic research and development. NATP has been evolved to facilitate the Indian Agricultural Research Management Systems in this direction. National Agricultural Technology Project Implemented through the Coastal Agro-Ecosystem has been a boon in technology generation for coastal region. This project has also helped in developing new research facilities.

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Promoting Farmers Participatory Research for Technology Assessment and Refinement in Coastal Agroecosystem

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The dream of self sufficiency has come true owing to the scientific breakthrough in the technology generation complemented by transfer of technology. Notwithstanding the fact, the production has increased four times since 1950, the agriculture growth is not uniform specially in view of regional imbalances in absorbing the technology and socially due to disparity among the farmers in technology adoption. The success of green revolution could not make much impact in more extensively farmed peripheral environments and failed to comprehend the needs of those environments which are heterogeneous. It has been well established now that farming conditions are different and technologies have to be accordingly to the needs and situation of farmers. Consequent to this concept, agriculture research scenario has witnessed the beginning of major shift in the approach for improving food production. Underlying this shift is a basic promise that the users of technology are not only adopters but also creators of solutions themselves. This means the end users of the technology must be elevated to the status of partners in technology assessment and thereby refining the technology to suit their system. Keeping this in view ICAR in its committed attempts to generate and transfer appropriate agricultural technologies has come up with a Novel project 'Technology assessment and refinement through Institution Village Linkage Programmes' – TAR-IVLP.

*(**Key words:** Participatory research, Technology assessment & refinement, Agriculture, Horticulture, Fishery, Animal husbandry, Knowledge dissemination, Economics)*

Main Objectives and Operation of IVLP

IVLP aims to assess the technology and refine through farmers participation.

The IVLP is operated through implementing centres drawn from ICAR Institutes and State Agricultural Universities and they in turn link themselves with a village or a cluster of villages having various production systems *viz.*, commercial, well endowed and small. The programme is implemented by the multi-disciplinary core team of scientists led by a Team leader, constituted at each implementing centre. It is the primary responsibility of the team members to conduct the agroecosystem analysis of the selected villages, diagnose the various problems confronting each production system, prioritize them, identify possible technological interventions for the biophysical and socioeconomic causes of the problems and prepare an action plan for the assessment and refinement of the technological interventions. The entire process has been carried out with the active cooperation, support and participation of the farm families. Thirteen centres are operating under Agro-Ecosystem (Coastal) for implementation of TAR-IVLP.

A total of 817 interventions were assessed for the period from 1999 to 2003 in all the 13 projects of IVLP. Some of the most successful interventions are mentioned below.

Rice

Rice farmers of Chenkal village under CTCRI experimented with more than 10 paddy varieties over a period of three years and found that Uma variety of rice was suitable both under *kharif* and *rabi* season giving a B:C ratio of 2.24 as compared to 1.74 in local variety. Uma variety was found ideally suited to the adopted village owing to high yield (4.37 t ha^{-1}). It gave a net return of Rs. 36,571 ha^{-1} which was higher when compared to other varieties. This variety was well accepted by the farmers as it gave highest return due to high grain yield, non lodging nature and it's field tolerant to pest and diseases.

Under IVLP of RARS, Pattambi, farmers through their on-farm trials in rice varieties to increase the production level found that Kanchana and Aishwarya performed well with yield of 2.51 t ha^{-1} and 3.30 t ha^{-1} with corresponding B:C ratio of 1.23 and 1.37. Due to the increase in total profit from cv. Aishwarya most of the farmers adopted this variety and at present 75% area is under this variety in these villages.

A salt tolerant variety of rice BTS-24 was evaluated by the farmers at Andaman Island to overcome the low yield of local variety C 14-8 and it was found to give a B:C ratio of 0.39 as against 0.32 of local variety. Salt tolerant variety BTS 24 recorded

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31.0% (3.12 t ha^{-1}) higher grain yield over local variety C 14-8. Farmers' acceptance of the salt tolerant variety was high due to higher yield, tolerance to lodging and higher spikelet fertility over local variety. At Pedakadmi village of West Godavari district medium and long duration high yielding varieties of paddy namely MTU 1001, MTU 2067 and MTU 4870 gave 10%, 9% and 20% more yields in place of local variety, respectively and reduced the cost of cultivation.

Due to non-availability of farmyard manure (FYM), farmers could not apply FYM. To overcome this, farmers under IVLP tried alternative source namely filter press cake which is very cheap. Filter press cake, a by-product of sugar factory is available in sufficient qualities at relatively cheaper price at Andhra. Sugars, Tanuku can be used as a substitute farmyard manure. Addition of filter press cake to *kharif* paddy increased the yields over non-application of organic manures at Mukkamala village of Rajahmundry. FYM application increased the yield by 7.49% over farmers' practice. Filter press mud/ cake proved superior with a yield increase of 13.59% over non-application of organic manure. Net income increased by Rs. 1200 ha^{-1} due to FYM and 2080 ha^{-1} due to filter press cake addition. Application of biocontrol agent *Pseudomonas fluorescens* (bacteria) for control of blast in irrigated upland fields of paddy gave a better benefit cost ratio of 2.43 as compared to 2.05 obtained in the farmers practice of application of Phosphomidon at Kattur village in Tamil Nadu.

Plantation crops

To increase the returns from coconut plantation, farmers of Chenkal village tried various interventions and found that ginger variety Varada as a profitable intercrop under upland rainfed condition. Drying is a post-harvest operation of coconut for extraction of oil manually done by sun drying by the farmes. Farmers of Pady and Edneer village evaluated the *copra* dryer developed by CPCRI was found that *copra* dryer was more advantageous than the usual practice with a benefit-cost ratio of 1.15 as compared to 1.02 in farmers practice. The farmers were of the opinion that the value of *copra* obtained from the *copra* dryer was higher than that obtained from sun drying, as the quality of *copra* was better in the case of *copra* from *copra* dryer. The *copra* from sun drying of coconut contained deposition of dust particles and fungal growth which reduced its market value. Farmers also said that the labour requirement and time taken for drying is also less in *copra* dryer, compared to sun drying. Practising of cultivating green manures like Mimosa and *Calpagonium mucanoides* was tried in coconut basins as compared to the local practice of applying FYM and it was found that Mimosa grown plots gave higher returns (3625 Rs ha^{-1}) as compared to Calpagonium (3325 Rs ha^{-1}) at Kasaragod. In the Pedakadmi village by the use of recommended dose of fertilizer (1440-720-1440 g NPK + 500 g of $MgSO_4$ + 50 g of boron in oil palm there has been a 21.7% increase in the fresh fruit bunch yield over the control. The net return was increased form Rs.25,806 to Rs.46,707 ha^{-1} for 8 months period.

Vegetables/pulses/oil seeds

Farmers of Andaman evaluated the Bacterial wilt resistant varieties of tomato LE 3704 and BT-1 and found that LE 3704 more tolerant to bacterial wilt and gave an higher net return and B : C ratio of 7.6 as compared to 0.93 in BT-1. The improved variety of Amaranthus viz., Kannara local was found to be more productive than the local variety at Elamkunnapuzha village in Cochin. It is resistant to attack by leaf eating caterpillar and white spot disease. Adoption of recommended spacing of 30 cm x 20 cm and seed rate 8 g percent resulted in increase in yield by 25.7%.

Banana

Farmers in Mukkamala village under CTRI have learnt that through nutrient management trials and balanced application of fertilizer per plant basis, the bunch yield has increased by 1.39% there by deriving an additional income of Rs.1900 ha^{-1}. Farmers in Chenkal village of Thiruvananthapuram experimented with Robusta Grand Naine a tissue culture banana and found that the tissue cultured banana gave net returns to the tune of Rs.1,51,015 ha^{-1} as compared to Rs.1,08,505 with local robusta variety.

Sugarcane

While experimenting with use of biofertilizers to overcome low yield of sugarcane due to imbalanced fertilizer application, farmers at Mukkamala village of west Godavari district found that the addition of biofertilizers and 25% reduction of N and P dose increased the sugarcane yield. Fertilizer application at the right time by placement method at recommended rates along with the use of suitable biofertilizers improved the fertilizer use efficiency. Further, the balanced fertilizer application reduced the incidence of pests and diseases. Integrated nutrient management of sugarcane main crop along with recommended fertilizer dose increased the yields by 9.73% over the farmers' practice. Adoption of this technology resulted in additional net returns of Rs. 5,049 ha^{-1}. Many farmers in the village are convinced of the beneficial effect of filter press cake application and have started adopting this technology after observing the results in the first year intervention.

Aquaculture

Shrimp under culture conditions are subjected to various stress factors such as, crowding, changes in water quality parameters, accumulating metabolites, etc. Under such challenging situations sustainable and enhanced shrimp production has to depend on measures that stimulate shrimp immunity. Immunostimulants of commercial origin has been costly and inconsistent in eliciting desired responses. Low cost immunostimulants, developed in CIBA using heat inactivated *Vibrio auguillarum* and administered through feed at fortnightly intervals, resulted in better growth and survival of the cultured tiger shrimp in a farmers's pond at Kattur Village. Use of immunostimulants enhanced the average body weight of shrimp by 4 g and the total production by 17% (2.135 kg ha^{-1}) compared to the level (1.766 kg ha^{-1}) obtained by the farmers existing practice.

Traditionally, fish was dried on coir mats, palmyrah mats, and gunny bags and on plain grounds. Fish was treated with contaminated salt solution before drying, resulting in microbial attack. The shelf life of the traditionally treated fish is 7-10 days. Rack drying of fish in wooden or iron racks [size: 4.5 m x 1m x 0.75] is the technology recommended by Central Institute of Fisheries Technology (CIFT). At Dumki village of West Bengal, fish farmers found that introduction of fish culture in the paddy fields during *kharif* season gave a net return of Rs. 28,725 ha^{-1} as against Rs. 6,750 ha^{-1} obtained with paddy cultivation alone. The B:C ratio was 3.42 in the new intervention as compared to 1.65 in old practice. At Bhubaneswar composite fish culture including *Rohu, Catla, Mrigal*, (Common carp, Grass carp and Silver carp) was taken up in 19 village ponds and farmers got around Rs. 40,000 ha^{-1}. The fish farmers of Pedakadmi village, West Godavari district found that use of *Rohu, Katla and Mrigal* at the ratio of 2 : 7 : 1 as against the usual practice of using fingerlings from the drains resulted in the increase of net return from Rs. 18,000/- to Rs. 37,440/-.

Backyard poultry

A comparative study between the performance of Gramalaksmi poultry and *desi* bird reared under homestead backyard poultry was conducted at Edneer and Pady village and it revealed that Gramalakshmi birds gave high return of Rs. 1284 as compared to local birds (Rs. 897). Nandanam breed of chicken performed well at Kattur village of Chennai.

Nicobari bird, the indigenous germplasm of Andaman islands, has been genetically improvised for its egg production trait retaining the disease tolerance trait of the bird. These birds have been found suitable for these islands under backyard poultry farming system and can serve a potential source for higher egg production in these islands.

Livestock

In Barua village of West Bengal farmers were trained on feeding of mineral vitamin mixture to cattle increase the conception rate and milk yield. The milk yield was increased from 8 to 21% when green fodder was also supplemented with mineral vitamin mixture @1kg per cow per month. Farmers of the same village tried urea-*gur*-mineral mixture treated paddy straw feed for cattle as compared to untreated straw and found that milk yield increased from 19 to 26%. Now many farmers are feeding treated straw and farmers of nearby villages have also adopted this. Nearly 77% of cattle were freed from helminth problem due to the application of de-wormer Albendazole to the cattle in the same village. Under IVLP project of CMFRI, Cochin de-worming and micronutrient supplementation in cows and goats helped in increasing the milk yield and meat yield, respectively

Training, publication, linkages

IVLP was implemented through network of about 13 centres located in coastal parts of the country. For upgrading skills & technological empowerment of farmer, farm women and youth a total of 127 trainings benefiting 4347 farmers were conducted.

Knowledge dissemination to the farmers was done through distribution of about 34 pamphlets/ leaflets in local language for ready reference. Besides 18 Instructional materials, 5 Technical bulletins, the salient findings were published in 10 refereed journals, popular journals for sharing of knowledge among scientific community of TAR-IVLP. Collaboration was sought in about 27 Institutions/ KVK's/SAU/NGO's for transfer of technical know-how to farmers and implementing of technological modules in the Agroecosystem.

Publicity of success stories for covering larger mass of population in rural areas was done through radiotalks (3), television coverage (1) national newspapers (5). Assessment of performance of technologies generated was done through 391 on-farm trials and 500 verification trials covering an area of 2247.39 hectares and 19623 farmers in about 105 villages of the Coastal Agroecosystem.

CONCLUSIONS

Appropriateness of any Agricultural Technology derives its fullest meaning when they are assessed and refined by the users themselves. TAR-IVLP has shown the methodology to do it and it would multiply its strength because

- Farmers know much about what works and what does not
- Farmers ultimately decide about what to use and what to discard
- Assessing technology with farmers is necessary to understand their perspective so as to prevent farmers from being losers in the technology generation adoption game.

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Technology Assessment and Refinement in Coastal Agriculture System Reducing Drudgery and Post-harvest Loss

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Alternative approaches for existing practices in harvesting, dehusking and storage were introduced using participatory rural analysis and its performance was evaluated. Insect trap instead of Nochi leaves, Bhopal serrated sickle in place of local sickle and Coconut dehusker instead of crowbar were introduced in 200, 100 and 20 farm families, respectively. Insect trap reduced the damage by 4 percent. Bhopal serrated sickles reduced the drudgery and saved 25 percent of time compared to local make. Coconut dehusker increased the rate of dehusking by 41.6% per hour and proved to women friendly device.

(***Key words***: *Post-harvest operations, Technology generation assessment & refinement, Reduction in drudgery*)

In most developing countries farmers adopt a conservative practice because they are not exposed to acceptable alternatives to their existing practices. Technologies have to be need-based, location specific and compatible to socioeconomic condition. Alternative approaches to existing practices to save time, energy and reduce losses are needed to be tried with resource poor farmers. Farm research over the decades has given many innovative, easy-to-adopt technologies and rural development requires these improved technologies to be transferred to the targeted audience. Alignment of resource objectives with local agricultural and resource management practices through participatory approach is necessary for development of appropriate farmer oriented technologies.

The Kattur village situated in Ponneri *taluk* of Tiruvallur district of Tamil Nadu was selected to identify and prioritise problems and refine technologies. Coconut garden was maintained in the backyard spaces of most of the households. Dehusking was done manually by using locally available implements such as sickle, crowbar, etc. Rice is a major crop and farmers used local sickles for rice harvesting. The practices like dehusking the coconut and harvesting the rice using local sickle takes more time and energy. The other problem identified was post-harvest loss in the stored grains. Considerable quantity i.e., about 10-15% (Chakravarthy, 1988) of harvested grains and pulses stored are lost due to the damage caused by common insects like lesser grain borer, red flour beetle and saw toothed beetle. This study is an attempt to identify the alternate practices for the above mentioned problems and evaluate the alternate technologies.

MATERIALS AND METHODS

The CIAE Bhopal sickle was purchased from Central Institute of Agricultural Engineering, Bhopal and distributed to 100 farmers and its efficiency compared to local sickle was assessed in the field using participatory rural analysis. To test the efficiency of the insect trap, 200 farm families were selected and trapping tube was pushed inside the grains. The trap was collected in weekly interval from the farmers place to assess the damage in stored gains. Among the resource poor farmers, twenty farm families were selected for the evaluation of coconut dehusker developed by Kerala Agricultural University.

RESULTS AND DISCUSSION

The Bhopal sickle is light in weight and had better serrated blade than local make. It cuts the crop by principle of friction cutting just like a saw blade. The sickle pulled along an arc to the right by right hand. Time consumed to harvest one cent of rice field was 15 min with Bhopal sickle whereas the local make consumed 20 minutes for the same area. At a stretch, 3-4 hills were harvested and 25% of time was saved. Strip of 16 gauge was made from mild steel and can be sharpened locally. The lengthy curvature increased the efficiency of the sickle and reduced the drudgery. The cost of the Bhopal sickle was Rs. 30 whereas the local sickle cost Rs. 25 per piece. The cost to start the CIAE sickle plant was worked out to be 2.3 lakhs.

Earlier, the Nochi leaves were mixed along with the grains to reduce the storage loss. The TNAU insect trap replaced the Nochi leaves. The wandering insects near the aerated region enter into the perforations in the gadget and get caught in the trapping tube at the bottom. The unscrewing mechanism of tapping tube helped to destroy the insects. It was noticed that periodical drying after noticing the insects in the insect trab helped to store the gains without loss. This practice reduced the percentage of damage by 4 compared to Nochi leaves. This is an simple and low cost (Rs. 30 per piece) device.

The coconut dehusker developed by Kerala Agricultural University was a real labour saving portable device and resulted in uniform dehusking. The rate of dehusking was 44 nuts/hr with less drudgery. Earlier farmers used to dehusk 24 coconuts per hr using crowbar and local sickle. This was women friendly farm equipment and easy to adopt. As the dehuskers increased operation efficiency with less manual work, this intervention was found acceptable by all sections of the village community. Cost of the dehusker was Rs. 125/-.

It is proved that farmers showed keen interest in adopting new technologies if found suitable. It is necessary to identify the other areas in farming whereas there is an need for alternative approaches and implement new technological interventions through farmers participatory approach.

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Transfer of Technology for Fishery Production System in Sundarbans under Coastal Agroecosystem

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Institute Village Linkage Program (IVLP) through Technology Assessment and Refinement (TAR) was implemented in Sundarbans to enable the farmers to participate in technology development by utilizing their local expertise. The project site Dumki was selected and fish polyculture technology was introduced to the farmers in which three species viz., *Catla* : *Rohu* : *Mrigal* in the ratio of 4:3:3 @ 500 fingerlings per 650 sq m was introduced in the ponds during July. The result revealed that the cost-benefit ratio from this technology was quite high (15.76) when compared to farmer practice (8.57). Further, introduction of paddy-cum-fish culture, where the above said species of carps were released into the paddy field, resulted in significant economic benefit to farmers.

(**Key words:** *Transfer of technology, Agroecosystem, Production system*)

Fish is the important source of protein for many fish consuming communities. India has a long coastal line, which are offering an immense scope and potential for aquaculture. In India, the average aquaculture productivity in coastal region of Andhra Pradesh, Tamil Nadu, and Maharastra is 1-2 t ha^{-1}, but in West Bengal the average productivity is only 250 –500 kg ha^{-1}. (Ayyappan and Diwan, 2003). So still there is a lot of potential to be tapped in this production system in West Bengal. The coastal areas of Sundarbans are remote, backward and economically underdeveloped, and soil salinity in the dry season and waterlogging in the rainy season leads to the Complex, Diverse and Risk prone nature of agriculture in this area. Apart from this, majority of the farmers in this area are landless followed by marginal and small farmers, and 30% of the people fell under the sub-poverty line. As far as the natural conditions are concerned, aquaculture is one of the potential enterprises which can be tapped very efficiently as an alternate income generating enterprise for this area. For efficient management of the aquaculture sector it is necessary to improve the information flow and communication system at national, regional and inter-regional levels. Information on new innovations and technologies for sustainable aquaculture development has to be developed and made available to the farmers/ industries/users. Keeping this in view a pilot Project on Technology Assessment and Refinement through Institute Village linkage programme (TAR-IVLP) has been undertaken in the Dumki village, which is the typical representative of the Sundarbans coastal areas. Under this project various production systems are covered with various suitable technological interventions. This paper is discussing the Transfer of Technology for increasing the Fishery Production and socioeconomic condition of the farmers by introducing scientific technological intervention under the coastal agroecosystem.

MATERIALS AND METHODS

To assess the prevailing agricultural and socioeconomic conditions of the area and the problems faced by the farmers, the Participatory, Learning and Action (PLA) tools were employed. Considering different soil-water characteristics, agroclimatic situations and the various biophysical factors at micro levels different microfarming situations (MFS) were identified. All the identified problems were subjected to problem-cause analysis through causal diagram for each to pinpoint the intervention points for action. Technological gaps between the existing and recommended practices were also analyzed so as to evolve suitable refined technological interventions for further action in achieving the desired solutions. By this process the resources like watersheds in the form of land / pond in *Kharif* was identified which can be utilized effectively for income generation by way of introducing new technological interventions. There were two technological interventions identified for the fishery production system which are scientific paddy-cum-fish culture and polyculture technique. For paddy-cum-fish intervention, 30 farmers' fields were selected, the seedling of paddy were transplanted in July and the fingerlings were liberated in the proper ratio i.e., *Catla* : *Rohu* : *Mrigal* :: 4:3:3 @ 500 fingerlings per 650 sq m, and it was allowed to grow upto the harvest of paddy (November-December). After the harvest of paddy fish was harvested from the respective pond. In the polyculture intervention, the fingerlings were liberated at the 30 farmers' ponds in the month of July at the same ratio of the above mentioned intervention where it remained up to next March-April. For effective transfer of technology technical know-how was provided to the farmers and the training programmes were also undertaken regarding that technological interventions. By the end of the season the data were collected from the farmers. The data were analyzed by comparing with the actual farmers' practice and it was subjected to tabulation.

RESULTS AND DISCUSSION

The ideal situation for paddy-cum-fish culture is very much present in many fields in this region as the depth of standing water in lowland areas is more than 60 cm in the *Kharif* season that suits the free movement of fish in the field. But farmers in this area are growing rice only. To increase the farmers' income from the unit of land the paddy-cum-fish intervention was introduced among the farmers in this region.

The mean of the results (Table 1) obtained from the paddy-cum-fish intervention undertaken by 30 farmers shows that the grain yield was 28.50 q ha^{-1} and the fish yield was 8.80 q ha^{-1}, both contributing to the income of Rs. 42000 ha^{-1}. The cost of cultivation for this treatment was Rs. 11930 ha^{-1}, and the benefit-cost ratio was estimated as 3.52. In case of farmers practice where only one *kharif* crop was grown, the yield of paddy was 28.50 q ha^{-1}, the total income received by the farmers was Rs. 19200 ha^{-1} with the cost of cultivation Rs. 10400 ha^{-1}, and the benefit-cost ratio was only 1.85. Due to the additional income generated by the fish cultivation, which did not exist before the introduction of IVLP, the adoption rate was faster for this intervention.

Table 1. *Comparative yield and income due to paddy-cum-fish cultivation*

	Farmers' practice (Rs./ha)	Treatments (Rs./ha)
Avg. fish yield (q/ha)	0.00	8.88
Avg. grain yield (q/ha)	28.50	25.45
Cost of cultivation	10400	11930
Total value of products	19200	42000
Net return	8800	30070
Benefit : Cost	1.85	3.52

In case of fish cultivation alone in the ponds the yield was not up to the expected mark due to excessive density and improper ratio among different types of fingerlings, followed by most of the farmers of this region. To improve the existing condition, the polyculture technique was introduced in this region. The data in Table 2 clearly show that the net returns from farmers' practice was Rs. 59737 when compared to the improved treatment where it was Rs. 83165. The benefit-cost ratio of the improved treatment was 15.76 where as, it was only 8.57 in the farmers practice. The result was very much encouraging as the average fish yield of the treated ponds was 29.60 q ha^{-1} against farmers' practice of 21.80 q ha^{-1}, which was 35.78% higher. This result was in line with the result obtained at Bhubaneswar where the composite fish culture including *Rohu, Catla, Mrigal* was taken up in 19 village ponds and farmers got around Rs. 40000 ha^{-1}. Similarly the farmers at West Godavari district used *Rohu* : *Katla* and *Mrigal* @ of 2:7:1 as against the usual practice of using fingerlings which resulted in the increase of net return from Rs.18,000/- to 37,440/- (Edison *et al.*, 2003).

Table 2. *Comparative yield and income due to polyculture technique*

	Farmers' practice (Rs./ha)	Treatments (Rs./ha)
Avg. fish yield (q/ha)	21.80	29.60
Cost of cultivation	7885	5635
Total value of products	67622	88800
Net return	59737	83165
Benefit : Cost	8.57	15.76

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Impact of Participatory Planning for the New Technology in Coastal Areas of Sundarbans

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The coastal areas of Sundarbans form a typical ecosystem with low productivity due to a variety of constraints, technical, socioeconomical and infrastructural in nature, which warrant special attention. Therefore, participatory approach was followed by applying Participatory Rural Appraisal (PRA) tools viz., problem-cause analysis, gap analysis and prioritization of techniques. The study has been done in two hamlets of coastal areas of Sundarbans under South 24-Parganas district of West Bengal.

*(**Key Words** : Transfer of technology, PRA tools, Technological intervention, Bottom-up approach)*

In the past, we had Green, White and Blue revolutions in our country but the impact of all those revolutions was not uniform. The scenario may be much more worse in the coastal agroecosystem, where Complex, Diverse and Risk (CDR) prone agricultural situation exists. It is very much required that transfer of technology should be so tuned as to fit in the requirements of the farmers in a given situation; since the suitability and adaptability of a technology differ under different microsituations. The coastal areas of Sundarbans form a typical ecosystem with low productivity due to a variety of constraints, technical, socioeconomical and infrastructural in nature, which warrant special attention. The productivity in this area lags seriously behind that in inland areas. On an average, more than 85 % of the total cultivated area is monocropped having an average yield potential of the rainfed rice as less than 1.75 t ha^{-1}.

Hence, to identify and introduce technological interventions for increasing the rice productivity in a sustained manner participatory approach was followed by applying Participatory Rural Appraisal (PRA) tools viz., problem-cause analysis, gap analysis and prioritization of techniques through the Institution Village Linkage Programme (IVLP) under NATP at two hamlets of Dumki village under Canning P.S. in the district of South-24 Parganas of West Bengal.

MATERIALS AND METHODS

The most crucial part for transferring the technology to the farmers is the selection of superior technology over the existing practice because, many a time, under the top-down approach, recommended package of practices is considered as the ultimate basis for technical planning and it has been observed that in many cases yield under demonstration plots was not significantly higher than the normal practice followed. So, for planning of the critical inputs/ technology, various tools of PRA were used to decide upon the most critical inputs in order of prioritization having effect on yield rice for deciding critical inputs. For this, problem-cause analysis was done with the paddy growers of the village.

The intervention points were identified (Table 1) in consultation with the farmers from the problem-cause tree and the deciding factors for selection of the critical inputs were gap in adoption of a technology and percentages of farmers not following recommended practices.

The following critical inputs were finalized by the farmers and scientists involved in the programme :

1) Need to introduce recommended variety.
2) Need to introduce balanced use of fertilizers preferably on soil test basis i.e., Neem coated Urea @ 60 kg N ha^{-1} + SSP @ 11 kg P ha^{-1}, and no potassic fertilizers.
3) Improvement in the awareness of the farmers regarding recommended package of practices for rice cultivation.

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Table 1. Adoption behaviour of paddy growing farmers and prioritization of technologies

Agricultural operation	Recommended practices	Existing practice	Gap in adoption	Farmers prioritization for critical inputs
Variety	Canning-7, Mohan, CST-7-1, CSR1, CSR 2, CSR3	Local variety	Full	I
Preparatory tillage	Deep tillage in cross direction, 2-3 ploughing	Shallow tillage, 1-2 ploughing	Partial	V
Seed rate	60 kg/ ha	40-48 kg/ ha	Partial	VII
Seed treatment	Hot water treatment, treatment with Agrosan GN @ 2-3 g/kg	Nil	Full	VI
Time of fertilizer application	P at final ploughing, N in 3 splits; one each at 7-10 days after transplantation, peak tillering and boot leaf stage, respectively.	Normal without any sequence	Partial	IV
Fertilizer dose	60:33:0 (N: P: K)	Incorrect dose	Partial	II
Weeding	2-3 times with raking of soil	Once without raking	Partial	VIII
Plant protection	Hinosan @ 0.1 %, Dimecron @ 0.1%, Metacid @ 0.1 % as and when required	Nil	Full	III

Table 2. Comparison of yield before and after treatment

Year	No. of Farmers	Yield after treatment (under IVLP) (q/ha)		Farmer's yield (without recommended practices) (q / ha)	
		Grain	Straw	Grain	Straw
1998-99	30	27.57	44.80	21.00	33.82
1999-2000	31	30.02	47.23	23.70	37.09
2000-01	30	28.53	41.57	25.20	39.21
2001-02	60	30.11	43.69	25.50	40.45
2002-03	120	36.00	54.72	28.50	43.32

RESULTS AND DISCUSSION

The demonstrations were conducted at the farmers' fields in consultation with farmers on the above finalized (Table 1) critical inputs (except improvement in awareness which was done through giving training). The results obtained during the last five years are given in the Table 2.

The result revealed that there was an increase of more than 30 percent in the grain yield in 1998-99, 26.67 percent in 1999-2000, and 26.32 percent during 2002-03. The data also indicated that there was a constant increase in the average grain yield of farmers' practice every year. It was 12.85 % from 1998-99 to 1999-2000; 6.30 % from 1999-2000 to 2000-2001; 1.19 % from 2000-2001 to 2001-2002 and 11.76 % from 2001-2002 to 2002-2003. This is an indication of increased awareness of the farmers.

The participatory approach in planning and conducting the demonstrations was to help to motivate the farmers for adopting the new technology. The approach in conducting the demonstration was very much positive from the farmers' side, as they felt involved. The bottom-up approach in planning and conducting the demonstration proved better as it created a sense of belongingness among the farmers. This approach led to the selection of the right intervention points and critical inputs for better transfer of technology.

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Gender-wise Participation and Decision Making in Crop Husbandry Activities in Coastal Areas of Sundarbans

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Rural women are traditionally less involved in decision making at all levels. Their position on family farms is not recognised and therefore, still not accepted in decision making. It is concluded that the key problem and cause for the lower participation of women in decision making at all levels lie in their present economic position. In order to increase their involvement in decision making we need to strengthen their economic position and independence. Since the role of men and women vary in decision making in agriculture including animal husbandry, it is pertinent to study the gender differential in activity analysis, access to and control over resources, and benefits and decision making pattern in dairy and crop husbandry activities.

***(Key words** : Gender participation, Rural women, Decision making, Crop husbandry)*

Women constitute a significant component of the agricultural labour force in India (46%). Although majority of rural women are involved in agriculture including animal husbandry, the nature and extent of their involvement varies widely and is strongly influenced by their economic status, caste, ethnic background and the stage of lifecycle of their household. Rural women, as elsewhere, play multiple roles; in the domestic sphere they are household managers, as mothers and wives; in the community they maintain social and cultural services, predominately on a voluntary basis; and terms of economy, if they are not formally engaged as employees or entrepreneurs, they are active in family businesses and farms. Cooperatives, traditionally the most important production and marketing links for farmers, which also play very important roles in political and cultural life in rural areas, have extremely less number of women as members in the management structure. Many women are not active in the formal labour market, even though they have an essential role in farm economy. Traditionally they have the "status" of farm wives or housekeepers.

Since the role of men and women vary in decision making in agriculture including animal husbandry, it is pertinent to study the gender differential in activity analysis, access to and control over resources, and benefits and decision making pattern in dairy and crop husbandry activities.

MATERIALS AND METHODS

The study was carried out in two hamlets of Dumki village namely, Chhoto Dumki and Boro Dumki of Canning P.S. under South 24 Parganas. A total of 50 respondents (consisting of twenty five-men and twenty-five women) were selected randomly from each of the hamlets. The responses of the respondents regarding their participation in crop husbandry activities and decision making were collected through the interview schedule developed for this purpose. In this study a total of thirteen practices related to agricultural operation and six practices related to household chores were identified in which the rural women were expected to participate. Whereas, regarding decision making altogether fourteen practices were identified consisting of agricultural operations, household works and social activities. The data thus obtained were analysed on percentage basis.

RESULTS AND DISCUSSION

Participation of women in agricultural operations are very much low in the area, since most of the farm jobs are performed by the male members. The data indicated that some of the jobs viz., land preparation, spraying, etc. were done only by the male members. In case of planting, harvesting and threshing operations 22, 36 and 28 percent participation of women were observed (Table 1).

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***Table 1.** Participation of male and female in crop production activities*

Activity	Male (%)	Female (%)
Land preparation	100	0
Seed-bed preparation for sowing	85	15
Raising nursery and transplanting	78	22
Direct sowing	75	25
Irrigation	77	23
Applying FYM (farmyard manure)	68	32
Fertilizer application	70	30
Weeding	65	35
Plant protection	100	00
Harvesting	64	36
Threshing	72	28
Bagging/storing of grain	57	43
Marketing of produce	90	10

Participation of women in application of fertilizers and FYM were found to be 30 and 32 percent, respectively while, in case of weeding operations it was more than one-third i.e., 35 percent participation. For marketing of the produce, women's contributions were only 20 percent. Participation of women in fuel collection and household works, in turn, was more than that of men. Women were fully responsible for cooking and have to bear about 80% of the workload in the childcare and cleanliness of the house (Table 2).

***Table 2.** Participation of male and female in household activities*

Activity	Male (%)	Female (%)
1. **Fuel collection**	20	80
2. **Household work**		
a) Cooking	0	100
b) Childcare	20	80
c) Children education	40	60
d) Cleanliness	20	80
e) Marketing	80	20

Regarding education of the children their participation was found to be 40 percent. Male members were however responsible for marketing of the produce (80%), which was in concurrence with the findings of Bhaumik *et al.*, (1996).

Data on gender-wise decision making in village life activities have been given in the form of a table (Table 3). The perusal of the data clearly indicated that in terms of decision making, male members dominated over female members. In this respect the women had very nominal role (10%) in all farm activities including land preparation except in case of winnowing where they have relatively greater role (20%). Women, in turn, dominated in deciding about fuel collection, cooking, childcare and shopping related issues (Table 3). Women also had a greater role in decision making for attending social functions (40%) and schooling of the children (80%). From these findings it is clear that involvement of rural women of Sundarbans was relatively higher in those practices which are easier for housewives to perform and this was in concurrence with the findings of Bhaumik *et al.* (1996).

***Table 3.** Decision making of male and female in crop production*

Activity	Decision Making	
	Male (%)	Female (%)
Land preparation	90	10
Ploughing	90	10
Planting	90	10
Mulching	90	10
Weeding	90	10
Härvesting	90	10
Threshing	90	10
Winnowing	80	20
Storing	80	20
Cooking	00	100
Schooling	80	20
Shopping	40	60
Social function	60	40
Child care	20	80

CONCLUSIONS

The data lead to the conclusion the women in general are not given equal opportunity for participating in various technical and extension activities and the key problem and cause for the lower participation of women in decision making at all levels may lie in their present economic position. There is a great need for involving rural women of Sundarbans in extension and training activities, particularly for augmenting their skills for the activities with which they are vitally concerned

(Bhaumik et. al., 1996). In order to increase their involvement in decision making it is required to strengthen their economic position and independence, which requires;

- Better access to education and information services
- Development support for self-employment and job creation for women on farms and in rural areas
- Enhancement of female extension personnel of total extension personnel to create interest and motivation among the farmwomen (Bahal *et al.*, 1993)
- Support in the development of social services to reduce isolation and assure greater mobility of rural women

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Participation Behaviour of Farmwomen in Rice Cultivation under Coastal Agroecosystem in Orissa

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Results of survey conducted at National Research Centre for Women in Agriculture, Bhubaneswar during 2001-02 and 2002-03 on varying categories of farm women of different socioeconomic status in the coastal region of Orissa revealed that the overall contribution of women and men in rice cultivation was 40.15 and 59.85 percent, respectively. The role of family women remained mostly with post-harvest operations and highest contribution (11.72 h per season) was recorded in storing of seeds. The paid women shared highest hours (32.90) per season in transplanting. The participation of women in total (family + paid women) was also recorded highest (39.06 h per season) in this particular operation. Men, however, contributed highest (94.34 h per season) in harvesting. Study also revealed that the participation of higher caste women was lowest (11.5%) while, that of SC categories, it was recorded highest (27.18%). Participation was also found to be affected by the number of members in the family, number of working women, size of land holdings, varying farming systems, cropping systems, and level of farming.

(***Key words***: *Farm women, Participation behaviour, Rice production systems*)

The role played by women in agriculture and allied activities is more enormous and fully recognized. Nearly 84% of all economically active women in India are engaged in agriculture and allied activities. The women share goes to as high as 40 percent (Dhaka *et al.*, 1994) to overall crop production besides her absolute responsibility for home and animals. In Asia, women provide labour to the tune of 50 to 90 percent for rice cultivation. Women participate in almost all the activities right from preparation of seed material, nursery raising field preparation (except ploughing), transplanting, fertilizer application, weeding, harvesting, winnowing, parboiling, drying till storage, and remain busy for 10 hours a day in the sowing of rice in the month of July, 11 hours a day in weeding in August and also for as many as 11 hours a day for harvesting and threshing in the month of October (Ahuja, 1998). Participation of women in agriculture is governed by many of the sociocultural and economic factors which varies from region to region and even within regions. There are regions in India where the caste system prevents women from participating in field work. This is the case for example in Bhitarkanika (Orissa). Under rigid caste codes, women from upper castes are not allowed to be seen outside their houses. On the other hand, women from lower castes are able to move outside their houses (Kanvinde, 1997). The present study has, therefore, been undertaken to study the participation of women in rice cultivation in reference to prevailing caste system and socioeconomic status of farm women in coastal region of Orissa. It is worth mentioning here that rice is the largely grown crop of coastal region of Orissa.

MATERIALS AND METHODS

The survey on participation of women in rice cultivation in relation to varying socioeconomic aspects was conducted during 2001-02 and 2002-03 on 50 farm families of 5 villages i.e., Basantapedi, Jagamara, Khamang Sasan in Khurda, Badabelari in Jagatsinghpur, and Gudubani in Puri districts, all in coastal region of Orissa. Ten farm families, three each belonging to higher, other backward caste (OBC) and scheduled caste (SC), and the tenth one, the village leader (belonging to any of the castes), were selected from each of the five villages. Data on operation-wise participation were collected from the head of the family farm women. General information on family pattern, socioeconomic conditions and crop production aspects was also collected so as to partition the involvement of farm women in various activities of rice cultivation with reference to their prevailing socioeconomic conditions.

RESULTS AND DISCUSSION

Operation-wise participation

Operation-wise participation was analyzed based on contribution of male and female members from farming family and that of paid labours.

Family women: Family women contributed highest hours (11.72 per season) in storing of seeds (Table 1). Winnowing operation was found to be second (9.90 h per season) followed by aftercare of seed (8.90 h per season), harvesting (7.46 h per season), drying of produce (7.14 h per season) and transplanting (6.16 h per season) operations. As far as percentage of total hours is concerned the aftercare of seed stood first (98.90%) followed by storing of seed (86.81%). Thus, role of family women remained mostly with post harvest operations.

Paid women : It is evident from Table 1 that paid women shared highest in transplanting both in terms of hours per season (32.90) and percentage (44.13%). Harvesting was the second highest (22.30 h per season) while uprooting of seedling stood third (15.08 hours) in the sequence.

With regards to participation of women in total (family + paid), transplanting accounted for highest hours (39.06 per season) which was 52.39 percent of total participation in this operation. Similarly, harvesting reported to be the second highest (29.76 h per season and 40.16%) while weeding stood third (18.96 h per season and 48.17%).

Harvesting was found to receive highest hours (44.34 per season) from the men, followed by transplanting (35.5 h per season) and threshing (26.24 h per season). In fact, these were the three operations, which accounted higher working hours in rice cultivation. In almost all the rice growing area of Asia, men traditionally undertake such activities such as, land preparation, ploughing, irrigation and field leveling. Women, on the other hand, are responsible for sowing, transplanting, weeding and crop processing (FAO, 1997). Overall the women and men contributions in different operations of rice cultivation were recorded 40.15 and 59.85 percent, respectively.

Community-wise participation of family/farm women

Study revealed that the participation in rice cultivation was the lowest i.e., 11.57 percent from women belonging to higher castes (Fig. 1) while, it was the highest from SC (27.18%), followed by OBC (12.13%) categories. Consequently, the share of paid women was higher with women of higher castes and lowest with SC category. The share of men in overall participation was higher with OBC (63.31%) and lowest with SC (53.72%).

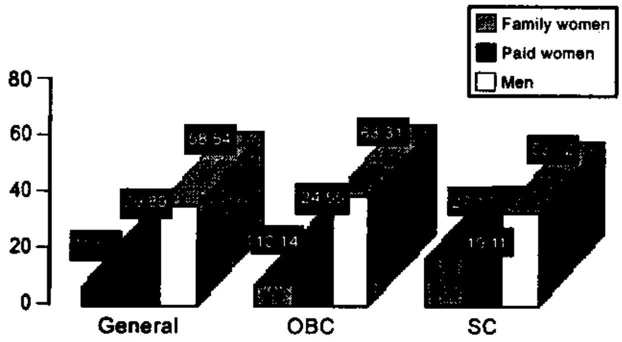

Fig. 1. *Community wise particupation (%) in rice*

Women participation and the number of family members

The women of farming families belonging to higher castes had the same level (12% to 13%) of participation in rice cultivation up to 5 numbers of family members (Table 2). This was, however, reduced (7.08%) when the family members increased beyond five. Almost same trend was reported with OBC category. In case of SC families, however, the participation increased with increase in number beyond five.

Women participation and number of working women in family

Number of working women in the family also affected the participation in rice cultivation (Table 2). The percent participation and total hours declined with increase in number of working women from two onward. The extent of decline was more with higher caste followed by OBC and SC. No family was reported having more than 5 working women in this particular survey.

Participation of women under different land holdings

The size of land holding influenced the participation of family women in rice cultivation. Under the landless category the participation of higher caste women was 8.11 percent, while that of SC category it was 23.00 percent (Table 2). The participation was higher in marginal land holding which declined in small holding size. No family was found having land more than 2 hectares in the reported samples. No family belonging to OBC was also reported under landless class.

Participation of women under different farming systems

A few farm families were found (Table 2) having only irrigated land. Most of the farmers had either

Table 1. *Participation (hours per season) of farm women in rice operations*

Name of operation	Family women		Paid women		Total women		Men		Total operation h/season
	h/season	%	h/season	%	h/season	%	h/season	%	
Seed bed preparation	2.50	11.75	0.72	3.38	3.22	15.13	18.06	84.87	21.28
Nursery manuring	0.44	8.87	0.44	8.87	0.88	17.74	4.08	82.26	4.96
Nursery sowing	1.48	9.04	3.18	19.41	4.66	28.45	11.72	71.55	16.38
Nursery weeding	2.44	12.92	7.60	40.25	10.04	53.18	8.84	46.82	18.88
Nursery watering	2.12	23.30	1.10	12.09	3.22	35.38	5.88	64.62	9.10
Seedling uprooting	3.32	8.45	15.08	38.39	18.40	46.84	20.88	53.16	39.28
Transporting seedling	1.62	9.07	3.30	18.48	4.92	27.55	12.94	72.45	17.86
Main field ploughing	0.30	1.97	0.10	0.66	0.40	2.63	14.82	97.37	15.22
Clod breaking	0.20	5.00	0.56	14.00	0.76	19.00	3.24	81.00	4.00
Removal of grasses	1.46	17.80	3.40	41.46	4.86	59.27	3.34	40.73	8.20
FYM application	1.36	9.05	1.10	7.32	2.46	16.38	12.56	83.62	15.02
Fertilizer application	0.16	1.33	0.40	3.32	0.56	4.65	11.48	95.35	12.04
Pre-transplant irrigation	0.00	0.00	0.20	9.09	0.20	9.09	2.00	90.91	2.20
Transplanting	6.16	8.26	32.90	44.13	39.06	52.39	35.50	47.61	74.56
Ridge making	0.28	2.25	0.00	0.00	0.28	2.25	12.14	97.75	12.42
Irrigation	0.32	2.72	0.00	0.00	0.32	2.72	11.44	97.28	11.76
Top dressing	0.00	0.00	0.00	0.00	0.00	0.00	5.06	100.00	5.06
Weeding	3.78	9.60	15.18	38.57	18.96	48.17	20.40	51.83	39.36
Herbicidal application	0.00	0.00	0.00	0.00	0.00	0.00	1.82	100.00	1.82
Hoeing	0.30	12.82	0.20	8.55	0.50	21.37	1.84	78.63	2.34
Sprayer handling	0.00	0.00	0.00	0.00	0.00	0.00	1.32	100.00	1.32
Harvesting	7.46	10.07	22.30	30.09	29.76	40.16	44.34	59.84	74.10
Carrying harvest to threshing floor	1.70	6.36	6.50	24.33	8.20	30.69	18.52	69.31	26.72
Drying harvest	2.92	36.78	2.62	33.00	5.54	69.77	2.40	30.23	7.94
Threshing	4.06	10.02	10.20	25.19	14.26	35.21	26.24	64.79	40.50
Winnowing	9.90	32.91	7.70	25.60	17.60	58.51	12.48	41.49	30.08
Carrying produce to home	4.50	23.12	2.80	14.39	7.3	37.51	12.16	62.49	19.46
Drying produce	7.14	64.09	2.40	21.54	9.540	85.64	1.60	14.36	11.14
Storing seed	11.72	86.81	0.40	2.96	12.12	89.78	1.38	10.22	13.50
Preparing produce for marking	3.28	33.13	0.80	8.08	4.08	41.21	5.82	58.79	9.90
Aftercare of seed	8.98	98.90	0.00	0.00	8.98	98.90	0.10	1.10	9.08
Total	92.80	15.62	145.73	24.53	238.53	40.15	355.51	59.85	594.04

Table 2. *Participation of women under different socioeconomic aspects*

Aspects	Higher castes		OBC		SC	
	h/season	%	h/season	%	h/season	%
Number of family members						
<2	0.15	12.61	0.00	0.00	0.00	0.00
3 -5	1.73	12.11	1.36	14.09	2.67	26.56
>5	0.16	7.08	1.28	11.95	1.36	27.92
Number of working women						
<2	1.88	12.18	2.32	12.32	3.64	28.23
3 -5	0.16	7.08	0.30	11.67	0.41	26.62
>5	0.00	0.00	0.00	0.00	0.00	0.00
Size of land holding						
Land less	0.03	8.11	0.00	0.00	0.69	23.00
Marginal (<1 ha)	1.58	13.78	1.13	16.16	3.06	28.82
Small (1-2 ha)	0.37	7.40	1.54	15.78	0.28	25.68
Farming systems						
Irrigated	0.09	9.38	0.00	0.00	0.00	0.00
Rainfed	0.34	19.65	2.04	13.24	1.68	23.46
Irrigated + Rainfed	1.14	9.53	0.74	7.84	2.03	35.48
Cropping systems						
Rice-pulse	2.00	11.36	2.55	12.40	8.32	26.34
Rice-oilseeds	1.10	13.92	1.43	11.65	0.61	21.94
Rice-Rice	0.00	0.00	0.00	0.00	0.51	21.88
Rice-vegetables	0.10	9.09	0.12	18.18	0.25	34.72
Level of farming						
Mechanized	1.68	11.79	2.32	12.30	2.79	28.18
Traditional	0.33	9.85	0.33	9.85	0.34	10.47

only rainfed or both rainfed as well as some irrigated lands. Women under each of the faming systems participated in rice cultivation. The participation of SC women was higher (23.46% and 35.48%) under both the farming systems followed by higher castes (19.65% and 9.53%) and OBC (13.24% and 7.84%).

Participation of women under different cropping systems

Rice-pulse, rice-oilseed, rice-rice and rice-vegetable cropping systems were prominent in the villages surveyed under this study (Table 2). The participation of higher caste women was higher in rice-oilseed (13.92%) cropping system while for OBC it was 18.18%, and for SC it was 34.72% in rice-vegetables. Only a few families under SC categories was found adapting rice-rice cropping system where women participation was recorded to an extent of 21.88 percent.

Participation of women under different levels of farming

The participation of family women reported to have increased under mechanized (i.e., under the use of improved tools and machinery) over traditional (i.e., under no use of implements). Among various categories of farm women the highest participation was reported with women of SC category, followed by OBC and higher castes under both the situations.

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Assessment of the Performance of High Yielding Cassava Varieties under TAR-IVLP in Coastal Agroecosystem

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Cassava is the most important secondary staple food crop of Kerala grown both under upland and lowland conditions. Non-adoption of high yielding mosaic resistant/field tolerant varieties owing to non-availability of such quality planting material emerged as the most important problem limiting the productivity of cassava from the agroecosystem analysis of the adopted village, Chenkal under the Institution Village Linkage Programme (TAR-IVLP) of CTCRI. Taking into confidence the cassava farmers, action plans have been drawn to conduct on-farm trials of high yielding cassava varieties namely, Sree Rekha, Sree Prabha, Sree Jaya, etc. under farmers field for detailed assessment and refinement. In the upland Sree Rekha recorded higher yield (46t ha^{-1}) with higher B:C ratio (7.87:1) when compared to the local variety Manja Noorumuttan which yielded 21t ha^{-1}with a B:C ratio of 3.60:1, whereas in the lowland Sree Prabha recorded the maximum yield (52t ha^{1}) with a higher B:C ratio (8.80:1) over the local variety Ullichuvala (22t ha^{-1}). Both the high yielding varieties are well accepted by the farmers due to high yield, high income and excellent cooking quality when compared to the local varieties. Currently the high yielding cassava varieties occupy a considerable area in the adopted village and through farmers exchange it has slowly spread to the nearby villages.

(***Key words:*** *Cassava, Assessment of varieties, Lowland, Upland, Yield, Growth, Economics*)

Cassava (*Manihot esculenta*) is a popular tuber crop of humid tropics, and it is widely grown in South India with Kerala, Tamil Nadu and Andhra Pradesh accounting for more than three-fourth of the area planted to it. In the year 1999-2000 cassava production reached an all time high of 67.684 metric tones. The increase in the productivity of cassava should be achieved mainly through the introduction of improved varieties.

India, with an annual root production of about 618 million tones from an estimated area of 0.235 million hectares, has a unique status in the cassava map of the world for its highest yield (26.32 t ha^{-1}). This could be possible because of the availability of high yielding varieties and the willingness of the farmers to adopt these varieties along with the sound agronomic management practices. The cassava production in the village was constrained by the cultivation of traditional local varieties that were low yielding due to severe pest and disease incidence resulting in a lower net income. The participatory evaluation of high yielding cassava varieties through Farmers Participatory Research (FPR), conducted in Chenkal village under TAR-IVLP. The technological interventions were planned to find out the most suited cassava high yield varieties under upland and lowland rainfed conditions. In order to find out the suitable variety, farmers participatory On Farm Trials (OFT) were conducted.

MATERIALS AND METHODS

The present study was conducted in the Chenkal village of Thiruvananthapuram district under Technology Assessment and Refinement through Institution Village Linkage Programme (TAR-IVLP) implemented by Central Tuber Crops Research Institute (CTCRI). A thorough analysis of problem-cause relationship through Participatory Rapid Appraisal (PRA) revealed that the low profitability in cassava based production system was due to non-availability of improved varieties, high incidence of cassava mosaic disease and non-availability of seeds of suitable intercrops. The objectives of these interventions were to assess the performance of the improved varieties in both upland and lowland rainfed conditions, compare with farmers own varieties cv. Ullichuvala and Manjanoorumuttan, and to work out the benefit-cost analysis.

The climate of the village is humid tropical with fairly distributed rainfall of 1500 mm during May to November, which account for 75% of total precipitation. January-April are the rain deficient summer months and only about 500mm of rainfall is received during this period. Clay loam soil of the site was acidic in reaction with a pH of 4.6-5.4. The fertility status of the soil is available N: 200-230 kg ha^{-1}, available P: 20-30 kg ha^{-1}; available K: 125-150 kg ha^{-1}, organic carbon : 0.62-0.85%. All agronomic practices were followed under farmers' management.

Four improved varieties were compared with the farmers own varieties cv. Ullichuvala and Manajanoormuttan in both upland and lowland rainfed conditions during *rabi* 2000. The high yielding varieties included in the trial were the two top cross hybrids Sree Rekha and Sree Prabha and two short duration varieties Sree Vijaya and Sree Jaya. All these varieties were released from Central Tuber Crops Research Institute, Sreekaryam having fresh tuber yield potential of 71 t ha^{-1}, 72 t ha^{-1}, 51 t ha^{-1} and 58 t ha^{-1}, respectively. Farmers were involved in evaluating the varieties throughout the crop period. The evaluation criteria were identified based on the farmers' preferences. The varieties were evaluated with farmers participation by collecting data on the important biometrical observations such as plant height, no. of tubers per plant, length of the tubers per plant, weight of the tubers per plant, general appearance, yield of tubers, etc.

RESULTS AND DISCUSSION

In the upland cassava variety Sree Rekha recorded the maximum height 197 cm followed by Sree Prabha 183 cm and Sree Jaya 168cm (Table 1). The local Manja Noorumuttan recorded least height of 159 cm. The hybrids Sree Rekha and Sree Prabha showed branching habit with a production of more number of leaves. More number of tubers was noted in Sree Rekha with 11 tubers per plant, followed by Sree Prabha 12 tubers per plant. The local variety Manja Noorumuttan had 8 tubers per plant. The weight of the tubers was also observed to be higher in the two hybrids viz., Sree Rekha (3.8 kg per plant) and Sree Prabha (3.7 kg per plant). The improved variety Sree Jaya also showed increased weight of the tubers (2.5 kg) when compared to the local Manja Noorumuttan, (1.80 kg per plant). The hybrids Sree Rekha and Sree Prabha recorded the highest average tuber yield of 46.7 t ha^{-1} and 45.9 t ha^{-1}, respectively, which were 118% and 114% higher than the local Manja Noorumuttan (21.4 t ha^{-1}). The increase in the yield might be due to the branching habit coupled with the production of more number of leaves that increased the photosynthetic efficiency and in turn its higher yield over the local variety. The findings are in line with those observed by Paramaguru *et al.*, 1991, Nair *et al.*, 2002). According to them the branching types had the highest leaf area index and were high yielders. In the upland net return from Sree Rekha was the highest (Rs.122285 per ha) (Table 2), followed by Sree Prabha (Rs.120325 per ha) and Sree Jaya (Rs.59980 per ha). The local Manja Noorumuttan gave the least net return (Rs.42900 per ha). The cooking quality of Sree Rekha and Sree Prabha were excellent. The duration of Sree Rekha and Sree

Table 1. *Biometrical observation of cassava varieties in upland*

Attributes	Sree Jaya	Sree Rekha	Sree Prabha	Manja Noorumuttan
Plant ht (cm)	168	197	183	159
No. of tubers/plant	10	11	12	8
Wt. of tubers/plant(kg)	2.20	3.80	3.70	1.80
Tuber length (cm)	14.80	21.00	19.50	13.70
General appearance	Good	Good	Good	Moderate
Yield (t ha^{-1})	25.90	46.70	45.90	21.40
Crop duration (month)	6-7	8-10	8-10	8-10
Percentage increase/ decrease in yield over local	+21%	+118%	+114%	—

Table 2. *Benefit-cost analysis for cassava varieties (Rs/ha) upland*

Attributes	Sree Jaya	Sree Rekha	Sree Prabha	Manja Noorumuttan
Cost of cultivation (Rs/ha)	17800	17800	17800	16500
Gross returns (Rs/ha)	77780	140085	138125	59400
Net returns (Rs/ha)	59980	122285	120325	42900
Benefit: Cost ratio	4.37:1	7.87:1	7.76:1	3.60:1

Table 3. Biometrical observation of cassava varieties in lowland

Attributes	Sree Jaya	Sree Rekha	Sree Prabha	Sree Vijaya	Ullichuvala
Plant ht (cm)	175	202	194	168	155
No.of tubers/plant	11	11	12	9	9
Wt.of tubers/plant(kg)	2.30	4.20	4.25	2.20	1.90
Tuber length (cm)	15.20	27.10	28.60	13.70	14.80
General appearance	Good	Good	Good	Moderate	Good
Yield (t ha^{-1})	28.60	51.90	52.50	25.80	22.20
Crop duration (month)	6-7	8-10	8-10	6-7	7-8
Percentage increase in yield over local	+30%	+133%	+136%	+15%	—

Table 4. Benefit-cost ratio analysis for cassava varieties in lowland (Rs/ha)

Attributes	Sree Jaya	Sree Rekha	Sree Prabha	Sree Vijaya	Ullichuvala
Cost of cultivation (Rs/ha)	17800	17800	17800	17800	16500
Gross returns (Rs/ha)	82940	155570	156640	78675	61210
Net returns (Rs/ha)	65140	137770	138840	60875	44710
Benefit: Cost ratio	4.66:1	8.74:1	8.80:1	4.42:1	3.71:1

Prabha were same as that of the local Manja Noorumuttan with 8-10 months. The variety Sree Jaya recorded the minimum duration of 6-7 months. Farmers received highest benefit: cost ratio (Table 2) from Sree Rekha variety (7.87:1) and the lowest from Manja Noorumuttan (3.60:1).

The improved varieties Sree Rekha, Sree Prabha, Sree Jaya and Sree Vijaya were evaluated in the lowland along with the local Ullichuvala. The variety Sree Rekha recorded the maximum height of 202 cm, followed by Sree Prabha (194 cm) and Sree Jaya (175 cm) whereas, the local Ullichuvala recorded least height of 155cm (Table 3). The weight of the tubers was more in the hybrids Sree Rekha and Sree Prabha with 4.2 kg per plant and 4.25 kg per plant, respectively, and the number of tubers was 11 tubers per plant and 12 tubers per plant, respectively, followed by Sree Jaya (11 tubers per plant) and Sree Vijaya (9 tubers per plant), which was at par with the local Ullichuvala having the tuber number as 9 per plant. The two top cross hybrids Sree Prabha and Sree Rekha performed well with a tuber yield of 52.5 t ha^{-1} and 51.9 t ha^{-1}, respectively, followed by Sree Jaya (28.6 t ha^{-1}) and Sree Vijaya (25.8 t ha^{-1}). The increase in the yield under lowland rainfed condition might be due to the availability of moisture throughout the crop period and the loose structure of the soil which might helped improvement in tuber growth. Another reason for the increased production of cassava was the adequate sunlight in the lowland without any shade. Due to these advantages cassava cultivation in lowland is picking momentum. In the lowland net return from Sree Prabha was the highest (Rs. 138840 per ha), followed by Sree Rekha (Rs.137770 per ha), Sree Jaya (Rs. 65140 per ha) and Sree Vijaya (Rs. 60875 per ha). The local variety Ullichuvala gave the least net return (Rs. 61210 per ha). Farmers received highest benefit: cost ratio (Table 4) from Sree Rekha variety (8.8:1) and the lowest from Manja Noorumuttan (3.71:1).

Thus the varieties Sree Vijaya and Sree Jaya owing to their short duration would fit well in lowland in a sequential cropping system following *kharif* rice.

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Farmers Participatory Evaluation of Amaranthus Varieties

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Amaranthus is an important leafy vegetable crop of Kerala. It is grown both as an intercrop and pure crop. A study was conducted with an objective of finding out the amaranthus variety best suited to the lands of Sothern Kerala. On-farm trials on three amaranthus varieties were tried as intercrop in banana in different localities of Chenkal village of Thiruvananthapuram district under Technology Assessment and Refinement through Institution Village Linkage Programme (TAR-IVLP) of Central Tuber Crops Research Institute (CTCRI) through farmers participation. The amaranthus varieties tried were Co-1, Arun and Co-5. The result indicated that the variety Co-5 was robust in growth and yield comparable to Arun and Co-1, but was less preferred in the market due to its green leafy nature. The variety Arun is highly preferred in the market due to its dark pink coloured leaves in contrast to Co-5 and Co-1 having dark green leaves. The variety Co-1 has shown low yield and less marketability when compared to other two varieties. While farmers give higher preference to Arun variety, it is observed that CO-5 is slowly gaining demand in the market.

(**Key words**:*Participatory evaluation, Screening of amaranthus varieties, Growth, Yield and Economics*)

Green leafy vegetables represent an excellent component of the habitual diet in the tropical countries making it richer in minerals, vitamins, proteins and also a good source of roughage. The per capita intake of leafy vegetables for a balanced diet is 80 g. Amaranthus constitutes single major group of leafy vegetables and its cultivation is widespread in Southern India. It is one of the cheapest leaf vegetables in our market and is often described as "poor mans' spinach". In nutritional perspective malnutrition is the single most problem for disability in rural people and hence thrust on growing leafy vegetables especially amaranthus assumes greater importance in present scenario.

Farmer's participation is crucial for agriculture and rural development and there should be the direct involvement of farmers at all the stages of the experiment right from the identification of the field problem to arriving at conclusions of the result, etc. So there is complete perfection, reliability and farmers approval (Devadas, 2001). Low net returns from amaranthus cultivation due to non-adoption of improved varieties had been identified as one of the problems of Southern Kerala. Generally farmers cultivate local varieties of the crop and the crop is having duration of 3 to 4 months and is susceptible to leaf spot diseases. Cultivation of improved and high yielding amaranthus varieties had been identified as a potential solution in this regard. Hence, a detailed study was carried out as on-farm trial with an objective of assessing the performance of different amaranthus varieties best suited to the village during the *kharif* season.

MATERIALS AND METHODS

The Technology Assessment and Refinement thorough Institution Village Linkage Programme (TAR-IVLP) is an innovative project initiated by the Indian Council of Agricultural Research (ICAR). It emphasizes the technology refinement through the farmers' participation to be facilitated by the multidisciplinary team of scientists. (Anantharaman, *et al.*, 2001). The study was conducted in Chenkal village of Thiruvananthapuram district as a part of Institution Village Linkage Programme (IVLP) implemented by Central Tuber Crops Research Institute (CTCRI), Trivandrum.

The climate of the village is humid tropical with fairly distributed rainfall of 1500mm during May to November, which accounts for 75% of total precipitation. January - April is the rain deficient summer months and only about 500mm of rainfall is received during this period. Clay loam soil of the site was acidic in reaction with a pH of 4.6-5.4. The fertility status of the soil is available N: 200-230 kg ha^{-1}; available P: 20-30 kg ha^{-1}; available K: 125-150 kg ha^{-1}; organic carbon: 0.62-0.85%. Banana is an important crop of lowland. The problem diagnosis done using information elicited through various PRA techniques revealed that the productivity and income from banana is low mainly due to the lack of cultivation of improved varieties and lack of proper utilization of interspaces of banana. In this circumstances on-farm testing and verification trial with farmers' participation enable the farmers to make an active contribution as decision makers in planning and executing an agricultural technology (CTCRI, 2000).

Three varieties of amaranthus were tested for assessing its performance as intercrop in banana in the adopted village. It includes Arun, Co-1 and Co-5 where leaves of Arun are purple and that of Co-1 and Co-5 are dark green in colour. Twenty selected farmers participated in conducting the experiment in 300 sq m of banana plot where each amaranthus variety was intercropped in 100 sq. m. of the land. The experiment was evaluated through farmer's participation by collecting data on the important morphological characters of amaranthus such as germination percentage, yield, number of pickings, leaf spot disease incidence, colour of the leaves, etc. Simple percentage analysis was used to analyze and interpret the collected data.

RESULTS AND DISCUSSION

The assessment of the performance of three amaranthus varieties indicated that the average yield was varying for different varieties. The maximum yield was recorded by Co-5 (37 t ha^{-1}) followed by Arun (21.5 t ha^{-1}) and Co-1 (18 t ha^{-1}) (Table 1). This indicates that the total yield from the Co-5 and Arun is high due to their compatibility with the village conditions.

Table 1. *Comparable biometerical observations of different amaranthus varieties*

	Arun	Co-1	Co-5
Germination percentage	Good (>80%)	Moderate 75%	Good (>90%)
Leaf spot incidence	Moderate	More	Low
Colour of leaves	Red	Green	Green
Yield (t ha^{-1})	21.25	18.0	37.0
Number of pickings	3	2	3-5

The germination percentage was observed more in Co-5 (>90%) followed by Arun (>80%). The germination percentage of Co-1 was only 75%. Incidence of leaf spot disease was low in Co-5 and moderate in Arun and was high in Co-1. It indicates that the variety Co-5 is comparatively tolerant to leaf spot. The incidence was less during the early phases of growth and little more during the later stages. But it was a serious problem for Arun. This might be one of the reasons for the reduction in yield in the case of Arun. The number of pickings was also comparatively higher in Co-5. It was also noted that there was no reduction in the yield of banana in all the cases.

Even though Co-5 was having the better yield potential, people of the village does not prefer green leaved amaranthus and hence it has got only less market value. People of South Kerala prefer to buy purple coloured amaranthus and the market value of such produce is higher. Due to less market value of Co-5 when compared to Arun the net return from CO-5 was less than that of Arun. Hence Arun had a higher B:C ratio (6.07:1) whereas, for Co-5 it was only 3.98:1 (Table 2). This is in accordance with the study conducted by Sunitha (1997) which concluded that farmers of Kerala prefer red coloured amaranthus to the green varieties.

Table 2. *Benefit-cost analysis for amaranthus varities*

	Arun	Co-1	Co-5
Cost of cultivation (Rs/ha)	5500	5750	5900
Gross returns (Rs/ha)	38000	12600	25900
Net returns (Rs/ha)	32500	6850	17600
Benefit : Cost ratio	6.07:1	2.1:1	3.98:1

Farmers were asked to compare the different varieties of amaranthus to find the best suited variety in the village conditions. The varieties were tested as intercrop in banana. The growth of Co-5 amaranthus was very fast and the plant itself was healthy with robust yield. The taste of this variety was also liked by the farmers. It was having more number of picking compared to other varieties. But its less preference in the market due to its green coloured leaves made the farmers reluctant to its cultivation. The farmers opined that even though the yield was low when compared to Co-5, Arun is the best variety owing to its purple coloured leaves and hence the better market value.

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Participatory Evaluation of the Performance of Ginger as Intercrop in Coconut Garden

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Coconut is the most important plantation crop of Kerala. Presently farmers get a net income of Rs. 17000 ha^{-1} from coconut as sole crop. Low income from coconut is mainly attributed to the lack of improved varieties, poor nutrient management, incidence of pest and diseases, lack of intercropping, etc. Intercropping is the most viable preposition to increase the net income from the coconut based farming system. There is a vast scope for effectively utilizing the interspaces of coconut so as to generate additional income. On-farm trials were conducted on intercropping coconut with four high yielding disease tolerant ginger varieties under upland rainfed condition during *kharif* season in the Chenkal village of Thiruvananthapuram district of Kerala under TAR-IVLP of CTCRI through farmers participation. The results indicated that average rhizome yield of the ginger was 15.4 t ha^{-1} and farmers could generate an additional net return of Rs. 88,950 ha^{-1}. In addition, it showed high marketability, high compatibility with the existing farming system in coconut garden, good quality rhizome, good taste, etc. It was further opined by farmers that ginger is highly profitable intercrop in coconut garden compared to other intercrops like banana, cassava, fodder grass, etc. Farmers accepted this intervention and the entire seed material has been reserved for planting during subsequent seasons. Now, farmers continue the practice of intercropping coconut with ginger in a sizeable area.

(***Key words**: Participatory evaluation, Intercropping of ginger with coconut, Yield, Economics*)

Coconut is one of the important commercial crops raised under lowland production system in South India. In Kerala during the year 2000-2001, coconut was cultivated in 9363,00 hectare of land. The production was 5496 million nuts and productivity was 5747 nuts ha^{-1}. Basically coconut is a small holders crop and 90% of the total area is under small holdeing with less than 0.2 ha. Under the present situation (where the price fluctuation is too high) growing coconut alone without any component crop/ animals cannot bring the farmer additional income for their satisfactory living. Thus coconut based cropping/farming systems involving cultivation of compatible crops in the interspaces of coconut and its integration with other enterprises like dairy, poultry etc. can lead to considerable increase in production and productivity per unit area, due to more efficient utilization of sunlight, soil, water and labour.

A spacing of 7.5 x 7.5 m in the square system is recommended for coconut (175 palms ha^{-1}). Coconut is usually raised in the adopted village giving a spacing of 5x5 m and at times cassava is grown in between coconut. But, there is vast scope for effectively utilizing the interspaces so as to generate additional income. Presently farmers get an income of Rs. 17000 ha^{-1} from coconut in a period of one year. To increase the income from coconut production system intercropping is a viable proposition. Experimental evidences have shown that a sole crop of coconut, at the recommended spacing of 7.5 x 7.5 m does not fully utilize the available resources like soil, air space and sunlight. The interspaces of coconut can be utilized profitably by growing suitable intercrops. Coconut palm of age between 8-25 years are not suitable for intercropping and palms with an age of more than 25 years are more suitable for intercropping since the light transmission increases with increase in age and it is ideal for raising annual and /or perennial crops (Krishnakumar, 1997).

Ginger (*Zingiber officinale*) is a herbaceous perennial plant of spice in the family Zingiberaceae, the rhizomes of which are used as the spice. India is the leading producer of ginger in the world. Kerala and Meghalaya are the major ginger growing States in the country. Ginger grows well in warm and humid climate and is cultivated from sea level to an altitude of 1500 m above the sea level. Ginger and turmeric are the important rhizomatous spices crop commonly intercropped in coconut gardens. Better performance and the partially shade conditions, assured market demand, early processing and long storage life are some of the factors that favour growing of this spice (Anantharaj *et al.*, 2003).

On-farm trial with farmers' participation enables the farmers to make an active contribution as decision makers in planning and executing an agricultural technology. The time lag between evolving a new technology and its final reach in actual farm level is reduced through participatory evaluation. It will speed up the transfer of technology since the farmers conduct the trials in the real farming situations by themselves in their own farms. By this we can save major quantum of time, human use, economic and infrastructure resources, etc. (Devadas, 2001).

MATERIALS AND METHODS

The Technology Assessment and Refinement thorough Institution Village Linkage (TARIVL) is an innovative project initiated by the Indian Council of Agricultural Research (ICAR). It emphasizes the technology refinement through the farmers' participation to be carried out by the multidisciplinary team of scientists. The study was conducted in Chenkal village of Thiruvananthapuram district as part of Institution Village Linkage Programme (IVLP) implemented by Central Tuber Crops Research Institute (CTCRI), Trivandrum. The team selected Chenkal village in Neyyattinkara taluk of Thiruvananthapuram district for the project keeping in view the guidelines stipulated. The agroecosystem analysis is the basic element of the project by which the problems are diagnosed and action plans are drawn to overcome the problems through technological intervention in various production systems. (Anantharaman *et. al.*, 2001).

The climate of the village is humid tropical with fairly distributed rainfall of 1500mm during May to November, which accounts for 75% of total precipitation. January - April is the rain deficient summer months and only about 500mm of rainfall is received during this period. Clay loam soil of the site was acidic in reaction with a pH of 4.6-5.4. The fertility status of the soil is available N: 200-230 kg ha^{-1}; available P: 20-30 kg ha^{-1}; available K: 125-150 kg ha^{-1}; organic carbon: 0.62-0.85%. The coconut is an important crop of lowland. The productivity of coconut is low mainly due to the lack of cultivation of improved varieties. The problem diagnosis was done using information elicited through various PRA techniques. Onfarm testing with farmers' participation enable the farmers to make an active contribution as decision makers in planning and executing an agricultural technology (CTCRI, 2002).

Four different varieties of ginger (Varada, ACC–117, ACC–35, and Himachal) were procured from IISR, Kozhikode and given to twenty-five farmers. Each farmer conducted the experiment in 400 sq m of coconut garden where 320 sq m (80x4) plot was intercropped with ginger varieties and the remaining 80 sq m without any intercrop. The experiment was evaluated through farmer's participation by collecting data on the important morphological characters of ginger such as weight of the planting materials used, plant population used, rhizome yield and incidence of soft rot disease. Simple percentage analysis was used to analyze and interpret the collected data.

RESULTS AND DISCUSSION

When coconut was intercropped with ginger the average rhizome yield of ginger was observed to be 166.75 g hill^{-1}. The yield per hill of ginger varieties Varada, ACC–117, ACC–35, and Himachal were 165g, 212g, 150g and 140g and yield per plot was 6.6kg, 8.5kg, 6kg and 6 kg, respectively (Table 1). Soft rot incidence was found to be absent in all these varieties under the partial shade of coconut. This indicates that the total yield from the crop combination is high due to the compatibility of ginger as intercrop in coconut gardens. This has also revealed that the ginger variety ACC-117 is more suited as the intercrop in coconut followed by Varada.

Table 1. *Biometrical observations in ginger*

Attributes	Varadha	ACC-117	ACC-3	Himachal
Yield per hill	165g	212g	150g	140g
Yield per plot (3mx1m)(kg)	6.6	8.5	6	6
Soft rot incidence	Nil	Nil	Nil	Nil

Average rhizome yield – 15.4 t ha^{-1} (166.75 g hill^{-1})

Table 2. *Economics of intercropping of ginger with coconut vis-à-vis sole cultivation of coconut*

Treatments	Coconut (sole crop)	Coconut + ginger		
		coconut	ginger	Total
Cost of cultivation (Rs./ha)	9,260	9,260	95,850	1,05,110
Gross returns (Rs./ha)	26,250	26,250	1,84,800	2,11,050
Net returns (Rs./ha)	16,990	16,990	8,89,50	1,05,940

The average rhizome yield was observed to be 15.4 t ha^{-1}. The plants in open condition were significantly inferior to those under shade in terms of rhizome yield. Hardy (1958) attributed the better performance of crops under shade to the presence of a threshold illumination intensity beyond which stomata of shade loving plants tends to use.

The net return from the cropping system also increased. By cultivating ginger as intercrop in coconut garden farmers get an additional net return of Rs. 88,950 per hectare (Table 2). This showed that ginger is a highly successful intercrop in coconut and it gives about 84% increase in net return from the farming system when compared to coconut as sole crop. These findings are in accordance with the findings of Sindhu (1996) where a study was conducted to find out the most profitable crop combinations with coconut. Ginger was observed to be most profitable followed by banana and cassava.

Farmers were asked to compare the different crop combinations between coconut and ginger and with other intercrops. When ginger was cultivated the farmers were highly satisfied about this crop combination as it was more profitable and compatible with the existing farming system. The crop has shown better resource use efficiency and better marketability as well. Quality and taste of the rhizomes were good and hence the farmers were able to get stable market price for their produce (Rs. 12-14 per kg of ginger). In case of low price of coconut due to the fluctuations in the market value, yield from ginger reduces the risk of coconut farmers. Farmers opined that ginger was the most profitable intercrop in coconut as compared to other intercrops like banana, cassava, fodder grass, etc.

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Proceedings

Proceedings of the Seventh National Seminar of Indian Society of Coastal Agricultural Research

on

Advances in Coastal Agriculture and Value Addition from National Perspectives

at

Central Plantation Crops Research Institute Kasaragod, Kerala, 21-24 January, 2004

The Seminar was inaugurated by Dr. S. Ayyappan, DDG (Fisheries), ICAR. Dr. J.S.P.Yadav, President, Indian Society of Coastal Agricultural Research presided over the Inaugural Session. The Key-note address was delivered by Dr. S.Edison, Director, Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala & AED Coastal Agro-ecosystem. Dr. S. Ayyappan, DDG, Fisheries (ICAR), Dr. S.K.Datta, Rice Biotechnologist, IRRI, Philippines and Dr. V. Rajagopal, Director, CPCRI, Kerala presented Special Invited Lectures. Dr. B. K. Bandyopadhyay, Joint Secretary, proposed formal vote of thanks for the Inaugural Session.

Following awards were conferred during the course of the seminar:

a) **Fellow of the Society :**

i) Dr. V. Rajagopal, Director, C.P.C.R.I., Kasaragod, Kerala

ii) Dr. Guru Raja Rao, Joint Director, C.S.S.R.I., RRS-Bharuch, Gujarat

b) **Dr. J. S. P. Yadav Best Paper Award (for the years 2000 and 2001) :**

The Award went to S. V. Sawardekar, S. S. Dhane,V. G. Sodaye and V. N. Deshpande for their paper entitled "Panvel-3, Promising Rice Variety for Coastal Saline Soils" appearing in Vol.18, No.2 at pages 155-160.

c) **Dr. H. S. Sen Best Poster Award :**

The Award went to the paper authored by R. S. Singhandhupe, Edna Antony and M. S. Behera of WTCER, Bhubaneswar, Orissa on "Effect of irrigation, fertilizers and mulches of fruit yield of drip irrigated pointed gourd (*Trichosanthes dioica.* Roxb.)

Five books/bulletins published by CPCRI, Kasaragod and one by Dr. K. R. Naskar, Principal Scientist, CICFRI, Salt Lake Campus were released during the Seminar.

In his presidential address Dr. J. S. P. Yadav made an overview of the research advancements and contributions made by the coastal agriculture in India vis-à-vis national demand and its future requirements. He felt that the holistic development of the coastal region can be achieved only through farming system approach to upgrade the productivity on sustainable basis through detailed characterization and optimal utilization of natural resources rather than aiming at the improvement of only a particular commodity. The participation of farmers in planning and implementation of programmes as well as maintenance of natural harmony were stressed.

Dr. S. Ayyappan in his inaugural address discussed at length the problems and prospects of the coastal ecosystem vis-à-vis national demand. He presented a crisp account of the up-to-date progress of research and future projection for each component under coastal ecology. According to him, a tremendous potentiality lies ahead to increase productivity for a number of commodities not only to meet the economic need of the inhabitants of the people in these areas, in the first instance, but also to meet the markets outside. Coastal aquaculture, especially the marine component, for example, is tremendously rich in terms of value addition and commercialization. Prospect for plantation, especially spices, aromatic and medicinal crops in the coastal ecosystem is very much under-exploited and needs due attention. Among the cereals rice is most dominant in the coastal ecosystem, although its productivity is far below optimal. According to him, appropriate blend of modern biotechnology and relevant breeding technologies will be useful to develop rice varieties suitable for biotic and abiotic stress situations, and the wild species naturally growing in the long stretch of coastal ecosystem may play a useful role in this respect. The animal husbandry sector deserves considerable attention in the coastal ecosystem for improvement in productivity, and some valuable indigenous species may be suitably utilized for this purpose. He also pointed out the need for shoreline stabilization with suitable tree species and conservation of the rich stock of mangroves to maintain and improve ecology of the area. He urged upon the scientists and all those engaged in the coastal ecosystem to be careful while implementation of the technologies that harmony with the nature is not disturbed.

Dr. S. Edison in his Key Note presented an overview of the research perspectives in agriculture in a systems mode. Relevance of this concept has been usefully applied under NATP in production system research (PSR) mode to address the problems related to coastal agro-ecosystem. He mentioned that PSR focuses on sustainability issues while responding to farmers needs, improved research, planning & management, and capacity building at the local level to monitor and address research priority setting, production and sustainability issues. The significant features are the involvement of farmers, inclusion of PRA and other rural diagnostic techniques, and on-farm and farmer-participatory evaluation of research outputs.

The Seminar was held under the following 8 technical sessions. Under each session there were 2-5 invited papers and the rest were voluntary contributions for oral presentation. Besides, there were 24 papers for poster presentation.

I Genesis, characterization and inventory of coastal soils including acid sulphate soils and its management

II Water management and drainage for coastal soils

III Management of plantation crops and its diversified uses alongwith home gardening

IV Crop management and value addition of alternate uses vis-à-vis weather adversities

V Advances in animal husbandry including dairy for improved economy

VI Recent advances in aquaculture and value addition

VII Forest plantation as wind breaks and for ecology and economic upliftment

VIII Technology transfer and changing socio-economic scenario for coastal agroecosystem

Following action points emerged out of the deliberations.

SOIL FERTILITY AND MANAGEMENT

Fertilizer recommendations

- For the coastal saline soils of Sundarbans long term fertility experiment suggests that regular application of N fertilizer is essential for higher yield of crops, while application of P @ 5.5 kg ha^{-1} for common rabi crops and 11 kg ha^{-1} for rice in kharif is necessary for maintaining P fertility status of the soil. Application of K can be omitted without affecting yield of crops and K fertility status of soil.

Integrated nutrient management & soil health

- For sustainable higher yields of crops integrated use of inorganic, organic and biofertilizers is to be stressed. FYM, city compost, press mud, azolla, etc. along with inorganic fertilizers have shown very encouraging results in terms of sustainable crop yields, soil physical conditions, soil nutrient availability, and microbiological activities in soil. Measurement of ninhydrin reactive nitrogen could be used as a useful and sensitive assay of microbial biomass carbon in coastal soils.

- The low cost vermicomposting technology standardized at CPCRI enabled bioconversion of lignocellulosic waste from coconut palms and other agricultural wastes into rich organic manure using local strain of epigeic earthworm belonging to the *Eudrilus* sp. and with the use of biopolymer degrading fungi. Further, for coconut plantation basin management with efficient N_2 fixing leguminous cover crops such as *Pueraria phaseoloides*, *Mimosa invisa* and *Calopogonium mucunoides* enabled generation of significant quantity of organic biomass and nitrogen at the site itself. For coconut alley cropping with *Glyricidia* and incorporation of nitrogen rich organic biomass was also recommended to maintain the fertility status in soil. For Lakshadweep Islands cultivation of sunnhemp itercropped with coconut was found to be good substitute for chemical fertilizer.

DRAINAGE AND WATER MANAGEMENT

Measures for controlled exploitation of groundwater & checking of seawater intrusion

- In Mangrol coast, Saurashtra estimation was made of the over-extraction of groundwater over the recharge by 300 % during drought years due to indiscriminate use of the water. This resulted in landward movement of seawater affecting the productivity adversely. Using rainfall-recharge relationship a method has been suggested under a IWMI-AKRSP collaborative project to reduce salinity level to an allowable limit with active participation of stakeholders.

Irrigation management options

- While discussing various irrigation options for coconut during summer (December– May) drip irrigation was recommended for seawater use in coarse textured soils and thereby increase profitability of the produce.
- There is also a good scope for use of paper mill effluent water from industries and city sewerage system for irrigation in the coastal area after initial treatments.
- Improvised *Doruvu* technology for irrigation by skimming of water at shallow depths, floating over saline water, should be utilized suitably particularly for sandy loam soils.

Landshaping for lowlying waterlogged soils for multiple crop cafeteria

- For a lowlying flat saucer shaped topography having problems of waterlogging in Mahanadi delta conventional drainage should be integrated with suitable land modification to create raised bed system-cum-pond in the ratio of 1:2.7. The smaller of the two pond system so created for pisciculture was provided with a scaffold to make additional 15 % space for creeper vegetables, and the combination gave 40 % more benefit than the adjoining lowland.

Model for prediction of watertable fluctuation and waterlogging

- In coastal areas there is scope for development of groundwater resources for irrigation. Model like MODFLOW has been successfully applied to predict water table fluctuations, potential and critical waterlogged areas, etc.

Radioisotope use for water management studies

- It was suggested by the Centre for Water Resource Development and Management, Kerala to use isotope tracer technique for precise estimation of groundwater recharge, salinity and pollution problems, interconnection between different water resources, dating of groundwater, seepage losses and extent and nature of sedimentation in rivers and lakes, etc.

PLANTATION AND HOMESTEAD GARDENING

Homestead garden models

- Different models for homestead gardening suited to market economy of the produce have been suggested by CPCRI. It has been suggested that cultivation of different crops in multispecies cropping pattern model, consisting of different canopy stratification, help to reduce soil temperature thereby reducing evaporative losses of water and maintain humidity of the system.

Diversified uses & intercropping of coconut

- It has been suggested that the coconut based economy may see a revival from the negative impact of liberalized policy when the use of coconut is based not only on oil in view of various other options for diversified uses shown by other coconut growing countries. Both edible and non-edible products may be explored for this purpose and various options have been suggested.
- Ginger cv. Varada was identified as profitable intercrop for coconut plantations at Chenkal.

Mushroom from coconut waste

- For Lakshadweep Islands mushroom cultivation with coconut waste material has been found to be have good market potentiality.

Value added products from by-product waste of cashew nut industry

- Cashew apple, a by-product of cashew nut industry, which otherwise goes waste for the want of proper post-harvest technology, may be used for value added products like beverages, syrup and jam.

Value added product from crude oil palm extract

- Crude palm oil contains pigments mainly carotenoids out of which â-carotene constitutes the major part. Methods were standardized at NRC Oil Palm, Pedavegi, A.P. for the extraction of carotenoids by saponification and absorption method. By saponification complete extraction could be made and the process might be useful for soap industry.

Value addition of tuber crops & spices

- In case of tuber crops value addition is possible on account of pharmaceutical uses through a judicious synchronization of indigenous technical knowledge on wild species and improved research methodologies developed at CTCRI, Kerala. Value added products from spices have also been identified.

Use of biocontrol agent for pest control in coconut

- Use of biocontrol agent through the introduction of microbial pathogen, *Oryctes* virus (earlier *Baculovirus oryctes*) for suppression of rhinoceros beetle, *Oryctes rhinoceros*, one of the major pests of the coconut palm, was studied at the Minicoy and Androth Islands of Lakshadweep. This could significantly bring down the population of beetle and increase virus incidence in pest. The virus was found to have a long term suppression effect on the pest. After 15 years, an augmentative release of the virus was warranted.

FORESTRY & ECOLOGY

Use of improved technology for mangrove health & growth

- The growth of mangrove, their aerial extent, growth and decay, their ecology, interactions between biological and non-biological factors, etc. can be studied and monitored by using the remote sensing technique. The spectral reflectance of mangrove species is useful to assess the plant health and local environment. Advances in the areas of biotechnology and tissue culture offer unique opportunity for generation of large scale planning material. Further, with the application of molecular tools it is possible to monitor the genotypic changes and ensure true clonal propagation of the desired material.

Use of tree as wind break and value added products

- Forest is an important component of coastal ecosystem; it acts as wind break and provide protection against soil erosion. Species such as *Casuarina equisetifolia, Anacardium occidentale, Acacia mangium, Acacia auriculiformis, Leucocephala* and *Thespesia populnea* are some of the preferred species as coastal wind breaks. Areas under mangroves along the coast should be extended for direct and indirect promotion of several value added products like honey, fish, shrimp, prawn, crab, sea foods, besides wood and a large number of other commercial products. Mangroves give stabilization to newly developed landmass and provide ecological security to the coastal region.

CROP MANAGEMENT

Rice biotechnology for abiotic stress tolerance suitable to coastal ecosystem

- Dr. S.K. Datta of IRRI, in his Special Invited Lecture, presented a few important strategies in use for a better understanding of water stress tolerance in rice and develop transgenic rice to survive critical period of water stress, which include: (1) 'Switching on' of transcription factor regulating the expression of several genes related to abiotic stress, (2) Use of suitable root-specific promoter driving the target gene for an efficient and directed expression in roots and modification of roots, (3) Understanding of phenotyping and GXE in a given environment, (4) Selection of a few adaptive rice cultivars suitable to drought/ salinity prone areas, (5) Microarray, proteomics, QTL and MAS may expedite the cloning and characterize the stress induced genes, and (6) Efficient transformation system for generating for generating a large number of transgenic rice of different background to eventually help in selection of desirable phenotype with adequate OA. He further mentioned that IRRI has developed transgenic rice lines with a number of transcription factor genes (DREB) driven by stress inducible promoters.

High yielding rice varieties for saline and flood prone areas

- CSRC(S) 5-2-2-5 was developed through recombinant breeding programme and found suitable to saline shallow waterlogging soils producing yield upto 4.54 t ha^{-1}, having resistance to common pests and diseases, and with good cooking quality grains. For coastal cyclone hit areas in Puri (Orissa) rice varieties like Gayatri, SR 26-B, Lunishree and Sonamani were found suitable in wet season with yield level of 3.0 to 4.5 t ha^{-1}, while in dry season varieties like CSR-4, Canning 7, Annapurna and Khandagiri were suitable with yield level of 3.0 to 3.5 t ha^{-1}. Other successful rice varieties suitable for specific areas include Uma at Chenkal, Trivandrum, Kanchana and Aishwarya at Mele Pattambi, Trichur, BTS 24 at Andaman, Trichy 1 and Trichy 2 at Kattur, Tamil Nadu.

Medicinal & aromatic plants for value addition

- Coastal ecosystem in India has a rich natural biodiversity of medicinal and aromatic plants. If the required logistic supports are provided it holds tremendous promise, a list of which has been prepared, for a global herbal market and aroma trade.

AQUACULTURE & ANIMAL HUSBANDRY

Value added technologies in fishery

- It has been suggested to tailor aquaculture product for higher value addition, say in semi-intensive system by modifying the fatty acid composition of fish (and hence its dietary value as human food) through minor manipulation in the feed mixtures. Recent data have also shown that a small addition of an oil mixture to a common feed composition can even increase the reproductive performance and improve the quality of juveniles of Indian major carp. Value added products from low-cost fishes have been identified.
- Other value added technologies include low-cost immunostimulants for shrimp, monoculture of juvenile crabs, and rack drying of fishes. Other identified opportunities for value addition are cage culture and trade of live fish, Fattening and trade of live crab and lobster, depuration and trade of live mussels, clams and oysters, value addition of fin fish, dry, smoked and salted fish, etc. for local market. Ornamental fish breeding holds high promise in coastal ecosystem.

Mariculture for value addition

- Locally relevant specific mariculture technology is to be disseminated for enhancing the income level of farmers and fishermen along the coast. There is a good prospect for value addition in this sector. The window pane oyster *Placuna placenta* produces seed pearls which are porcelaneous and translucent. These have medicinal value and also used as jewelry. The natural beds of window bed oyster, locally known as 'chandra' are available in Raigad district. These are exploited by fishermen and after removal of pearl the shells are sold to private firms for production of lime and calcium powder.

Integrated farming and polyculture in fishery for high income generation

- Integrated farming practice with fish, prawn, poultry, milch cattle, vegetables, flower and fruit was shown as profitable and sustainable in a waterlogged area in Orissa. Stress should be given for protecting the local breeds of poultry birds and animals, etc. for propagating them through suitable selective breeding programmes for better adaptability and yield. The organic system of duck rearing in paddy fields, as followed in lowlying Kuttanad area in Kerala is useful for biocontrol of weeds, insect pests, and the exotic herbivorous snails. This practice needs to be popularized for high income generation.
- Paddy-cum-fish culture as such was found to be remunerative in farmers fields in Sundarbans as compared to paddy alone in lowlying fields. Polyculture in fishery with Catla:Rohu:Mrigal in the ratio of 4:3:3 in ponds resulted in much higher return with B:C = 15.76 as compared to 8.57 under monoculture under farmers condition.

TECHNOLOGY TRANSFER FOR SOCIAL UPLIFTMENT

- It has been revealed that the coastal ecosystem is having multiple regimes of production systems and is supported by large number of technological options. An efficient mode of transfer of the technologies among the highly heterogeneous clientele should essentially be participatory. Before introducing any technology in an area due considerations are to be given to the socio-economic status of farming community, demand in the market and quality requirement, scope for value addition, employment generation, diversification and environmental protection, etc. with long term vision.

The Plenary session was chaired by Dr. J. S. P. Yadav, President, Indian Society of Coastal Agricultural Research. Dr. H. S. Sen, Hony. Secretary, ISCAR proposed vote of thanks. The seminar ended with thanks to the chair.

LIST OF PARTICIPANTS

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1.	J. S. P.Yadav	President, ISCAR
2.	S. Ayyappan	DDG (Fisheries), ICAR
3.	S. B. Kadrekar	Vice President, ISCAR, Ratnagiri
4.	A. K. Bandyopadhya	Vice President, ISCAR, Calcutta
5.	H. S. Sen	Hon. Secretary, ISCAR, Barrackpore
6.	B. K. Bandyopadhyay	Jt. Secretary, ISCAR, Canning Town
7.	S. K. Dutt	Treasurer, ISCAR, Canning Town
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9.	K. V. A. Bavappa	CPCRI, Kerala
10.	V. S. Korikanthimath	ICAR Res. Complex, Goa
11.	S. Edison	CTCRI, Trivandrum
12.	A. K. Singh	WTC, New Delhi
13.	Swapan Datta	IRRI, Phillipines
14.	S. Maiti	NRC for MAP, Anand
15.	Mohan Modayil Joseph	CMFRI, Cochin
16.	P. K. Mandal	NRCOP, Pedavegi
17.	R. A. Raju	Agril. Research Station, Maruteru
18.	B. L. Manjunath	ICAR Res. Complex for Goa, Goa
19.	V. N. Varma	Pondicherry
20.	P. R. K. Prasad	Pondicherry
21.	Y. Murali Dharudu	Hyderabad
22.	M. Jayanthi	CIBA, Chennai
23.	R. Singaravel	Annamalai University
24.	P. George Joseph	CTCRI, Trivandrum
25.	K. P. Santhosh Kumar	CTCRI, Trivandrum
26.	M. Anantharaman	CTCRI, Trivandrum
27.	C. S. Ravindran	CTCRI, Trivandrum
28.	M. Jayanthi	CTCRI, Trivandrum
29.	James George	CTCRI, Trivandrum
30.	R. C. Pandalai	KFRI, Peechi, Kerala
31.	P. Ravi Kumar	Spices Board, Kalpetta
32.	T. N. Rathinam	Spices Board, Calicut
33.	Renji Thomas	Indian Potash
34.	Raneesh P. Thomas	Indian Potash
35.	K. Vasu	CWRDM, Calicut
36.	C. Muthiah	CMFRI, Mangalore
37.	P. K. Krishna Kumar	CMFRI Centre, Mangalore
38.	P. U. Zacharia	CMFRI Centre, Mangalore
39.	Prathibha Rohit	CMFRI Centre, Mangalore
40.	A. P. Dinesh Babu	CMFRI Centre, Mangalore
41.	Geetha Sasikumar	CMFRI Centre, Mangalore
42.	P. K. Asokan	CMFRI, Calicut
43.	K. K. Philipose	CMFRI, Calicut
44.	S. Janardhanan Pillai	College of Agriculture, Vellayani
45.	Raghavan	KAU, Mannuthy
46.	O. N. Resmy	College of Horticulture, Vellanikkara
47.	A. S. Vidya	College of Horticulture, KAU, Thrissur
48.	Filitte Stephen	College of Horticulture, Vellanikkara, Thrisur
49.	P. A. Peethambaran	College of Vet. & An. Sciences, Mannuthy
50.	T. P. Devarajan	Regional Manager, Southern Phosphate
51.	R. B. Singandhupe	WTCER, Bhubneswar
52.	S. Roy Choudhury	WTCER, Bhubaneswar
53.	R. R. Sethi	WTCER, Bhubaneswar
54.	P. Nanda	WTCER, Bhubaneswar
55	R. K. Mohanty	WTCER, Bhubaneswar
56.	S. K. Jena	WTCER, Bhubaneswar

Sl. No.	Name	Institute/Designation
57.	Nihar Ranjan Sahoo	OUA&T, Bhubneswar, Orissa
58.	M. P. S. Arya	NRC for women in Agril., Bhubaneswar
59.	P. Sen	CRRI, Cuttack
60.	Sanjoy Saha	CRRI, Cuttack
61.	B. Maji	IISS, Bhopal
62.	R. H. Wanjari	IISS, Bhopal
63.	I. K. Girdhar	NRC for Groundnut, Junagadh
64.	K. B. Polara	Gujarat Agril. University, Junagadh
65.	J. V. Polara	Gujarat Agril. Univ., Junagadh
66.	N. B. Babaria	Gujarat Agril. University, Junagadh
67.	N. K. Timbadia	Gujarat Agril. University, Junagadh
68.	Jayesh Talati	IWMI-Tata water Policy Programme, Vidyanagar
69.	G. Gururaja Rao	CSSRI Regional Res. Station, Bharuch
70.	S. S. Dhane	KRS, RARS, Maharashtra
71.	Shashikant J. Meshram	KRS, RARS, Maharashtra
72.	Prakash E. Shingare	KRS, RARS, Maharashtra
73.	S. V. Sawardekar	KRS, RARS, Maharashtra
74.	Shamrao Laxman Powar	KRS, RARS, Maharashtra
75.	T. Ram	DRR, Hyderabad
76.	I. V. Subba Rao	DRR, Hyderabad
77.	P. Kumara vadivelu	Multiplex Biotech Pvt. Ltd., Bangalore
78.	C. R. Biswas	CRIJAF, Barrackpore
79.	S. K. Jha	CRIJAF, Barrackpore
80.	Kumudranjan Naskar	CICFRI, Calcutta
81.	Saikat Naskar	CICFRI, Calcutta
82.	P. K. Mukhopadhyay	CIFA, Kolkata
83.	A. K. Singh	PDCSR, Meerut
84.	N. D. Shukla	PDCSR, Meerut
85.	B. Gangwar	PDCSR, Meerut
86.	R. K. Sahu	Indira Gandhi Agril. University, Raipur
87.	Gautam Kumar Das	Calcutta
88.	R. D. Iyer	CPCRI, Kasaragod
89.	S. Arul raj	CPCRI, Kasaragod
90.	George V.Thomas	CPCRI, Kasaragod
91.	P. M. Kumaran	CPCRI, Kasaragod
92.	Rohini Iyer	CPCRI, Kasaragod
93.	K. V. Kasturi Bai	CPCRI, Kasaragod
94.	K. N. Ponnamma	CPCRI, Kasaragod
95.	R. Dhanapal	CPCRI, Kasaragod
96.	V. Krishna Kumar	CPCRI, Kasaragod
97.	Anitha Karun	CPCRI, Kasaragod
98.	C. V. Sairam	CPCRI, Kasaragod
99.	C. Palaniswamy	CPCRI, Kasaragod
100.	A. C. Mathew	CPCRI, Kasaragod
101.	C. Thamban	CPCRI, Kasaragod
102.	P. Subramaniam	CPCRI, Kasaragod
103.	P. M. Jacob	CPCRI, Kasaragod
104.	K. Madhavan	CPCRI, Kasaragod
105.	Vijaya Kumar	CPCRI, Kasaragod
106.	S. J. D. Bosco	CPCRI, Kasaragod
107.	K. N. Induraj	CPCRI, Kasaragod
108.	K. Muralidharan	CPCRI, Kasaragod
109.	Alka Gupta	CPCRI, Kasaragod
110.	A. R. Bal	CSSRI, RRS, Canning Town
111.	A. B. Mandal	CSSRI, RRS, Canning Town
112.	D. Burman	CSSRI, RRS, Canning Town
113.	K. K. Mahanta	CSSRI, RRS, Canning Town
114.	S. Tripathi	CSSRI, RRS, Canning Town
115.	P. K. Chandrasekharan Pillai	Kerala

Tel : 03218-255085, 255241 *Fax : 03218-255084* *e-mail : iscar@rediffmail.com*

INDIAN SOCIETY OF COASTAL AGRICULTURAL RESEARCH

CENTRAL SOIL SALINITY RESEARCH INSTITUTE, REGIONAL RESEARCH STATION

P.O. Canning Town (743329), South 24 Parganas, West Bengal (India)

MEMBERSHIP APPLICATION FORM

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CSSRI, Regional Research Station,
P.O. Canning Town, South 24 Parganas, West Bengal (India)

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2. **Dr. S. B. Kadrekar**
3. **Dr. A. K. Bandyopadhyay**
4. **Dr. M. Rai**
5. **Dr. I. C. Mahapatra**
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10. **Dr. N. K. Tyagi**
11. **Dr. B. K. Bandyopadhyay**
12. **Dr. V. Rajagopal**
13. **Dr. G. Gururaja Rao**
14. **Dr. B. Gangwar**

ANNOUNCEMENT

This is to invite nominations for the award of **'Fellow of Indian Society of Coastal Agricultural Research'** for the year 2005-06. Two scientists will be awarded the **Fellow** of the society from among the nominations received.

The nominated scientist should either be a life member of the society or annual member for the last 10 years. Nominations must be proposed and seconded by a member of the society. Nominations must reach the office of the society latest by **30-09-2005**. All nominations in the prescribed proforma (enclosed) must be accompanied by a bio-data of the nominated member and also a brief outline of his/her contributions to the development of agriculture in the coastal areas.

As per existing rules, nominations received within the due date will be scrutinized by a selection committee headed by the President of the society and the award will be conferred on the selected member at the 8th. National Seminar of the society to be held at CTCRI, Thiruvananthapuram, Kerala from 21-24 December, 2005.

Hony. Secretary
ISCAR

NOMINATION FOR THE AWARD OF "FELLOW" FOR 2005-06

To:
The Hony. Secretary, I.S.C.A.R.
CSSRI, RRS-Canning
P.O: Canning Town-743329,
Dist: South 24-Parganas, WEST BENGAL

Sub : Nomination for fellow of ISCAR for 2005-06

Dear Sir,

I do hereby nominate

Dr./Shri ....

Designation ....

Membership No: ....

for the award of 'Fellow' of Indian Society of Coastal Agril. Research for 2005-06

Proposed by :

Dr./Shri ....

Designation ....

Address ....

....

.... (Signature of Proposer)

....

Membership No: ....

Seconded by :

Dr./Shri ....

Designation ....

Address ....

....

.... (Signature of Seconder)

....

Membership No: ....

I do hereby agree to the above proposal.

(Signature of nominee)

N.B: All proposals must be accompanied by the bio-data of the nominee and his/her contributions to the development of agriculture in the coastal areas.

ANNOUNCEMENT

8th NATIONAL SEMINAR
on
Strategies for Improved Farming and Ecological Security of Coastal Region

Venue: Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala

Date: December 21-24, 2005

Organised by

INDIAN SOCIETY OF COASTAL AGRICULTURAL RESEARCH

in collaboration with

INDIAN SOCIETY FOR ROOT CROPS
CENTRAL TUBER CROPS RESEACH INSTITUTE
CENTRAL RESEARCH INSTITUTE OF JUTE AND ALLIED FIBRES

The details of the National Seminar will be published and circulated shortly.

For further details please contact :

Dr. B.K. Bandyopadhyay
Hony. Jt. Secretary (ISCAR)
Central Soil Salinity Research Institute, Regional Research Station,
Canning Town, South 24- Parganas,
West Bengal, Pin-743329
Tel: 03218-255241/255085 Fax: 03218-255084
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