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CONTENTS

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Acknowledgement

The Indian Society of Coastal Agricultural Research (ISCAR) is grateful to the Indian Council of Agricultural Research (ICAR), New Delhi for recognizing 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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Invited Paper

Designing Rice Varieties Adapted to Coastal Areas of South and Southeast Asia

ABDELBAGI M. ISMAIL, MICHAEL J. THOMSON, R. K. SINGH, GLENN B. GREGORIO and DAVID J. MACKILL

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Coastal ecosystem is characterized by wide variation in soil types, water and land uses, and is extremely dynamic with apparent long term and seasonal changes. These areas are highly fragile because of the numerous natural hazards and human interventions, yet they hold enormous potential for food production. In South and Southeast Asia, these areas still remain under-exploited while mostly overpopulated by impoverished communities. Most soils are affected by salinity and other abiotic stresses, such as acidity, high organic matter and nutritional problems. Currently, about 27 million ha are affected by salt stress, of which 3.1 million ha are in India, and majority of which are not in use despite their suitability for rice. Beside soil problems, excess water during monsoon season causes long term partial or even complete short term submergence, with consequent drastic reduction in productivity. We aim to develop resilient varieties combining tolerances to major abiotic stresses in coastal areas through effective breeding tools that can help dissect and incorporate tolerances into modern varieties and breeding lines. We will summarize our progress with breeding for salinity and submergence tolerance.

Tolerance of both stresses is complex and involves numerous physiological mechanisms. We attempt to identify and fine-map quantitative trait loci (QTLs) associated with tolerance and combine them in suitable genetic backgrounds. For salinity, a mapping population between IR29 (sensitive) and Pokkali (tolerant) was used to map several tolerance QTLs, including *Saltol*, a major QTL on chromosome 1. We are developing a precision marker assisted backcrossing system to efficiently transfer these QTLs into popular varieties. For submergence; *Sub1A*, the gene underlying the *Sub1* QTL that confers high level of submergence tolerance, was identified from the Indian cultivar FR13A. We developed an efficient maker assisted backcrossing system and incorporated this gene into six popular rice varieties. The lines with *Sub1* gave 2-3 times the yield of the sensitive parent under submergence. Preliminary testing in farmers' fields has confirmed that *Sub1* varieties can provide protection against short term flooding. *Sub1A* has a large effect that is independent of genetic background and has no negative effects on yield or other economic traits. We aim to combine *Sub1A* with tolerance to longer duration partial flooding common in coastal areas, as well as with tolerance to salt stress to develop more resilient varieties that can ensure higher and stable food production.

***(Key words:** Designing rice varieties, Salt tolerance, Flood & submergence tolerance, Drought tolerance)*

Coastal zones represent the interface of land and fresh water with the ocean and saline seawater. These zones are characterized by a wide variation in soil types, water and land uses, and are extremely dynamic with apparent long term and seasonal changes. Moreover, these areas are highly fragile because of the frequent natural hazards such as typhoons, floods and tidal activities, as well as numerous human interferences. However, these areas still hold enormous potential for food production and industrial uses via eventual integration of agriculture and aquaculture as well as mangroves and marine products. In South and Southeast Asia, most coastal areas still remain under-exploited while largely overpopulated by impoverished communities. The predominant rice farming in these areas is hindered by various environmental perturbations such as adverse soils, poor quality water, excess water and drought, all of which vary in occurrence and severity based on the season. The dynamic nature of these stresses coupled with the scarcity of resources makes it difficult to counter them through long term solutions involving infrastructural changes and soil amendments. Rice is the dominant crop in these areas because of its ability to thrive under excess water, particularly during the monsoon season. Yet, its productivity is still very low, because of the lack of high yielding varieties that could tolerate the prevailing high salt and water stresses. In this paper we will discuss our strategy and progress in developing modern rice varieties with better adaptation to coastal areas.

Problem soils in coastal areas

Most of the soils in humid and subhumid coastal climates of South and Southeast Asia are affected by salinity and other associated abiotic stresses, such as acidity (acid sulfates), high organic mater (peat soils) and nutritional problems, which render them less productive (Ismail *et al.*, 2007). Salinity in these areas is commonly caused by marine influence including periodic floods with tidal saline water. Secondary salinization can also take place in coastal areas where poor quality water is used for irrigation during the dry season, together with poor drainage in most cases. Currently about 27 million ha were reported to be affected to some extent by salt stress in coastal South and Southeast Asia (Ponnamperuma and Bandyopadhya, 1980), of which, about 3.1 m ha are in India, 2.8 m ha in Bangladesh, and 2.1 m ha in Vietnam. The majority of these areas are not currently in use for agriculture despite being potentially suited for rice. Salinity in these areas varies with the season, being very high in the dry season with the peak before the onset of rains. Salinity level in soil and water then decreases progressively during the monsoon season and reaches the ground level usually between June to September. This dynamic nature of salinity makes it difficult to handle through management options involving long term soil reclamation.

Rice is one of the few crops that can grow on most of the coastal saline soils despite being sensitive to salt stress (Maas and Hoffman, 1977), because it thrives in standing water that can help leach salts from top soils. The vast genetic variability in tolerance to salinity in rice (Akbar *et al.*, 1972, Flowers and Yeo, 1981) makes it suitable for further improvement through breeding. Rice is relatively more sensitive to salt stress during early seedling stage and reproduction (Akbar *et al.*, 1972). It is necessary to combine tolerances at both stages to develop more resilient cultivars for both dry and wet seasons despite the weak association between tolerances at these two stages (Moradi *et al.*, 2003). Tolerance to salinity in rice is complex and involves a plethora of physiological and molecular mechanisms (Moradi *et al.*, 2003, Moradi and Ismail, 2007, Ismail *et al.*, 2007). An interesting feature in rice is that most salt tolerant genotypes are superior in only one or few of these traits, suggesting greater potential for further improvements if superior alleles for all useful mechanisms were combined (Ismail *et al.*, 2007). Our aim is to adequately understand the genetic bases of these traits to help formulate an effective breeding strategy to design tolerant varieties broadly adapted to local conditions.

Developing salt tolerant rice varieties

Traditional salt tolerant rice landraces such as Pokkali and Nona Bokra, have been used in conventional breeding programmes to develop high yielding salt tolerant cultivars. The tolerance of the breeding lines, however, is not as high as that of the traditional donors, reflecting the difficulty in obtaining high tolerance while avoiding the negative characteristics of the donor landraces (Gregorio *et al.*, 2002). This complexity, together with the multiple traits involved and the diversity of target environments slowed progress in development and adoption of new varieties. We propose a breeding strategy to select separately for individual component traits and then combine them in a single variety to achieve higher levels of tolerance. This approach is recently becoming more feasible through the application of QTL mapping to genetically dissect tolerance into discrete QTLs for different physiological traits, and then pyramid them through marker assisted selection (MAS) for multiple tolerances. For this purpose, a recombinant inbred line (RIL) population between the tolerant landrace Pokkali and sensitive IR29 identified several QTLs of reasonable effects, few of them map to regions containing candidate genes for salinity tolerance (Bonilla *et al.*, 2002, Ismail *et al.*, 2007). One of these QTLs on chromosome 1, designated *Saltol*, explains 43% of the variation for seedling Na^+ uptake (Fig. 1). Current efforts at IRRI include targeting these QTLs for fine mapping, candidate gene analysis, and development of a marker assisted backcrossing system to combine them in suitable genetic backgrounds. The *Saltol* locus was mapped to a 1.2 Mb interval and is currently being introgressed into several popular rice varieties adapted to coastal areas, using marker aided selection. Longer term strategies will work towards fine mapping additional QTLs and cloning tolerance genes for pyramiding multiple tolerances for salinity and other prevailing abiotic stresses for wider adaptation.

Excess water stress in coastal areas

Coastal areas in the humid tropics are characterized by heavy rainfall during the monsoon

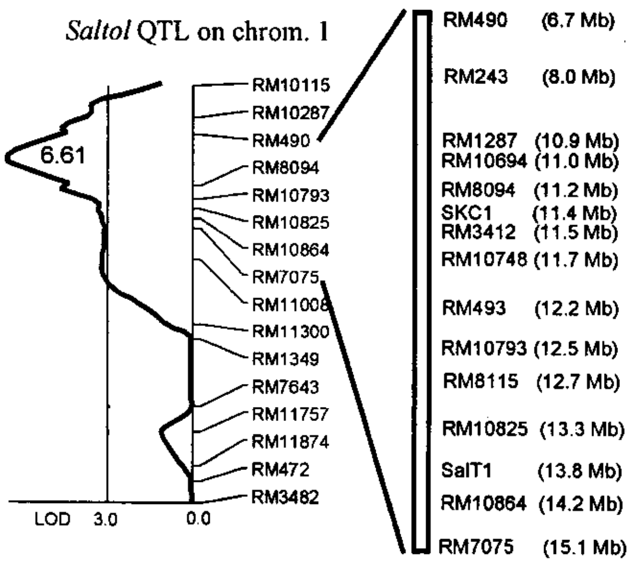

Fig. 1. *Saltol* QTL for salinity tolerance on chromosome 1, showing the QTL interval plot for the ratio of Na/K concentration (R^2 = 0.26 to 0.43), and the fine-map region with the physical map positions in mega-base pairs.

season from June to September. These heavy rains, together with the poor or non-existing drainage create serious waterlogging conditions, and sometimes complete submergence. Prolonged waterlogging, where water stagnates for up to 50 cm for most of the season, currently affects about 3 million ha in coastal India and more than 1 million ha in coastal Bangladesh. Modern rice varieties are not adapted to this partial flooding and their yield is severely reduced because of lower tillering, reduced panicle size, and high sterility. This is probably the major reason why modern rice varieties are not widely adopted in these areas and farmers still grow their local low yielding landraces. Breeding and management options for improving productivity in these areas must, therefore, consider long term water stagnation. Our current efforts involve large scale screening of varieties and landraces to identify sources of tolerance of these conditions and to use them for breeding and for further genetic studies.

Complete inundation or submergence can also be experienced in coastal areas in periods of heavy rain or when flooding occurs through overflowing rivers as in most coastal deltas. Short term submergence (for 1 to 2 weeks) can occur at any time during the season, and even more than once, with consequent severe yield losses, estimated to be over $650 millions annually in Asia. Tolerant landraces, such as the Indian cultivar FR13A, were identified before and have been extensively used to study the mechanisms of tolerance and for genetic studies. The adverse effects of flooding constitute complex responses that vary with genotype, carbohydrate status before and after submergence, developmental stage when flooding occurs, duration and severity of flooding, and temperature and degree of turbidity of floodwater (Jackson and Ram, 2003, Das *et al.*, 2005). Both elongation growth and reduction in concurrent carbon fixation during submergence can result in depletion of carbohydrate reserves with a consequent reduction in plant survival (Ella *et al.*, 2003, Sarkar *et al.*, 2006).

Development of varieties adapted to flood prone coastal areas

Breeding to improve rice productivity in flood prone areas has been ongoing for the last two decades but with limited progress. However, the recent identification and cloning of *Sub1*, the major QTL for submergence tolerance, substantially accelerated these efforts. *Sub1* was identified on chromosome 9 from FR13A (Fig. 2), and was recently cloned, and *Sub1A*, an ethylene responsive like factor (ERF), was identified as the gene underlying this QTL (Mackill *et al.*, 1993, Xu and Mackill, 1996, Xu *et al.*, 2006). *Sub1A* confers a high level of submergence tolerance. An efficient maker assisted backcrossing system was developed and used to incorporate this gene into popular rice varieties (Neeraja *et al.*, 2007, Septiningsih *et al.*, 2008) and the lines with *Sub1A* gave 2-3 times the yields of the sensitive parent under submergence for a period

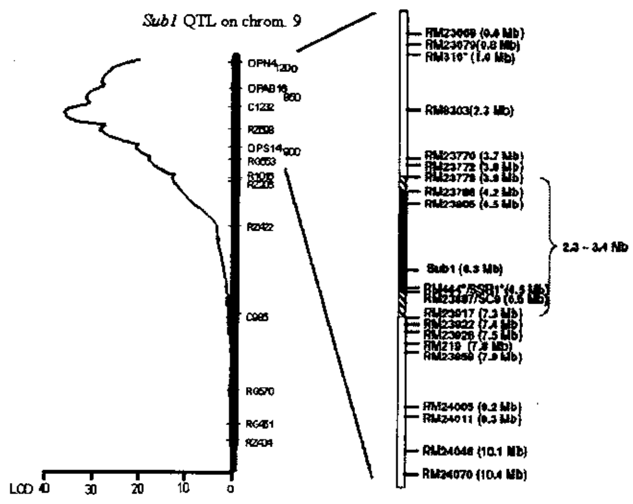

Fig. 2. *Sub1* QTL for submergence tolerance on chromosome 9, showing the original QTL interval plot for tolerance (R^2 = 0.70), and the position of the cloned *Sub1* gene at 6.3 Mb. To the right is the size of the *Sub1* introgression in the Swarna-*Sub1* line (Neeraja *et al.*, 2007).

of 12-17 days (advantage of 1-2 tons ha^{-1}). This gene was successfully incorporated into six popular rice varieties and preliminary testing of these introgression lines in farmers' fields has confirmed that *Sub1* varieties can provide protection against short term flooding. *Sub1A* has a large effect that is independent of genetic background and has no negative effects on yield or other economic traits. Varieties with the *Sub1A* gene have the same yield and other agronomic and quality characteristics as the original variety, and they can be used to replace these varieties in flood prone areas. Seeds of these newly developed varieties are being multiplied for large scale dissemination in flood prone areas that are experiencing flash flooding.

Designing varieties suitable for coastal zones

The multifaceted abiotic stresses in coastal areas (high salinity and other soil problems, submergence, stagnant flooding, and drought) mean that most areas are monocropped with rice during the monsoon season. Local rice varieties have some level of tolerance of these conditions, including water stagnation, but their productivity is very low. During rest of the year, the area remains fallow due to high soil and water salinity and lack of good quality irrigation water. We aim to combine *Sub1A* with tolerance to longer duration partial flooding common in coastal areas, as well as with tolerance to salt stress conferred by *Saltol*. Our long term goal is to develop resilient varieties combining tolerances to major abiotic stresses prevailing in coastal areas through the development of effective breeding tools that can help dissect and incorporate tolerance into modern varieties and breeding lines adapted to these areas. Combining the use of varieties with broader tolerance to these stresses, alongwith proper and affordable management options, can ensure higher and stable food production in coastal areas.

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Invited Paper

Improved Rice Based Production Systems for Higher and Sustainable Yield in Eastern Coastal Plain in India

SANJOY SAHA, D. P. SINGH, D. P. SINHABABU, K. R. MAHATA, K. S. BEHERA and M. P. PANDEY

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The Indian coastline runs a distance of 8,129 km and the total coastal area is estimated to be 10.78 million hectare, of which 3.1 million hectare is salt affected. Farmers are resource poor, mostly belonging to small and marginal groups. Rice monocropping with low and unstable yield under rainfed condition is main characteristic feature of the eastern coastal ecosystem. During the dry season, land mostly remains fallow due to unavailability of fresh water and presence of moderate to high soil salinity. However, rice and certain other salt tolerant crops like sunflower, chilli, watermelon, sugarbeet, cotton and barley are grown in pockets depending on the soil and climatic conditions and availability of harvested rainwater.

Concerted efforts need to be made for developing and deploying suitable rice varieties with tolerance to major abiotic and biotic stresses. This should be combined with appropriate water and crop management practices. It is possible to integrate certain pulses, oilseeds, tuber crops and vegetables under rice based production system. Rice-fish farming system has a great potential in waterlogged situations.

Construction of embankments along the rivers and peripheral *bunds* around the catchments and individual fields can serve as a protective measure for stopping the ingress of seawater into rice fields. Rainwater harvesting through on-farm and off-farm storage structures is also important for increasing the availability of surface and ground water. However, these measures are expensive and require the support from the government and financial institutions.

*(**Key words:** Eastern coastal plain, Constraints to productivity, Soils & climate, Crop diversification, Improved management strategies, Rice-fish farming system)*

The Indian coastline runs a distance of around 8,129 km and a continental shelf of 50,000 square kilometer distributed in the nine coastal states (Gujarat, Maharashtra, Karnataka, Kerala and Goa in the west, and Tamil Nadu, Andhra Pradesh, Orissa and West Bengal in the east), besides Lakshadweep, Andaman Nicobar Islands, and Union Territories of Puduchery and Daman & Diu. The coastal ecosystem in India can be broadly classified into two zones, Eastern Coastal Plain and Western *Ghats* & Coastal Plains (Sehgal *et al.*, 1992). The ecosystem provides livelihood to several million people and contributes to the national economy to a significant extent. However, agricultural productivity in these areas lags behind that in the inland areas. The situation is still worse in coastal saline areas, which are mostly rainfed and monocropped with rice during the wet season. The major abiotic constraints to crop production in these areas are salinity, early and terminal drought, occasional cyclonic storms and prolonged waterlogging due to heavy rainfall and poor drainage. In this paper, important features of the eastern coastal plain, major constraints to rice based production system and strategies to overcome these constraints for higher and sustainable productivity are discussed.

General features of eastern coastal plain

Soils & climate: According to the National Bureau of Soil Survey and Land Use Planning, the eastern coastal plain can be divided into five agroecological sub-regions: South Tamil Nadu Plain, North Tamil Nadu Plain, Andhra Plain, Utkal Plain, and East Godavari and Gangetic Delta. The climate is hot dry semiarid in South Tamil Nadu Plain, hot moist semiarid in North Tamil Nadu Plain, hot dry subhumid in Andhra Plain, Utkal Plain & East Godavari Delta, and hot moist subhumid to humid in Gangetic Delta. The occurrence of devastating cyclones resulting in ecological disaster is a common feature in the east coast because of the lower slope and greater frequency of wind and rain storms as compared to the west coast. In the Bay of Bengal, 4-5 tropical cyclonic storms are formed every year and 2-3 of them may be severe causing damage in Andhra Pradesh, Orissa and West Bengal (Ramakrishna *et al., 2001*). Andhra Pradesh is most prone to tropical storms and more than 60 cyclones have occurred since 1900. Sometimes, high intensity rainfall received during a short period coupled with impeded drainage cause prolonged waterlogging. High water table, high humidity, prolonged cloud cover and loss of nutrients are a few other important factors hindering the agricultural productivity during the wet season. High soil and ground water salinity along with scarcity of fresh water are the major constraints limiting the crop productivity in the dry season in salt affected areas. Frequent intrusion of tidal brackish water in land and aquifer, particularly in unprotected areas, further aggravates the problem of salinity.

Soils in the east coast are predominantly derived from deltaic alluvium, although red loam, red sandy loam, coastal sand and black soils are also found in some areas. The pH of most soils is slightly acidic to neutral, although alkaline soils in some parts of Andhra Pradesh and Tamil Nadu are also found. Salt affected soils occur in narrow strips along the entire east coastline and have low to medium organic C, N and available P, and adequate available K. Though the saline soils have adequate supply of micronutrients, Zn and Mo deficiencies are occasionally observed in some places, particularly in light textured soils near the shore. Important characteristics of salt affected soils are presented in Table 1.

Sulphates constitute about 40-50% of salts in the saline soils and their reduction under submergence results in the formation of H_2S gas and metallic sulphides. The concentrations of Fe, Mn, Zn, Cu and P in plant are reduced drastically while the concentration of H_2S in soil increased to 100 ppm (Bandyopadhyay *et al.*, 2001). Thus, besides the direct toxic effect of H_2S on rice plants, the detrimental effect of soluble sulphides on nutrient availability and their absorption by plant roots may also be responsible for the reduced yield. Some soil problems in coastal saline areas related to rice cultivation are listed in Table 2.

Cropping system & livelihood pattern: Farmers are resource poor, mostly small and marginal with land holdings of < 2.0 ha and their proportion gradually increases with land fragmentaion due to increase in population. The proportion of marginal and small farmers is highest (> 90 %) in Tamil Nadu and West Bengal, followed by Orissa (83.8 %) and Andhra Pradesh (82.7 %). There are also landless families who engage themselves in sharecropping and as farm labourers. These areas have poor infrastructure and communication facilities and lag behind in the developmental activities. Rice monocropping under rainfed condition with low and unstable crop yield is the common feature of the eastern coastal ecosystem (productivity < 2.0 t ha^{-1}).

The total cultivated area in the eastern coastal plain is about 8.6 million hectare with a cropping intensity of 134 % (Subba Rao *et al.*, 2001). Rice based production system is the major form of land

Table 1. *Some important characteristics of coastal saline soils in eastern India*

State	Texture	pH	EC (dSm^{-1})	Dominant salts
West Bengal	Silty clay and clay loam	5.5 - 7.0	4 – 53	NaCl and Na_2SO_4
Orissa	Sandy loam, clay loam and clay	5.0 - 7.5	2 – 50	NaCl
Andhra Pradesh	Sandy loam, clay loam and clay	6.0 - 8.8	0.5 – 17	NaCl and Na_2SO_4
Tamil Nadu	Sandy loam and clay loam	6.0 – 8.2	2 – 10	NaCl and Na_2SO_4

Source: Ponnamperuma and Bandyopadhaya (1980), Velayutham *et al.* (1999)

Table 2. *Soil type and associated problems in coastal ecosystem*

Soil Type	Associated problem
Acid saline soil	Al and Fe-toxicity, P-deficiency
Coastal acid sulphate soil	Al and Fe-toxicity, P-deficiency, deep water
Neutral & alkaline coastal soil	Zn-deficiency, deep water
Coastal organic soil	Deficiencies of N, P, Zn, Cu, Mo; toxicities of Fe, H_2S and organic substances; deep water

Source: Ponnamperuma and Bandyopadhaya (1980) utilization pattern. Important crops and cropping patterns prevalent in different states in eastern coastal plain are listed in Table 3. Rice is the main crop grown during the wet season under different hydrological situations in all the states and covers 7.32 million hectare of cultivated area (Siddiq and Shiv Kumar, 1998).

The salt affected coastal areas are generally rainfed and monocropped with rice. During the dry season, land mostly remains fallow due to unavailability of fresh water and high soil salinity. However, rice and certain other salt tolerant crops like sunflower, chilli, watermelon, sugarbeet, cotton, barley, etc. are grown in pockets depending on the soil and climatic conditions and availability of harvested rainwater. Pulses like blackgram, greengram, cowpea, etc. and groundnut are also grown in some areas having mild salinity.

Crop diversification through the introduction of salt tolerant non-rice crops should be given priority in areas with less water availability. With proper water, soil and crop management strategies, it is possible to integrate certain pulses, oilseeds and vegetables with rice in a rice based production system. Crops like barley, cotton, chilli, sunflower, groundnut, ladies finger, watermelon, sugarbeet, *Basella* can be grown after rice in large areas during dry season with proper soil and rainwater management. These crops must be carefully selected based on their suitability to local agroclimatic conditions, profitability and farmers' preferences. The tropical tuber crops such as cassava, sweet potato, yams are well adapted to these coastal agroecosystems, and play an important role in the socioeconomic upliftment of the small and marginal farmers.

There are tremendous prospects for income and employment generation in rural areas at both on-farm and entrepreneur levels in crops like rice, groundnut, pulses, cashew, coconut, arecanut, mango and spices. Strategies and infrastructures need to be developed for storage and transport of the produce and byproducts for consumption in rural areas and for marketing the surplus stocks after value addition.

Among the integrated farming system options, rice-fish farming has great potential in the coastal waterlogged rice ecologies like canal based waterlogged areas, rainfed medium deep (30-50 cm) and deep water (50-100 cm) situations. Technology options are also available for salt affected waterlogged areas particularly of low to medium salinity. This farming system can ensure food, nutrition, economic, employment and also environmental security for the poor farming communities in these coastal areas (Sinhababu, 1996). An adoptable rice-fish diversified farming system technology has been developed at the Central Rice Research Institute, Cuttack for improvement of farm productivity, and generation of income and employment in rainfed waterlogged areas. This system integrates various compatible components like rice, other field crops, horticultural and ornamental plants, fish, prawn, birds, agroforestry, etc. Adoption of this technology in coastal areas of Orissa has greatly benefited the farmers including the small farmers by way of an increase in net farm income by 15 times besides providing higher farm employment (110 additional mandays) than the traditional rice farming (Sinhababu *et al.*, 2006).

Table 3. *Important crops and cropping systems in coastal ecosystem of different states in Eastern India*

State	Field Crops		Prevalent cropping system	Source
	Wet season	Dry season		
Andhra Pradesh	Rice, cotton, sugarcane, tobacco, groundnut	Blackgram, greengram, groundnut, chilli	Rice-based, Groundnut-based, Sugarcane-based	Rastogi (1991)
Orissa	Rice, jute, sugarcane	Rice, blackgram, greengram, chilli, groundnut, sunflower	Rice-based	Gangopadhyay (1991a)
Tamil Nadu	Rice, sugarcane, sorghum, pearl millet, tapioca	Rice, groundnut, cotton	Rice-based	Gangopadhyay (1991b)
West Bengal	Rice, jute	Rice, barley, lathyrus, sunflower, sugarbeet, chilli, watermelon	Rice-based	Gangopadhyay (1991c)

not always cost effective, and hence, selection of salt tolerant crops and crop varieties is a more feasible and viable option. In coastal areas of eastern India, rice during the wet season often suffers from drought and salinity at seedling and reproductive stages and submergence/waterlogging at vegetative stage. Breeding rice varieties for tolerance to these abiotic stresses, therefore, has a tremendous potential for increasing and stabilizing rice production. However, rice varieties like Canning 7, CSR 4, CSR 6, Lunishree, Panvel 1 to 3, ADT 35, SLR 5214, Bhutnath, Sonamani, SR 26 B, Sumati, Utpal, Vytylla 1 to 6, etc., developed and recommended for coastal ecosystems in different states, have not performed well under the diverse and multiple stress situations. The future breeding strategy for coastal ecosystems should be more location specific depending upon the prevailing microclimate, hydrology and soil conditions. Major emphasis should be put on the development of short duration salt tolerant rice varieties for the dry season in areas where adequate irrigation water is available. Innovative biotechnological tools should be used, where conventional breeding was deemed slow in overcoming specific stress induced metabolic disorders or in developing varieties better adaptable under coastal environment.

Use of robust (fertilized with 10 kg each of NPK + 5 t FYM ha^{-1}) and aged seedlings (40-50 day-old), closer planting (15 x 10 cm) during the wet season and early planting (first fortnight of January) during the dry season along with integrated nutrient management and need based plant protection measures in both the seasons are some of the important crop management strategies for improving productivity of rice in coastal areas.

Integrated nutrient management involving 50% recommended dose of nitrogen through *sesbania* green manuring and remaining 50% through chemical fertilizer during the wet season, and 100% recommended dose through chemical fertilizer during the dry season are promising for improving and sustaining the productivity of rice-rice system. However, use of fertilizers along with green manure enhanced the yield under favourable conditions. The deficiency of micronutrients, especially Zn and S, is observed in certain pockets of east coast plain. Application of 5 kg Zn and 25-50 kg S ha^{-1} is recommended for Orissa, Andhra Pradesh and Tamil Nadu (Gangawar *et al.*, 2004). The practice of *sesbania* green manuring + *azolla* was found to be as effective as prilled urea @ 60 kg N ha^{-1} in shallow lowlands while *sesbania* green manuring was found to be as effective as urea supergranule @ 45 kg N ha^{-1} in intermediate lowland situations during the wet season. In the dry season, *azolla* + prilled urea @ 50 kg N ha^{-1} produced 15% higher yield than the recommended dose of 80 kg N ha^{-1} (Mahata *et al.*, 2006). Integrated nutrient management not only increases the yield of rice but also improves the soil health.

The problem of aquatic weeds is more intense in medium deep and deep water ecologies. In situations of sudden water accumulation and high water depths from the beginning of the season, the problematic weeds like *chara* can be effectively controlled by pre-emergence application of oxadiazon @ 0.75 kg ha^{-1} or post-emergence application of copper sulphate ($CuSO_4$) @ 8-10 kg ha^{-1}. Application of $CuSO_4$ also helps in controlling other algal weeds. Application of 2, 4-D @ 0.75 kg ha^{-1} 25-30 DAS helps in controlling floating weeds. Results from different on-farm trials in Puri and Jagatsinghpur districts of Orissa indicated that application of pretilachlor @ 0.6 kg ha^{-1} 3 DAS combined with application of 2, 4-D @ 0.6 kg ha^{-1} 30-35 DAS controlled the weeds effectively in deep water ecology.

Spraying of monocrotophos or chlorpyriphos @ 500 g ha^{-1} at the time of brood emergence to kill the adults and application of carbofuran @ 1.0 kg ha^{-1} to kill the larvae effectively control the stem borer. Application of phorate @ 1.0 kg ha^{-1} is recommended against gall midge. For controlling plant hoppers, monocrotophos @ 500 g ha^{-1} or imidacloprid @ 40 g ha^{-1} is recommended while leaf folders can be controlled by spraying monocrotophos @ 500 g ha^{-1} or indaxacarb @ 40 g ha^{-1}. Spraying of streptocycline (150 mg) + copper oxychloride (1.0 g) per litre of water helps against bacterial blight. Spray fluid should be 200 litres for an area of 0.4 ha in all the cases.

There is a great scope for increasing the productivity of rice and rice based production system in eastern coastal plains through development and adoption of suitable crop varieties with site specific crop and natural resource management under appropriate rice based cropping/farming systems. Promotion of small entrepreneurship in the farming sectors like integrated rice-fish farming system is necessary for income and employment generation. Technology validation, refinement and dissemination along with capacity building and infrastructure development not always cost effective, and hence, selection of salt tolerant crops and crop varieties is a more feasible and viable option. In coastal areas of eastern India, rice during the wet season often suffers from drought and salinity at seedling and reproductive stages and submergence/waterlogging at vegetative stage. Breeding rice varieties for tolerance to these abiotic stresses, therefore, has a tremendous potential for increasing and stabilizing rice production. However, rice varieties like Canning 7, CSR 4, CSR 6, Lunishree, Panvel 1 to 3, ADT 35, SLR 5214, Bhutnath, Sonamani, SR 26 B, Sumati, Utpal, Vytylla 1 to 6, etc., developed and recommended for coastal ecosystems in different states, have not performed well under the diverse and multiple stress situations. The future breeding strategy for coastal ecosystems should be more location specific depending upon the prevailing microclimate, hydrology and soil conditions. Major emphasis should be put on the development of short duration salt tolerant rice varieties for the dry season in areas where adequate irrigation water is available. Innovative biotechnological tools should be used, where conventional breeding was deemed slow in overcoming specific stress induced metabolic disorders or in developing varieties better adaptable under coastal environment.

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Coconut Plantation and its Commercial Uses in the Coastal Areas of Bangladesh: Contribution to the Socioeconomic Uplift and Poverty Alleviation

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The paper deals with the coconut plantation and its commercial uses in coastal belt of Bangladesh and their contribution in socioeconomic uplift and poverty alleviation of local and tribal people of those areas. Research results on the adaptation of coconut as a single crop and under mixed as well as alternate cropping system in the coastal areas based on trials conducted at three coastal sites for creating socioeconomic uplift have been thoroughly discussed. Finally, the paper focuses on the future policy of the management of coastal ecosystem through coconut plantations.

*(**Key words:** Coconut based plantation, Cropping system, Coconut diversity, Industrial uses, Value addition & marketing, Livestock rearing, Training & manpower development, Impact & opportunities)*

Bangladesh is one of the coastal countries along the Bay of Bengal. The country is sloping gently from the north to the south, meeting the Bay of Bengal at the southern end. The southern most part of Bangladesh is bordered by about 710 km long coastal belt, which has the continental shelf up to 50 m deep with an area of about 37,000 km^2. According to the coastal zone policy (CZPo, 2005) of the Government of Bangladesh, 19 districts out of 64 are in the coastal zone covering a total of 147 *upazillas*1 (Fig.1) of the country. Out of these 19 districts, only 12 districts meet the sea or lower estuary directly.

The coastal zone covers 47,201 square kilometer land area, which is 32 percent of total landmass of the country (Islam, 2004). India is at the west of the zone whereas Myanmar is at the east of the coast. About 60 islands are identified in the coastal zone. St. Martin is the only coral island of the country located in the Bay of Bengal, about 9.8 km (Hossain, 2001) to the southeastern side of mainland. A vast river network, a dynamic estuarine system and a drainage basin intersect the coastal zone, which made coastal ecosystem as a potential source of natural resources, diversified fauna and floral composition, though there also have immense risk due to natural disasters.

Total population living in the coastal zone is 35.1 million that represents 28 percent of total population of the country (BBS, 2003). Population density in exposed coast is 482 persons per square kilometer whereas the value is 1,012 for the interior coast. Fishing, agriculture, shrimp farming, salt farming and tourism are the main economic activities in the coastal area. The Sundarbans is a major source of subsistence for almost 10 million people (Islam and Haque, 2004). Main activities in the Sundarbans area are fisheries, wood collection and honey collection. Almost ten thousand households in the area have neither homestead land nor cultivable land. On the other hand, more than a million households in the area have only homestead but no cultivable land. Per capita gross domestic product (GDP) for the coastal zone is US$277, slightly lower than the national value (US$278), during the fiscal year 1999-2000.

Again, with regard to calorie intake the same in the coastal belt is significantly more than that in other parts of the country. Distribution of households in the coastal zone is also different in comparison to non-coastal areas. In the coastal zone the distribution of non-farm households is 29.6%, which is lower than that (35.5 %) in non-coastal areas. But the number of small farmer is higher in coastal zone (57.7%) than in other parts of the country (51%). The agriculture census 2001 reveals that 53.4 percent people of the coastal area are functionally landless. This 53.4 percent people own simply 17 percent land, in contrary 12 percent people own 47 percent of total available land.

Existing cropping status in coastal area

Field crop production decreased in coastal area due to unavailability of fresh water and soil degradation. Rice production (16%) in the coastal area

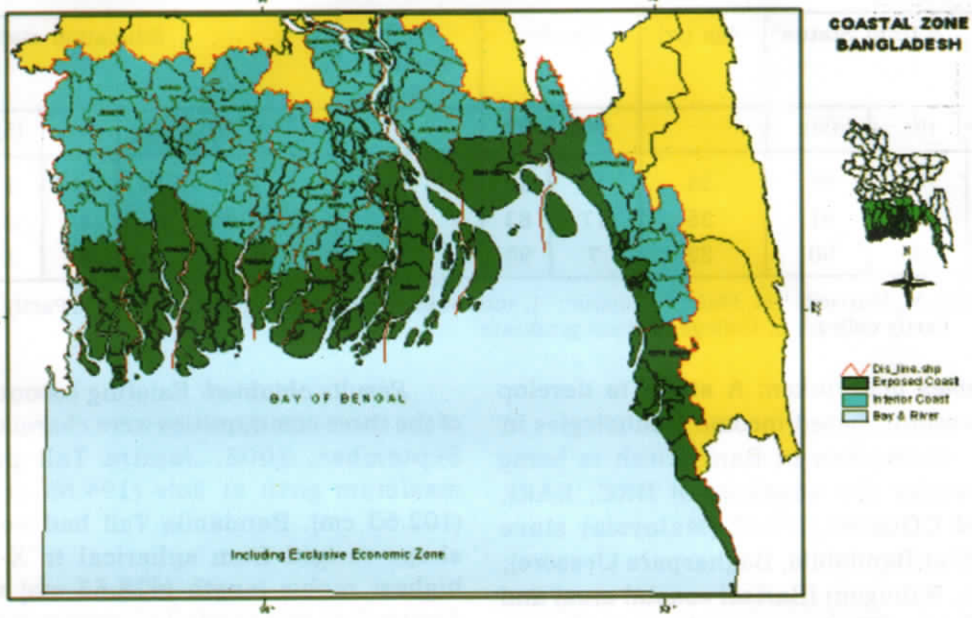

Fig. 1. Coastal zone of Bangladesh (Source: Islam, 2004)

is lower as compared to production in other areas (24%). The coastal zone is very important for pulses and oil seeds production, which also fall gradually similar to rice, with increase in salinity in the zone.

Coconut based coastal ecosystem

Present status: Bangladesh has a wide genetic diversity of many tropical fruits covering an area of about 0.22 million hectare producing 1.8 million tons (BBS, 2003). Coconut (*Cocos nucifera*) has an excellent entity for its versatile uses. It is grown at homesteads with a unique farming system for effective utilization of land. Many of the households depend on coconut for their livelihood. The growers are generally smallholders or marginal farmers. Average holding size is 0.035 hectare (BBS, 2003). At present number of coconut palm per family is 2 only with a prospect for planting of 10-15 palms per household. However, in the two other southern districts, Jessore and Perojpur, average number of trees per household is 35. Bangladesh Typica which is the only coconut variety grown by the community has acceptable nut quality and yield consistency. Its tall stature provides scope of intercropping at the homestead. However, the farmers are not aware about the high yielding varieties and hybrids. The southern part of the country contributes to 80 % of the total production. National yield of coconut has been estimated as 21 nuts per year per tree, whereas yield at the research station is 69 nuts per year per palm. The gross and net incomes from coconut were estimated to the extent of Tk 11824.00 and Tk 7489.00 per year per household, respectively. Around 35% of the production is consumed as tendernut and 40% as mature nut for fresh consumption. Only nine percent is processed in the industry. Livestock rearing in coconut holdings could increase income and employment to the coconut farmers. Although farmers grow a variety of crops in the coconut holdings, cropping models compatible with the local edaphic and climatic conditions are to be developed and popularized for wider acceptance. Unemployment and under-employment are severe problems in farming communities in Bangladesh. Because of small holding size, income of the farmers is not enough to meet the daily necessities. Around 44 % people of the country are living below the poverty line. Average income of the selected communities had been estimated as US$ 121 per person per year, and as such they fall below the poverty line. Lack of diversified uses along with improper marketing channel of the products is limiting the consumption and utilization of products from coconut. Farmers cannot involve themselves in more profitable activities because they lack access to efficient village level technologies and machineries, capital and markets. Exploitation of income opportunities from coconut is hindered due to the absence of community based organization, especially involving women. Investment at village level coconut processing industries is considered risky for low nut production.

***Table 1**. Baseline survey information derived from the 100 CBO members for each of three project sites*

Site	Marital Status[a]		Age (yr)	Gender[b]		Family Members (No.)	Education status[c]						
	(N)	(M)		(M)	(F)		(1)	(2)	(3)	(4)	(5)	(6)	(7)
Bandabila	3	97	33	16	84	5	5	62	14	14	1	2	4
Chandrapara	9	91	35	17	83	5	27	36	20	6	3	8	-
Jamira	10	90	32	7	93	5	69	8	14	6	1	2	-

[a] N, Non-married, M, Married; [b] M, Male, F, Female; [c]1, Informal/ Non-formal; 2, Elementary; 3, Partly high school; 4, High school; 5, Partly college; 6, College; 7, Post-graduate

Programmes undertaken: A study to develop sustainable coconut based income technologies in poor rural communities in Bangladesh is being conducted under the auspices of HRC, BARI, Gazipur and COGENT/IPGRI (Malaysia) since January 2002 at Bandabila, Bagharpara (Jessore); Chandrapara, Babugonj (Barisal coastal area) and Jamira, Phultala (Khulna coastal area). Salient demographic features for each are given in Table 1. Training on CBO and microcredit management, livestock production and feed formulation, intercropping and preparation of high value products have been conducted for 100 CBO members at each of the three CBO sites. Three field days at three project sites had been arranged. Under the microcredit programme, 30 locally made rope and fibre producing machines and fifteen doormat preparing machines have been distributed among 45 CBO members. Now, the CBO members are producing rope and doormat from coconut husk and they are earning money. Furthermore, livestock (goat, duck, hen, etc.) has been loaned out to the CBO members for additional income, breeding and subsequent multiplication. Intercropping loan has been given to 123 CBO members to cultivate selected annual cash crops like banana, pineapple, vegetables, spices and others as intercrops with coconut to generate additional income. Besides these, seeds of improved vegetable varieties, i.e. lady's finger, (cv. BARI-Lady's Finger-1), stem amaranth (cv. Stem Amaranth-1) and red amaranth (cv. BARI-Red Amaranth-1) have been provided to the CBO members to cultivate those with coconut as intercrops. A coconut nursery of about one thousand seed nuts of BARI-Narkel-1, BARI-Narkel-2 and local farmer's varieties at each of the three project sites has been established. A cumulative total of 3473 coconut seedlings have been planted by the members of 3 coconut communities.

Results obtained: Existing coconut germplasm of the three communities were characterized during September, 2003. Jamira Tall produced the maximum girth at bole (194.66 cm) and trunk (102.63 cm). Bandabila Tall had no bole. Crown shape ranged from spherical to X-shaped. The highest rachis length (428.53 cm) was found in Jamira Tall. Bandabila Tall produced the maximum number of leaflets (197.26). The number of spikelets with female flowers was recorded as the highest (23.66) in Bandabila Tall, while Jamira Tall produced the lowest (3.70). The highest number of fruits was produced by Chandrapara Tall, but the meat weight was found highest (375.10 g) in Bandabila Tall. TSS of meat varied from 5.00 to 6.75. The highest amount of husk (37.65 %) per fruit was recorded in Jamira Tall. Bandabila Tall had the highest percentage of nut per fruit (66.24%) and highest percent of endosperm per nut (42.52 %).

A survey with a view to find out the change that has taken place among 300 community members of 3 CBO sites was conducted. Among three communities the highest 52% members of Bandabila site had the elementary education. The number of coconut plants per household was found to be the highest at Bandabila site (10) while the yield per tree was obtained maximum at Jamira (133) site. The annual income derived from oil was found maximum (Tk 843.54) at Jamira CBO site while the income from vegetables cultivated as intercrops with coconut was recorded the highest (Tk 11401.49) at Bandabila. The highest annual income per family (Tk 2498.93) was obtained from hen rearing.

Identification of marketable products based on market survey

A market survey was conducted in each of the three CBO sites, and some marketable coconut based products like rope, doormat, coconut oil, oilcake at Chandrapara; rope, doormat, coconut oil, oilcake at Bandabila; and rope, doormat, coconut oil, oilcake at Jamira were identified. The informations were collected from 150 individual respondents. The products identified as having better prospects for marketing within and outside the community were coconut oil, rope and doormat.

Installation, operation and evaluation of other processing machineries for meat, fibre, shell, leaf and wood products

Three decorticating machines were installed at Chandrapara, Bandabila and Jamira CBO sites. One machine can produce fibre from 5000 husks within a period of about 8 hours. About 5 members per CBO have been trained up on the operation system of decorticating machine. Fifteen rope and 10 doormat preparing machines were loaned out and installed in each community. All 300 CBO members of three communities received training on fibre, rope and doormat preparation in August, 2004. A member can prepare 1 kg rope or a doormat within about 2-3 hours to fetch price of about US$ 1.03-1.21.

Impact

Previously the women, who were involved in rope and door preparation, had to prepare the fibres through normal beating which was very much laborious and painful. To avoid beating the only alternative was installation of decorticating machine. Due to easy preparation of quality fibre and easy operation of simple rope and doormat preparing machines, the trained members became encouraged to engage them in rope and doormat preparation to generate additional income. As a member is capable to earn at least US$ 1.03-1.21 per day, working only for 2-3 hours, their livelihood was uplifted.

Production and marketing of high value coconut products

Out of a total of 130 members 123 were women and 7 men at 3 CBO, and thus they availed training and with the help of machines provided through microcredit engaged themselves in the production and marketing of rope and doormat. Total income earned by three communities from rope and doormat produced were US$ 10685.26, US$ 350.00 and US$ 200.00 for Jamira, Chandrapara and Bandabila, respectively.

Impact

The members engaged in the production of rope and doormat have been earning money for more than a year. A man/women is now capable to earn at least US$ 0.86-1.03 per day after completion of his/her other family activities. Due to additional income, a positive change has been experienced in their food, health care, sanitation and education of child.

Production trials of intercrops

A total of 115 CBO members (24 men and 91 women) at 3 CBO sites either individually or in groups were involved in intercropping trials receiving microcredit from the CBO revolving fund. Annual cash crops like vegetables (bitter gourd, ribbed gourd, snake gourd, ash gourd, teasel gourd, aroid, bean, bottle gourd, tomato, Indian spinach, amaranths and papaya), spices (chili, zinger and turmeric), and fruits (banana, papaya and guava) were cultivated along with coconut as intercrops to generate additional income. One hundred and fifty saplings of BARI-Guava - 2 were disbursed among the members of each of the three CBO sites. Until now a total of US$ 1851.65 was loaned out among 115 CBO members of three communities to increase their income through intercropping trials. Crops like upland rice and wheat were cultivated to ensure the food security of CBO members.

Impact

The members (115) involved in intercropping have earned upto US$ 3961.69 in 12 month period, where the share of Chandrapara, Bandabila and Banchte Shekha coconut community was US$ 975.03, US$ 117.52 and US$ 1814.14, respectively against a total loan US$ 1851.65 disbursed among three communities. Hence, the income was derived after satisfying the household dietary needs. The average net income was more than double of the investment. This is the income derived in addition to that from coconut, and farmers/women felt encouraged to adopt more intensive intercropping by high value compatible crops.

Livestock production trials

Receiving training on livestock production and feed formulation, 42 members (2 men and 40 women) at Bandabila, 82 (39 men and 43 women) at Jamira, and 54 (9 men and 45 women) at Chandrapara reared chicken, goat, duck and cow and gained benefits of about US$ 792.51, US$ 2499.97 and US$ 706.65, respectively over a period of 18 months.

Impact

A positive impact on income generation was created among the members involved in livestock rearing. A total net income of US$ 3581.68 was generated over a 18 month period by 178 CBO members receiving only US$ 2411.12 as credit. Among the livestock components, goat rearing was found to be more profitable. In a case study at Bandabila on 5 CBO members with average holding size of 0.35 ha on livestock production the average net income was found to be US$ 136.91, which ranged from US$ 115.07 to 259.56.

Coconut diversity

As the farmers grow coconut, conserve and utilize genetic resources in wide range of environment for diverse purposes, they are best informed of the characteristics of the coconut varieties. Hence, the experience of farmers were utilized to identify and cataloguing their varieties from utility angle. Existing coconut germplasm at each of the three CBO sites have been characterized. Three high yielding and 3 high value varieties of coconut at each of the three CBO sites were identified through coconut diversity programme and Participatory Rural Appraisal (PRA).

The varieties characterized were Bandabila as high yielding, high value green and high value red, Chandrapara as high yielding and high value green, and Jamira as high yielding and high value green. In addition to the identified coconut varieties other improved varieties like BARI- Coconut - 1 and 2 have been popularized by introducing them to the communities from BARI.

Two community managed coconut nurseries and one integrated nursery per CBO were established. A total of 1750 coconut seedlings at Jamira, 1152 at Bandabila and 571 at Chandrapara has been planted. As of August 2004, one hundred members of Jamira, 88 members of Chandrapara, and 100 members of Bandabila planted the coconut seedlings, of which 1396 at Jamira, 495 at Chandrapara and 921 at Bandabila are surviving in the homestead as well as in the field.

Impact

Due to identification of high yielding and high value coconut varieties at three CBO sites and establishment of community managed nurseries of those varieties and other improved varieties, the members became aware and encouraged to plant more seedlings of those varieties. As a result, the production would obviously be increased in the near future, since a total of 3473 good coconut seedlings have been planted in homesteads as well as in the fields of the community members.

Opportunities

Poverty reduction throughout Bangladesh using the sustainable technologies generated at 3 CBO sites on nursery management, high value product preparation, intercropping and livestock production:

- Establishment of community based organization and microcredit system
- Community managed nurseries of farmers' coconut varieties and other improved varieties of coconut and other fruits, vegetable and spice seedlings in each of the 3 CBO sites established to be effective for income generation as well as for conserving the local ecotypes
- Livestock production especially goat, duck, hen and cow rearing as effective technology for income generation and breeding purpose in the poor rural communities
- Developing skill for CBO and microcredit management, nursery management, high value product preparation, intercropping and livestock production, as well as feed formulation
- Sourcing of inexpensive village level machineries for rope and doormat preparation; oil extraction; candy, bread and cookies preparation; handicrafts from wood and shell; and similar other technologies as well as developing expertise for each
- Technical and financial support for the production and marketing of products through the various income generating activities such as the production of seedlings from CBO managed nurseries, high value coconut products, intercropping and livestock fodder production
- Developing the capacity of farmers and women to participate and manage these entrepreneurial activities, as well as researchers and extension workers to provide technical support to these village level activities

Before the project, most of the farmers of the coastal project sites were involved in shrimp culture as their main earning source. After the implementation of the project, most of the farmers were involving themselves not only in shrimp culture, but also in cultivating diversified crops like coconut and other fruits, vegetables and spices, in generating additional income. The farmers are also preparing different high value products from the carnel and biproducts of coconut. In order to do that the farmers were trained up by the experts from Vietnam and Srilanka. As a result, the poverty has been reduced at the project areas as they have found out the ways to make themselves self-dependent.

CONCLUSION

Therefore, farmers should be encouraged to plant more fruits and plantation crops in coastal regions (i.e. Cox's Bazar, Noakhali, Barisal, Patuakhali, Borguna, Piruzpur, Jhalokati, Khulna, Bagarhat and Bhola districts) of Bangladesh. In that case, plantation of more coconut, hog plum, jujube, sapota, mango, guava, etc. will be very good practice for maintaining the coastal ecosystem. Moreover, the generated technologies from COGENT (Coconut Genetic Resources Network) should be viable throughout the coastal area of Bangladesh.

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Invited Paper

Role of National Horticulture Mission in Poverty Alleviation and Livelihood Security in the Coastal Areas of West Bengal

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The Horticulture sector of West Bengal offers a wide variety of crops suitable for cultivation under six agroclimatic conditions with possibilities of multiple, intercropping and multitier cropping systems. This would enhance return per unit area of land, enabling diversification, providing food and nutritional security, as well as creating better employment opportunities and fostering export. National Horticulture Mission (NHM) is a centrally sponsored scheme in which Government of India provided 100% assistance to the state during 10th plan and during the 11th plan Central Government's assistance is 85% of the total budget. The main objectives of NHM are to provide holistic growth of the horticulture sector of the state through an area based regionally differentiated strategies which include research, technology, promotion, extension, post-harvest management, processing and marketing in order to meet the overall objectives stated above.

Thus, the National Horticulture Mission has a great role in poverty alleviations and livelihood security in the coastal areas of West Bengal which includes Sundarbans areas of South 24 Parganas, North 24 Parganas (Basirhat Subdivision), Purba Medinipur and Southern parts of Howrah districts. The strategies being adopted under NHM for socioeconomic development of the coastal areas of West Bengal are: (i) enhancement of acreage, production, productivity as well as quality of horticultural crops, (ii) diversification from traditional crops to fruits like guava, mango, banana, flower, spices, betelvine and cashewnut through area expansion, (iii) establishment of Model Nurseries and upgradation of existing tissue culture units for availability of good quality genuine planting materials, (iv) rejuvenation and replacement of senile mango and cashewnut plantation, (v) creation of water resources through construction of community tanks, farm ponds with plastic lining for rainwater harvesting which will solve the scarcity of irrigation water in these particularly coastal areas, (vi) extension of modern, scientific technology to the farmers for high tech horticulture like green house cultivation, use of plastic mulch, agroshade net, plastic tunnels, promotin of IPM, establishment of plant health clinic, adoption of organic farming, setting up vermicompost unit, beekeeping for pollution support, etc., (vii) establishment of post-harvest facilities like pack house, multipurpose cold storage, CA cold storage, refrigerated van, mobile precooling or processing units, infrastructure for collection/ grading/ sorting centers, (viii) creation of market infrastructure, (ix) human resource development through trainings and demonstrations, (x) financial assistance for adopting microirrigation system.

*(**Key words:** National Horticulture Mission, Crop diversification, High tech technologies, Post-harvest facilities, Market infrastructure, Human resource development)*

The Horticulture sector of West Bengal offers a wide variety of crops suitable for cultivation under six agroclimatic conditions in the plains and hills with possibility of multiple, intercropping and multitier cropping systems. This would enhance return per unit area of land, enabling diversification, creating better employment opportunities, and fostering export. This sector may be viewed as an engine of growth for the rural economy, while simultaneously providing food and nutritional security.

National Horticulture Mission (NHM) is a centrally sponsored scheme in which Government of India provided 100% assistance to the state during 10th plan and during the 11th plan Central Government's assistance is 85% of the total budget. The main objectives of NHM are:

- To provide holistic growth of the horticulture sector of the state through an area based regionally differentiated strategies which include research, technology promotion, extension, post-harvest management, processing and marketing
- To enhance horticultural production, improve food and nutritional security as well as income support to farmhouse

- To create opportunities for employment generation for skilled and unskilled persons, especially unemployed youth
- To promote, develop and disseminate technologies, through a seamless blend of traditional wisdom and modern scientific knowledge

With the above objectives, the National Horticulture Mission has a great role in poverty allevation and livelihood security in the coastal areas of West Bengal which includes Sundarbans areas of South 24 Parganas, North 24 Parganas (Basirhat Subdivision), Purba Medinipur and Southern parts of Howrah districts.

Strategies of NHM

The following strategies are being adopted under NHM for socioeconomic development of the coastal areas of West Bengal through enhancement of acreage, production, productivity as well as quality of horticultural crops:

A. *Diversification from traditional crops to fruits, orchards, flower, spices and plantation crops:* In the following schemes financial assistance is given to area expansion of guava, mango, banana, flower, spices, betelvine and cashewnut in coastal areas of West Bengal. Physical target is given in Table 1.

Table 1. *Physical target of area (ha) expansion of different crops*

Sl No.	Name of the crop	North 24 Pgs.	Paschim Medinipur	South 24 Pgs.	Purba Medinipur	Howrah
1	Guava	600	—	—	—	—
2	Mango	550	200	—	—	—
3	Banana	400	—	—	—	—
4	Flower	380	300	—	50	—
5	Spices	300	—	—	—	—
6	Plantation crops					
	a. Cashewnut	—	800	—	—	—
	b. Betelvine	40	40	—	—	—

Table 2. *Establishment of Model Nuirsery, Tissue Culture Laboratory (Public/ Private)*

Sl No.	Item	North 24 Pgs.	Paschim Medinipur	South 24 Pgs.	Purba Medinipur	Howrah
1	Model Nursery (Private sector) (1 ha)	48 no.	45 no.	—	—	—
2	Model Nursery (Public sector) (4 ha)	—	1 no.	—	—	—
3	Model Nursery (Private sector) (4 ha)	1 no.	1 no.	—	—	—
4	Tissue Culture Laboratory (Private sector)	3 no.	—	—	—	—
5	Tissue Culture Laboratory (Public sector)	1 no.	—	—	—	—

Table 3. *Physical target for rejuvenation pf mango and cashewnut plantation*

Sl No.	Name of plantation	North 24 Pgs.	Paschim Medinipur	South 24 Pgs.	Purba Medinipur	Howrah
1.	Mango plantation	600 ha	—	—	—	—
2.	Cashewnut plantation	—	700 ha	—	—	—

***Table 4**. Extension of appropriate technologies to farmers under protected cultivation*

Sl No.	Schemes	North 24 Pgs.	Paschim Medinipur	South 24 Pgs.	Purba Medinipur	Howrah
1	Hi tech Green House	2 no.	8 no.	—	—	—
2	Normal Green House	4 no.	4 no.	—	—	—
3	Use of plastic mulch	—	65 ha	—	—	—
4	Use of Agroshade net	80 unit	80 unit	—	—	—
5	Use of plastic tunnels	—	120 nos.	—	—	—
6	Promotion of IPM	2000 ha	1100 ha	1100 ha	—	1100 ha
7	Establishment of Plant Health Clinic	—	—	—	1 no.	—
8	Adoption of Organic Farming	650 ha	650 ha	—	—	—
9	Setting up of Vermicompost Unit (to support organic farming)	170 unit	170 unit	—	—	—
10	Beekeeping (for support to pollination)	10000 no.	10000 no.	—	—	—

***Table 5.** Assistance for creation of post-harvest facilities*

Sl No.	Item	North 24 Pgs.	Paschim Medinipur	South 24 Pgs.	Purba Medinipur	Howrah
1	Pack House	16 no.	11 no.	11 no.	11 no.	11 no
2	Multipurpose Cold Storage	4 no.	3 no.	3 no	2 no.	3 no.
3	Controlled Atmosphere Cold Storage	1 no.	—	—	—	—
4	Refrigerated Vans/ Container	4 no.	2 no.	4 no	4 no	5 no
5	Mobile Precooling or processing Units	2 no.	2 no.	2 no.	2 no.	2 no.
6	Functional Infrastructure for collection/ grading/sorting Centres	16 no.	11 no.	11 no.	11 no.	11 no.
7	Construction of low cost storage for onion bulbs	35 unit	—	35 unit	—	—

B. *Establishment of Model Nurseries and upgradation of existing tissue culture units for availability of good quality, genuine planting material:* Initiatives are taken to set up model nurseries of one ha and four ha area as well as tissue culture laboratory in both private and public sectors by giving financial assistance. Details of target is given in Table 2.

C. *Rejuvenation and replacement of senile plantation for productivity as well as quality improvement:* Financial assistance is given to rejuvenate old mango plantation and senile cashew plantation. Physical target of rejuvenation is given in Table 3.

D. *Creation of water resources through construction of community tanks, farm ponds/reservoirs with*

Table 6. Assistance for creation of market infrastructure

Sl No.	Item	North 24 Pgs.	Paschim Medinipur	South 24 Pgs.	Purba Medinipur	Howrah
1	Establishment of Rural Markets/ Apni Mandi/ Direct Market	4 no.	3 no.	3 no.	4 no.	2 no.
2	Establishment of Marketing Infrastructure for horticultural produce in Govt./ Private/Co-operative Sector	5 no.	3 no.	2 no.	2 no.	2 no.
3	Marketing Intelligence Centre	1 no.	1 no.	—	—	—

Table 7. Human resource development programme

Sl No.	Item	North 24 Pgs.	Paschim Medinipur	South 24 Pgs.	Purba Medinipur	Howrah
1	Farmers training programme (25 farmers per training)	10 no.	10 no.	—	—	—
2	Farmers training cum visit outside state (25 farmers per training)	1 no.	1 no.	—	—	—
3	Training of Supervisor & Entrepreneurs in different training institutes					
4	Training of the officials concerned with the implementation of the programme and the field level workers who will in turn train or guide the farmers.					

plastic lining for rainwater harvesting to solve the scarcity of irrigation water in the coastal areas: Efforts are given to create ten nos. of water resources (each of 10 ha area) through financial assistance in Paschim Medinipur district.

E. *Extension of appropriate technology to the farmers for high tech horticulture cultivation as well as for precision farming:* There are provisions of giving subsidy for establishment of normal and high tech green house and for use of plastic mulch, agroshade net, plastic tunnels per cultivation of horticultural crops. Details are given in Table 4.

F. *Financial assistance for setting up post-harvest facilities and processing units:* These are essential for increasing the marketability of the horticultural produce, value addition, increasing profitability and reducing losses. Details are given in Table 5.

G. *Market infrastructure:* Assistance for creation of Market Infrastructure is the ultimate end of all the produce. Details are shown in Table 6.

H. *Human resource development:* Capacity building and Human Resource Development at all levels through trainings and demonstrations are essential requirements. Details are given in Table 7.

I. *Microirrigation:* Drip and Sprinkler irrigation form essential input for improving productivity and quality of horticultural produce. In this centrally sponsored scheme, farmers get 50% subsidy of the total cost.

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Invited Paper

Role of AVRDC in Technology Generation and Transfer for Poverty and Malnutrition Alleviation

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The expansion of markets and the liberalization of trade policies are providing new opportunities for both rural and urban people to escape poverty through production of high value crops, especially vegetables, the best means for overcoming micronutrient deficiencies. Moreover, demands of local, regional and international markets for vegetables are changing rapidly, fueled by health concerns and economic opportunities stimulated by the spread of supermarkets. AVRDC- The World Vegetable Center, whose mission is to reduce malnutrition and poverty in the developing countries through vegetable R&D, is headquartered in Taiwan and has set up a new regional centre for South Asia in Hyderabad, India. Over the past 35 years AVRDC has developed a vast array of improved germplasm and technologies that address economic and nutritional needs of the poor; empower farmers; collect, characterize and conserve vegetable germplasm resources for worldwide use; and provide globally accessibie, user-friendly and science based appropriate technology (AVRDC 2005). This paper will throw light on the role AVRDC plays in developing and promoting good agricultural practices (GAPs) and technologies in vegetable production.

AVRDC currently maintains more than 55,000 accessions of diverse vegetables, making it the largest collection of vegetable germplasm worldwide. AVRDC has developed promising lines of tomato, chilli, pepper, eggplant, garlic, onion, cucurbits, soybean, mungbean and lots of other vegetables including indigenous vegetables with high yield, nutrition and disease resistance. To cite one, AVRDC recently developed tomato lines that could resist multiple diseases as well as "golden tomatoes", which provide 3-6 times more vitamin A than the standard types. Recent achievements at AVRDC include virus resistant tomatoes raising farmers' income, hybrid peppers breaking the yield barrier in the tropics, flood tolerant chilies opening new market opportunities, broccoli varieties for monsoon season, pesticide-free eggplant and leafy vegetables that are safer to grow and consume as well as protect the environment. In 2002, new IPM strategies were developed that allow pesticide-free production of leafy vegetables and eggplant, two of the most heavily sprayed food crops. In addition to this, the promotion of indigenous vegetables (IVs), which are a neglected lot today, can reduce both poverty and malnutrition. Eggplant and tomato grafting technology, developed by AVRDC has the potential to become a cottage industry that provides employment and income. In mungbean, farmers have eagerly accepted the early maturing, disease resistant lines and AVRDC's partners are producing tons of seed to meet the demand.

AVRDC research work translated into new technologies, showed the benefits of producing safe leafy vegetable under low tunnel net, efficient use of water, microirrigation technologies for year-round vegetable production; and a starter solution technology for enhancing fertilizer use efficiency, early growth and improved yield of selected vegetable crops. AVRDC helps in disseminating improved germplasm/lines and other GAP technologies worldwide through the national agricultural research and extension systems (NARES), NGOs and private sectors. This is achieved through present and future research strategies now covered under the five new research themes of AVRDC that will help the farmers to improve their incomes while protecting the environment and thus provide the consumers access to safe vegetables.

(***Key words***: *AVRDC, Crop resource management, Nutritional & crop management, Organic production, Capacity building*)

Rising populations, land degradation and water scarcity for cultivation, pesticide abuse and widespread malnutrition are some of the greatest challenges facing global agriculture today. The expansion of markets and the liberalization of trade policies are providing new opportunities for both rural and urban people to escape poverty through production of high value crops, especially vegetables, the best means for overcoming micronutrient deficiencies. Moreover, demands of local, regional and international markets for vegetables are changing rapidly, fueled by health concerns and economic opportunities stimulated by the spread of supermarkets.

AVRDC- The World Vegetable Center, whose mission is to reduce malnutrition and poverty in the developing countries through vegetable R&D, is headquartered in Taiwan and has set up a new regional centre for South Asia in Hyderabad, India. Over the past 35 years AVRDC has developed a vast array of improved germplasm and technologies that address economic and nutritional needs of the poor; empower farmers; collect, characterize and conserve vegetable germplasm resources for worldwide use; and provide globally accessible, user-friendly and science based appropriate technology (AVRDC 2005). Research and development themes are focused on improving genetic resources through conservation and varietal improvement, sustainable production systems, natural resource management, post-harvest and food safety, market systems, nutrition and human health. This paper will throw light on the role AVRDC plays in developing and promoting good agricultural practices (GAPs) and technologies in vegetable production.

Genetic resource improvement and use

AVRDC had started with 590 accessions in 1972 and currently maintains more than 55,000 accessions of diverse vegetables including indigenous, making it the largest collection of vegetable germplasm worldwide. AVRDC not only characterizes and standardizes vegetable germplasm resources but also shares useful germplasm material with NARS and public and private sectors worldwide. AVRDC has developed promising lines of tomato, chilli, pepper, okra, eggplant, garlic, onion, cucurbits, soybean, mungbean, and lots of other vegetables including indigenous vegetables with high yield, nutrition and disease resistance.

Cultivar identification, release and distribution: A survey of 29 Asian seed companies indicated that 33% of tomato and 16% of chili pepper cultivars to be released in the near future contain AVRDC germplasm. More than 350 varieties have been released by national partners utilizing AVRDC breeding lines. Seventy-two percent of seed companies in Asia use improved lines from AVRDC. Within the past three decades, AVRDC has made significant progress in developing mungbean breeding lines with early maturity (55-60 days), high yield (up to 2.5 t ha^{-1}), and bold seeds. These lines are resistant to mungbean yellow mosaic virus, cercospora leaf spot and powdery mildew. Utilizing AVRDC materials, national partners around the world have developed and released to their farmers more than 110 varieties, including more than 35 in South and Southeast Asia.

For the documentation of collected and characterized material, AVRDC recently established online AVRDC Vegetable Genetic Information System (AVGRIS). The software is based on Microsoft Access and the template will be made available to NARS, and will also expand this database within SINGER (CGIAR System-wide Information Network for Genetic Resources). This is an online seed catalogue of widely adapted, well characterized and popular selections on the AVRDC website; and seeds of tomato, eggplant, okra, sweet and chili pepper, mungbean, vegetable soybean, and promising indigenous vegetable lines will be available to partners. AVRDC website will continue to be updated with new features and information and also be available in Mandarin, Spanish and French.

AVGRIS – AVRDC Vegetable Genetic Resources Information System has the passport, and is actively involved in characterization, evaluation, and IK of germplasm. AVRDC will utilize information technologies to make our resources and information more widely available to our partners.

AVRDC has also developed red onion lines that produce 50% higher yields and 70% larger-sized bulbs than the most widely grown variety, Red Creole. These new onion lines offer greater marketing opportunities for farmers with longer storage capacity. Recently, AVRDC has identified lines well suited for long term storage and developed simple practices, such as using limestone to absorb moisture, which extends the storability of soybean seeds for two years or even longer.

Nutritional improvement

AVRDC recently developed tomato lines that could resist multiple diseases as well as "golden tomatoes", which provide 3-6 times more vitamin A than the standard types. Mungbean research at AVRDC has focused both on the production and consumption side. This has resulted in the availability of short duration varieties with uniform maturity and high yields and higher iron content, and in the identification of utilization practices that increase iron bioavailability. In some coastal Asian countries the availability of new varieties has led to remarkable adoption rates, such as in Bangladesh and Sri Lanka. AVRDC has been conducting research on nutritional aspects on moringa, spinach, ipomoea, ivy gourd, amaranth, mungbean crops and has selected varieties with improved nutrition.

Crop management

AVRDC has developed and adapted integrated crop management system for safe vegetable production as a model project (Fig. 1). This system includes several important component technologies under seedling health, fertilizer management, water management, integrated pest/disease management and crop management. Vegetable crops are grown using healthy seedlings, starter fertilizer solution, balanced fertilization, water management techniques such as drip irrigation, IPM/IDM technologies, including resistant varieties, grafting, net houses or net tunnels, sex pheromones, biofumigation, colored sticky traps, and crop management techniques such as staking, mulching, raised beds, pruning and binding branches. Also, it has been shown that year round tomato production is possible using heat tolerant varieties from AVRDC; the use of tomatotone and raised beds in polytunnels in Bangladesh increased tomato yield.

Resistance and varietal adoption

AVRDC has regularly been conducting multilocation testing of its promising breeding materials in International Nurseries with its NARS partners. The promising lines are being selected for different traits like yield, nutrition, biotic and abiotic stresses.

Pest and disease management: In Asia the vegetables are grown on an area of 7.22 million ha with annual production of 630.75 t. Pest and diseases are the major hurdles in tropical Asia for

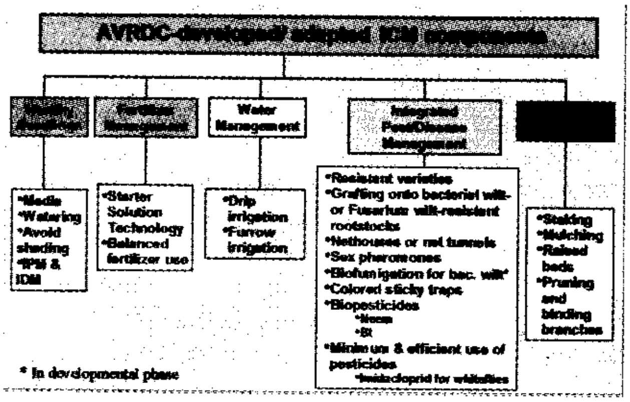

Fig. 1 Framework for integrated crop management for safe tomato production

vegetable production. For control of disease and pest the injudicious use of chemical pesticides are being used as a major control method, as vegetables are more remunerative, *e.g.* 56 sprayings in Central Luzon (Philippines) to control eggplant fruit and shoot borer are used. Many pesticides, commonly available in Asia are hazardous and banned for use in developed countries (WHO). The chronic and acute health effects like non-Hodgkin's lymphoma, leukemia, as well as cardiopulmonary disorders, neurological and hematological symptoms, and skin diseases are the pesticide use results in human beings. Moreover, the value of crops lost to pests when pesticides are not used is invariably lower than the cost of treating diseases caused by their use.

In 2002, new IPM strategies were developed that allowed pesticide free production of eggplant and leafy vegetables, two of the most heavily sprayed food crops. Recent achievements at AVRDC include virus resistant tomatoes raising farmers' income, hybrid peppers breaking the yield barrier in the tropics, flood tolerant chilies opening new market opportunities, broccoli varieties for monsoon season, pesticide free eggplant and leafy vegetables that are safer to grow and consume, and are also environment friendly. In addition, a number of technologies have been developed to shield the crops from insect pests and diseases, e.g. tomato (bacterial wilt, fusarium wilt, late blight, tomato mosaic virus, cucumber mosaic virus, tomato leaf curl, and other gemini virus); chilli (leaf curl virus, Anthracnose, wilt, powdery mildew); eggplant (eggplant fruit and shoot borer, wilt disease, bacterial wilt); okra (powdery mildew, yellow vein mosaic virus); and mungbean (yellow vein mosaic virus, cercospora leaf spot, powdery mildew, bruchid). AVRDC regularly conducts trials for disease management and screening of resistant varieties of these crops in its INM.

For the past several years AVRDC has been developing and refining the grafting technology as the one for controlling and managing soil borne diseases of tomato such as bacterial wilt (BW), the most destructive disease in Southeast Asia. The control mechanism in grafting is the scion/rootstock (RT) combination. Both scion and rootstock contribute to control the disease, but RT contribution is more important than scion. Therefore, selection is being done carefully for a stable resistance to BW, fusarium wilt (FW), and root knot nematode (RKN). Generally, grafted tomatoes have smaller fruit size than non-grafted plants. A good combination should aim for larger fruit size and higher yield. AVRDC has promoted the grafting technology for cherry tomatoes in Taiwan through on-farm testing and has made some impact in terms of higher percentage of adoption by Taiwanese farmers. Eggplant and tomato grafting technology, developed by AVRDC, has the potential to become a cottage industry that provides employment and income.

In addition to this, the promotion of indigenous vegetables (IVs), which are a neglected lot today, can reduce both poverty and malnutrition. In mungbean, farmers have eagerly accepted the early maturing and disease resistant lines, and AVRDC's partners are producing tons of seed to meet the demand. AVRDC with NARS partners have identified a number of indigenous vegetables and promoted these and their production technologies in Tanzania, Bangladesh, Africa and coastal parts of India.

Safe/protected management: AVRDC research work translated into new technologies showed the benefits of producing safe leafy vegetable under low tunnel net, efficient use of water, microirrigation technologies for year-round vegetable production; and a starter solution technology for enhancing fertilizer use efficiency, early growth and improved yield of selected vegetable crops. AVRDC Crop Management Unit has been developing and promoting simple plastic rainshelters and net houses for year-round vegetable production especially during the rainy season. Two types of rain shelter have been tested for growing leafy and fruit vegetables. The single and double bed rain shelters effectively provide protection against the heavy impact of rainfall during the wet season for tomato, sweet and chilli peppers, cucumber, yardlong bean, bitter gourd, Chinese cabbage, lettuce, and okra. The simple plastic rain shelters have been introduced in the Philippines, Cambodia, Laos and Vietnam. Farmer managed trials demonstrated the effectiveness and efficiency of net cover in protecting leafy vegetables against insect pests and impact of heavy rains. It was shown that insect population and damage were lower under net cover than in the open field. Marketable yields were higher under net cover than in open field resulting in higher gross and net revenues. Vegetables grown under net cover are of high quality (no insect damage) and free of pesticide residues since there was no need for spray application compared to vegetables grown in open field.

Water management: Drip irrigation - a technology for managing water and nutrient in soil-rhizosphere system. Hand watering by sprinkler cans is inefficient in both water and labour use, moreover, global climatic changes are resulting in uneven distribution of water, due to either scarcity of water (drought) or excess water (flood) in many regions of the world. Water is increasingly becoming a scarce resource even in the humid tropics. Therefore, there is a need to develop technologies that promote efficient use of water and fertilizers in vegetable production. Although drip irrigation developed in early days was a labour saving practice, it is now an imperative technology for managing water and nutrient in soil-rhizosphere system. Drip irrigation uses less volume of water and increases land area under irrigation. Furthermore, it promotes more efficient use of fertilizers due to reduced nutrient leaching. It improves yield and quality of vegetables and reduces spread of soil borne diseases and the risk of ground water contamination and pollution as well. Low cost drip irrigation system for developing countries is being popularized by AVRDC because it is easy to access water and provide efficient utilization of it. The low cost drip system developed by the International Development Enterprises (IDE) has been utilized at Aurungabad (India), Nepal, Cambodia and selected countries in East Africa. Drip irrigation reduces soil borne diseases like southern blight in pepper. Furthermore, N fertilizer can be applied with drip (fertigation) thus, saving labour cost in fertilizer application. The advantage and benefit of drip irrigation were also demonstrated on tomato trial in Cambodia.

Soil management: AVRDC integrated soil management research involves starter fertilizer solution, composting and use of organic fertilizers for efficient nutrient use and improved soil and crop quality. The major objective of the soil management research is to improve the efficiency of fertilizers and produce vegetables that are safe for farmers, consumers and the environment. Soil management research is based on improving practices for managing soil fertility in the soil-rhizosphere system (Fig. 2).

For achieving fast fertilizer responses, farmers tend to apply in excess both organic and inorganic fertilizers in intensive farming system. Excessive applications of fertilizer cause environmental pollution and human health hazards. On the other hand, improper fertilizer management also results in nutrient imbalance in soils and creates land degradation in many countries. Asian farmers urgently need judicious fertilization strategies that can improve the efficiency of nutrient uptake by plants and minimize environmental risks. When plant roots are injured due to transplanting, disaster or heavy rain, it is crucial to receive an instant, readily available nutrient for facilitating the recovery. Based on this concept, the Starter Solution Technology (SST) was developed for enhancing early growth and overall yields of vegetable crops tested (cucumber, tomato, chilli pepper, cabbage, lettuce, etc.).

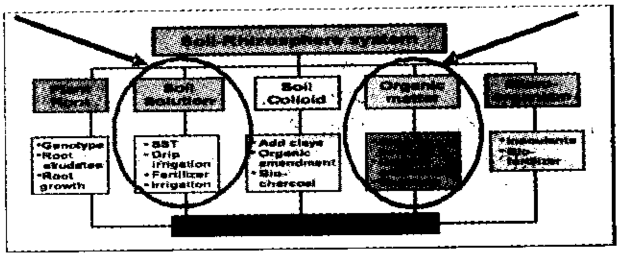

Fig. 2. Practices for managing soil fertility in the soil-rhizosphere system

In SST readily available nutrients are directly supplied to the soil-rhizosphere system. Small amounts of very concentrated inorganic fertilizer solution are applied to rhizosphere soils immediately after transplanting which build up high nutrient gradients in soil solution providing young plants with readily available nutrients before their root systems are well established, thus, enhancing initial growth. Healthy young plants can be more tolerant to environmental stress and increase their early yields, which can increase income to farmers. Unlike field crops, vegetable crops in general have great nutrient demands in a relatively short growth period. Plant's roots have difficulty in taking up nutrients directly from soil particle surface. In general, the roots take up nutrients from the soil solution. Most of the nutrients applied to soils are attached either to soil particles or to part of the organic matter. Only a small proportion of the total nutrients in soils are in solution. Therefore, all the nutrients must be dissolved in soil solution before they can be taken up by plants. Sustaining adequate NPK concentrations in the soil solution from sowing to harvesting is crucial for increasing productivity. After adsorption on soil surface and interaction with organic matter, it can still tentatively raise high nutrient gradients in soil solution around soil-rhizosphere system. Initial growth of plant and root can be greatly enhanced by this single application of starter solution. When fertilizers are applied in solid form, they need to be dissolved first, then diffuse or flow to the root's vicinity. The processes may take few hours or days. It is not able to meet the immediate requirements of the transplants. Direct injection of the starter solution to rhizosphere soil, just like injection of booster solution to the plants, provides vital nutrients and has instant effect on plant growth. SST is developed based on ecology-friendly concept and plant's nutrient requirement principle. Farmers can easily adjust the concentration and timing of application to fit their crops and soils. It provides a new fertilization option other than conventional fertilization method. According to many experimental results conducted at AVRDC, the most optimum concentration of starter solution for many vegetables tested is 240 mg each of N-P_2O_5-K_2O in 50 ml solution for each plant. By conversion to concentration, the starter solution is 4800 ppm (mg L^{-1} of N-P_2O_5-K_2O).

Organic vegetable production

Organic agriculture in tropical Asia, Africa and Latin America is growing rapidly and the markets for organic vegetables are expanding in response to increasing demands in developed countries. Sustained growth in organic vegetable production and marketing in developed and developing countries opens a new window of opportunity for AVRDC to initiate organic vegetable research and development programme.

Crop protection, soil fertility and nutrition, availability of resistant varieties and their seeds as well as the markets for organic produce are the major constraints to organic vegetable production in Southeast Asia. Therefore, there is a need for organic research and development to develop suitable and science based components for organic vegetable production that can be integrated into organic farming systems in addition to other conventional production systems. Moreover, for organic vegetable production there is a need for multidisciplinary approach. AVRDC's organic vegetable research and development is based on a multidisciplinary approach (Fig. 3).

AVRDC-The World Vegetable Center has recently initiated research on organic vegetable production, which is considered to be safe for consumers, farmers and the environment. So far three donors are supporting AVRDC's Organic Vegetable Programme including (1) Deutsche Gesellschaft fuer Technische Zusammenarbeit (GTZ) under the Federal Ministry for Economic

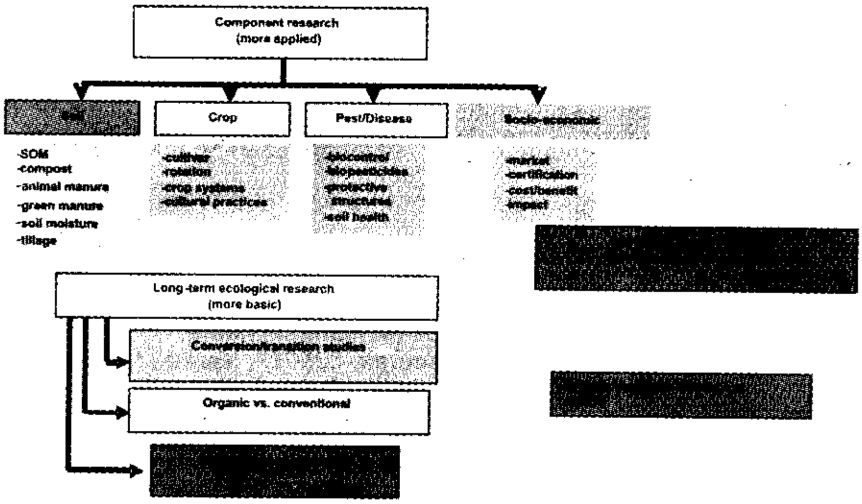

Fig. 3. Framework of AVRDC Organic Vegetable Research and Development

Cooperation and Development (BMZ), Germany, (2) The Organic Center for Education and Promotion, U.S.A., and (3) COA the Council of Agriculture, Taiwan ROC.

Capacity building

AVRDC-the World Vegetable Center works with partners from both the public and private sector. In 2005 over 250 agricultural professionals and students were provided with training in advanced vegetable production where one of each five candidates comes from the seed industry. A good number of scientists, extension specialists and lead farmers are given training each year. Moreover, the frontline trainings for research and extension professionals backed up by extensive web and library services are provided through AVRDC's regional centres. Regional centres also provide short term and long term training courses and research facilities for graduate, post-graduate and Ph. D. students.

CONCLUSION

AVRDC is disseminating improved germplasm/ lines and other GAP technologies worldwide through the national agricultural research and extension systems (NARES), NGOs and private sectors. It recognizes the constraints influencing vegetable production worldwide as well as global needs that have to be addressed. USAID global horticulture assessment study for vegetables put high priority on genetic resources conservation and development, sustainable production systems and natural resource management, post-harvest system and food safety, market systems, and nutrition and health. AVRDC CEM Unit is playing an important role in addressing these needs through its R&D programmes in developing countries. This is achieved through present and future research strategies now covered under the five new research themes of AVRDC that will help the farmers to improve their incomes while protecting the environment and provide the consumers access to safe vegetables.

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Integrating Tuber Crops in Coastal Agroecosystems of India: Current Developments and Future Prospects

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In the coastal ecosystem of India, though rice is the principal crop, tuber crops like sweet potato, aroids, yams and sweet potato are grown as sole crops in many pockets, in homestead, and as an integrated practice under various farming systems. The tuber crops are mostly grown under rainfed condition, which are also suitable for coastal ecosystem, but the productivity is better under irrigated conditions. Some of them have drought resistant characteristics, grown in low management conditions, and produce yield where other crops fail. These crops provide food and nutritional security to a large number of people in many developing countries. Besides, they offer tremendous potential in animal feed and starch industries. In India, these crops are grown mostly as subsidiary vegetables, except cassava, which has been utilized in Tamil Nadu and Andhra Pradesh as a source of starch for the manufacture of sago, textile and paper industries. Research in India has led to several technologies such as high yielding/early maturing varieties, production system for various agroecological zones, integrated pest and disease management practices for better production and, thereby enhance the prospect of utilization in the food, feed and industrial sector, etc. However, due to lack of awareness, marketing problems and government policies the potentials of these crops for socioeconomic improvement of small and marginal farming communities has not been fully exploited. This paper discusses the current development and future prospects of tuber crops in agricultural development and its potential in food, feed and income generation of small and marginal farming communities in India, and its integration in coastal ecosystem.

***(Key words:** Research development, Industrial prospect, Cassava, Sweet potato, Yams, Taro, Elephant foot yam)*

The coastal agroecosystem of India alongside the East and West coast regions comprises of states of Orissa, West Bengal, Andhra Pradesh, Tamil Nadu, Kerala, Karnataka, Goa, Màharsahtra, Gujarat and Lakshadeep. This region occupies commendable position in the export of horticultural produce, spices and marine products to the international market besides supporting the livelihood of several million people with diverse socioeconomic conditions. However, the agricultural scenario in this region is not bright due to acute water scarcity, rampant soil erosion, depleting biodiversity and possible threat of rise in sea level due to global warming. The states like West Bengal, Orissa and Andhra Pradesh, in particular, are prone to cyclones, floods and frequent droughts. The above problems, one and all, are compounded with widespread poverty and malnutrition. The tuber crops could come as a saviour for improving socioeconomic conditions of the small and marginal farmers in this ecosystem which are by and large constrained due to various factors.

Tuber crops – a saviour in coastal agroecosystem

Tuber crops, though traditional food of human beings during the early days of evolution, gradually lost their importance owing to modern life style and food habits. However, their potential remained the same or even enhanced with time through persistent research efforts. With the emerging agricultural scenario to develop new ways of producing and consuming crops, owing to stagnation in productivity and associated problems, tuber crops could take new roles. These crops have a higher biological efficiency as food producers and show the highest rate of dry matter production per day per unit area among all the crops. They are also recognized as the most efficient converters of solar energy, with cassava producing 250×10^3 kcal ha^{-1} and sweet potato 240×10^3 kcal ha^{-1} as compared to 176 x 10^3 for rice, 110 x 10^3 for wheat, and 200 x 10^3 kcal ha^{-1} for maize. These crops supply cheap source of energy especially for the weaker sections of the population.

Due to their adaptability to wider soil and environmental conditions, it is considered as important in many developing countries. Tuber crops like cassava and sweet potato have the ability to survive under extreme weather conditions and could produce reasonable yield, where other crops do not, due to adoption of appropriate agronomical characteristics in case of the former.

Tuber crops, besides producing substantial amount of energy, also supplies reasonable amount of vitamins and minerals. While cassava and sweet potato supply good amount of ascorbic acid, the orange or yellow flesh sweet potatoes supply essential beta-carotene, which can prevent night blindness and malnutrition prevalent in many parts of the country. Besides, taro and yams supply good quantities of calcium, phosphorous and iron. Yams also supply reasonable amount of proteins.

Owing to their faster growth and short duration, sweet potato is popular as animal feed in many developing countries. Cassava based animal feeds like silage and palette poultry feed are popular in Southeast Asian countries. In Northeastern region, cassava sweet potato and aroids plant parts are fed to animals after boiling. Recent FAO estimates indicated 65% of total sweet potato output in China and 35% in Brazil are used as animal feed. Besides, the sweet potatoes can yield large quantities of fodder in a shorter time period.

Tuber crops – an Indian scenario

Tropical tuber crops are cultivated in India mainly in the Southern, Eastern and Northeastern states. Cassava is grown in India in an area of 2.6 lakh hectare with a total production of 6.7 million tonnes. Cassava production is mainly from the states of Kerala, Tamil Nadu and Andhra Pradesh. Cassava is primarily an industrial raw material for starch extraction in Tamil Nadu and Andhra Pradesh. Over 1100 starch factories, spread over the Salem belt, provide employment to about 5 lakh people of the state. These industries also provide direct/ indirect employment to over 20000 people in this region. Sweet potato is cultivated mainly in the states of Bihar, Orissa, West Bengal and Eastern Uttar Pradesh. Commercial cultivation of Yams and Aroids is popular in Andhra Pradesh, Tamil Nadu, West Bengal, Uttar Pradesh and Orissa states.

Research developments in tuber crops

There are 15 different tuber producing species which form the mandatory crops of the Central Tuber Crops Research Institute, Thiruvananthapuram including two major crops of cassava (*Manihot esculenta*) and sweet potato (*Ipomeas batatus*), three yam species (*Dioscorea alata, D. esculenta* and *D. rotundata*), five aroids species (*Colocasia esculenta, Xanthosoma sagittifolium, Amorphophallus paeniifolius, Alocasia macrorrhiza, Cyrtosperma chamissionis*) and five minor tuber crops (*Solenostemon rotundifolius, Pachyrrhizus erosus, Maranta arundiacea, Psophocarpus tetragonolobus, Canna edulis*).

Research at CTCRI has led to several innovations, such as development of improved high yielding/early maturing varieties, appropriate cropping systems for various agroecological zones, integrated pest and disease management packages for improved production, technologies to reduce post-harvest losses, and enhancing the prospects of utilization in the food, feed and industrial sectors, etc.

Cassava

In India, cassava is mostly grown both as irrigated and rainfed crop. In Tamil Nadu, Andhra Pradesh and Kerala, it is commercially grown under irrigated conditions mainly for raw materials for industries such as starch. Cassava comes up well in all types of soils, except saline, alkaline, heavy and ill-drained soils. Besides, for tribal and disadvantaged people in all the states, this forms an important secondary staple in their diet, so they cultivate it.

The research conducted at CTCRI has yielded 15 improved cassava varieties including Sree Padmanabha, a cassava mosaic resistant variety that are suitable for a wide range of farming systems in India. Important technologies like rapid propagation technique, improved nutrient management studies under rainfed conditions, incorporation of biofertilisers -AM fungi and phosphobacteria, preventing soil loss and runoff from cassava fields by growing multiple crops like banana and coconut, have been generated.

Cassava is a popular crop in the multitier systems of homestead farming in Kerala, Karnataka and Tamil Nadu. In Kerala, in the coconut based multitier cropping systems, tuber crops like cassava, elephant foot yam, greater yam and taro were cultivated. The tubers are commonly grown in bottom layer of the homesteads. This system could be replicated in other states to maximize yield.

Cassava is also raw material for sago and starch industries and a component of animal, fish and poultry feeds. Cassava starch is better than potato or maize starch, as the tubers are practically free from non-starchy constituents like protein and lipids and hence the extraction is easier and direct. Cassava starch finds application in an array of industries in India – textiles, corrugation box, liquid gums in domestic sector, paper industry, etc., besides food and sago industry are also the major ones. Environmentally degradable plastic products involving cassava starch has been developed and commercialized in India through NRDC. Technology for economic production of alcohol from cassava tubers has also been developed.

Sweet potato

Sweet potato is an important crop for food, feed and raw materials for industries. The crop can be grown in marginal soil with less input. It is ecofriendly in the sense that it is fast growing and covers soil rapidly to prevent soil erosion. Its roots and leaves are highly nutritious besides providing high dry matter. Sixteen sweet potato varieties with important horticultural attributes, which could contribute to food and nutritional security, besides having flexibility to adapt to the existing farming systems, have been developed.

In the coastal regions of Orissa including Cuttack, Puri and Balasore districts that are prone to cyclones, sweet potato is an important crop blessed with abilities to survive under adverse climatic conditions. In this view, the Regional Centre of CTCRI, Bhubaneswar has participated in a project during 2001-2005 for restoring coastal agroecosystem of Orissa affected by supercyclone. Under this project, 16,00,000 sweet potato cuttings, 44 q colocasia, 36 q elephant foot yam, 41 q yam, 12 kg yam bean and 10750 cassava setts were distributed free of cost to 2400 affected farmers that helped in restoring seed system. Demonstration trials with sweet potato revealed that it could yield reasonably under such conditions. Varieties like Gouri, Sankar, Pusa Safed, Sree Bhadra, Kalinga, Gautam and Sourin are commercially suitable for cultivation in coastal regions of Orissa.

Sweet potato is grown as rainfed crop during rainy (*kharif*) or autumn (*rabi*) seasons and as irrigated crop during other periods. Besides standardization of production technology, cropping sequences for different growing areas have been worked out. Raising sweet potato after *kharif* maize is suitable for Eastern states. In West Bengal, elephant foot yam-sweet potato-moong or taro-sweet potato-moong; while in Orissa paddy-sweet potato-fallow, and in Tamil Nadu and Andhra Pradesh vegetable cowpea-sweet potato sequences are profitable. Sweet potato weevil is the most important pest causing damage to vines and tubers. An Integrated Pest Management strategy using pheromone traps and adopting crop rotation with rice is effective against sweet potato weevil.

For industrial processing, starch and dry chips of sweet potato have been used as raw materials in the manufacture of products such as deep processing starch, alcohol, liquid glucose, high fructose syrup, maltose citric acid and monosodium glutamate, and for food processing, fresh roots dry flour or starch can be used for noodles, fried chips, canned flakes and candid pulp production. In feed processing, the main product is sweet potato flour used by the compound feed industry. Wine, sweet potato curd, pickles have also been developed. As its vines can withstand drought better than many other common fodder crops, the vines can be used as fodder for cattle during off-season.

Yams

In India, yams are grown as rainfed crops and the tubers are mainly consumed as vegetables. They are also useful for processed products like fries and chips. Yam starch resembles sweet potato starch in respect of many chemical atributes. It is a common vegetable in various food preparations like *dalma*, chat and various curries in Orissa.

Extensive research at CTCRI has produced ten yam varieties including greater yam (5 nos.), lesser yam (2nos.), white yam (3 nos.). Among yam varieties, Sree Dhanya is a highly promising dwarf type, which eliminates the cost of staking. In case of greater yam, Sree Shilpa, Sree Keerthi and Sree Roopa for Kerala, Orissa elite, Hathi khoj for Orissa, and CoDa-1 for Tamil Nadu are commercially cultivated. Sree Latha is a lesser yam variety suitable for West Bengal, Kerala and Andhra Pradesh, whereas Konkan Kanchan is a suitable variety for Maharashtra.

Production technology of greater yam has been standardized. Intercropping with maize not only enhances cost-benefit ratio per unit area but also saves costly operation like staking. Growing sweet potato variety, viz. Sree Bhadra as a trap crop can control nematode pests of yams and Chinese potato. Yam is a suitable crop for multistoried cropping systems of Kerala, Karnataka and parts of Andhra Pradesh and Tamil Nadu.

Taro

Taro is native to Northeast region and is an important vegetable in many households. The corms, cormels and pseudostem are good source for pig feed. Starch of taro is very fine and is used in cosmetic industry and also as filler material for biodegradable plastic material. Taro is well grown in humid environment and it flourishes under shaded condition. The corms are baked or cooked and eaten like potato. It has longer shelf life than cassava and sweet potato. However, its industrial utilization has so far been very limited in India.

Eight taro varieties were released for the farmers of various states of India. Taro varieties like Satamukhi for Andhra Pradesh, Maharashtra, Karnataka and West Bengal; Muktakeshi, Jhankri and Sonajuli for upland conditions, Panisaru 1 and Panisaru 2 for wetland conditions in Orissa, and Sree Reshmi, Sree Kiran and Sree Pallavi for Kerala are the ideal ones. Production package of taro for different conditions have been standardized.

Phytophthora leaf blight is a common disease affecting taro in coastal states. This yield loss is estimated to the extent of 20 % to 90% in severe cases. Tolerant varieties of taro, *viz.* Jhankri and Muktakeshi with high yield potential have been developed which have good scope for improving the taro productivity level in coastal states.

Elephant foot yam

It is an important vegetable and commercially grown in many parts of India. Though it is a long duration crop, the importance of the crop as intercrop with coconut and banana is well recognized. Among the edible tuber crops, elephant foot yam can be stored for a longer period or can be harvested at any time after attaining the required size. So, during off-season when other vegetables cannot be found in market this crop can be sold at a higher price. The CTCRI has released two elephant foot yam varieties, namely Sree Padma and Sree Athira. Varieties like Gajendra, Sree Padma, Bidan Kusum and NDA-9 are the important ones identified for West Bengal and Uttar Pradesh. Among them Gajendra with an yield potential of 50 to 80 t ha^{-1} in 180-200 days is popular all over India. In Eastern India, cropping sequence of elephant foot yam-wheat/Bengal gram/pea or elephant foot yam-okra/taro is found to be profitable. During the initial period of 2-3 months after planting, crops like leafy vegetables, green gram, black gram, cowpea, cucumber; etc can be grown as intercrops.

Intercropping of elephant foot yam in banana, coconut and other newly planted orchards gives additional income to farmers. In the coastal state of Kerala, where the cultivated land is limited, this technology could maximize farm income with minimal expenditure. Besides, yam can be integrated well in the homestead gardens of Kerala, Karnataka, Tamil Nadu and other coastal states.

CONCLUSION

The problems like non-availability of quality planting materials, lack of knowledge and skills on improved technologies, lack of awareness among the potential entrepreneurs to start processing units, marketing problems, inadequate storage facilities, and stiff competition with other crops affect the transfer of tuber crop technologies. The socioeconomic strategies like popularization of tuber crops as alternate crops, integrated product development, production and distribution of quality planting materials, participatory technology development, capacity building and market regulation with government policy support will improve tuber crops scenario. So it is high time for various stakeholders involved in agricultural development to promote tuber crops among the farming communities for food, feed and income generation.

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Soils and Land Use in and Formation of Lakshadweep Islands

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Lakshadweep Islands are coral islands in the Indian waters of Arabian sea. Darwin suggested the formation of coral islands highlighting simultaneous subsidence of volcanic formation and growth of fringing reefs to develop centre-island-free ring reefs. An attempt is made in this paper to describe the soils, explain the formation of these islands and to present the land use scenario.

***(Key note:** Lakshadweep coral islands, Soil formation, Land use)*

The Islands have formed along the eastern fringe of the atolls with a southwest – northeast orientation in the case of Minicoy, Kavaratti and Amini Islands and a north-south orientation in the case of Kalpeni and Kadmat Islands. The position and orientation of the Islands inside the ring reefs are the result of sea surface circulation and wave action which follow seasonal monsoon (southwest monsoon) winds. The sea surface circulation in the Arabian Sea is stronger and steadier during southwest monsoon compared to those in the northeast monsoon. During the southwest monsoon the surface currents in the open ocean are eastwards and clockwise in direction due to the coastal configuration. It flows northeastwards along the Arabian Coast and southwards along the Indian Coast as wind driven ocean current (Boievert, 1966, Prasad, 1951). Where reefs grow up in shallow seas, bottom currents (both geostrophic and tidal) may exert a great influence on reef from right in the beginning of the reef building by depositing sediment to the leeward side of the initial coral colonies and by transporting there coral larvae which subsequently initiate reef growth on these leeward sediments (Fairbridge, 1968). This action of sea current is accompanied by the Island building action of the wind and the waves. These factors begin to play role in the reef upgrowth to sea level. The waves gaining energy from the east and northeastward blowing monsoon winds break the western portion of the ring reefs and carry the coral shingle and sand towards the eastern portion of the reefs. As a result, ramparts of coarse shingles are deposited at some distance from the reef edge. The finer fragments and coral sands are carried further on by the waves and come to rest along the eastern part of the ring reefs as noticed in Minicoy, Kavaratti and Kalpeni Islands or in the lagoon when the wave energy is greatly diminished as observed in Kadmat and Amini Islands where the sand cay started forming at some distance from the eastern ring reefs. The Islands or the cays are thus formed, whose position on the reefs is determined by the frequency and force of waves and winds coming from southwest. This kind of deposition by waves is a continuous process, the earliest deposit occupying the easternmost part of the atoll followed by subsequent deposits.

The mere presence of these Islands show that they also have been growing upwards keeping pace with sea level changes in the post-glacial period. According to Wood (1983) 15,000 years ago the seas were about 120 m lower than where they are now, and 7000 years ago they were about 20 m below the present level. The sea level change should have been slow and gradual during these periods. Had it been a sudden process, these coral Islands would not have existed because corals can grow in only shallow waters. The fact that the corals kept growing during sea level changes support the conclusion that the sea level changes were slow and gradual. Therefore, the modern reef growth related to the present sea level must have begun only about less than 5000 years ago (Wood, 1983).

Session 3 : Soil Resource Management and Inventorization

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Soils

Several pedons in the Islands of Minicoy, Kavaratti, Kalpeni, Kadmat and Amini were studied in west-east transects. The results show that the colour of the soils near the western coast was lighter with high values and it darkened progressively in the pedons of the central and eastern parts of the Islands. Some other properties also followed similar higher developments in the eastern parts. They are heavier in texture with increasing clay content (sand to sandy loam), with better aggregation of peds, stronger calcium carbonate cementation in the subsoils, and higher organic matter content. Thus, the increase in pedogenic activities in the soils showed that the Islands are older in the eastern parts than in the west.

Land use

Coconut plantation forms the major land use. Vegetable crops are also grown in some places over small areas. Though the soils are sandy coconut yields are good under proper management. A cropping system (intercropping) experiment conducted at ICAR Research Station, Minicoy produced 18,000 to 21,000 nuts (180 palms) and 2 to 4 tonnes of banana from 1 hectare in 1 year. The net return ranged from Rs.10,000 to Rs.19,000 (Muralidharan and Bopaiah, 1993) over the years. Another experiment on organic manuring produced 30 tonnes of brinjal per hectare. Other vegetable crops, such as tomato, cowpea, gourds, chilli, radish, amaranthus, etc. produced yields of 20 tonnes per hectare when organic manure was added and supplementary irrigation provided (Anon., 1994). Thus with addition of organic manures, chemical fertilizers in several splits alongwith supplementary irrigation cultivation of vegetable crops and coconut is profitable with high yields.

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Management of Soil Fertility for Sustaining Crop Productivity in Coastal Agroecosystem in India

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The coastal agroecosystem in India covers an area of 10.78 million ha of land along the 8129 km coastline of the country, extending over the coastal belts of West Bengal, Orissa, Andhra Pradesh, Tamil Nadu, Kerala, Karnataka, Maharashtra, Gujarat, Pondicherry, Goa, Duman & Diu, Andaman & Nicobar islands and Lakshadweep & Minicoy islands. The soils of the coastal region are highly variable in nature due to their differences in parent materials, climate, drainage characteristics, vegetative cover, relief, topography, hydrological and hydrochemical characteristics, etc. About 3.1 m ha of land under the coastal agroecosystem has soil salinity > 4.0 dSm^{-1}, which pose a greater fertility and other management problems. Such soils vary in their levels of salinity and kinds of salts present. Because of diverse nature of soil, climatic and agroecological conditions the soil fertility problems are also diverse in the coastal region. The coastal soils are generally low in available N & organic carbon and low to high in available P. The soils are usually well supplied with micronutrients except Zn.Balanced fertilization is essential for sustainable crop production. Since, nitrogen is the major deficient nutrient application of nitrogen is very beneficial for all the crops on coastal soils although the efficiency of inorganic nitrogen fertilizers is very poor. A considerable portion of applied nitrogen fertilizer is lost through volatilization which increases with increase in soil/ water salinity. The volatilization loss can be reduced and N use efficiency can be increased by placement of fertilizers in soil, and combined use of inorganic fertilizers and organic manures. The coastal soils are usually rich in available K and do not require application of K fertilizers. However, light textured red/ lateritc soils and sandy soils may be deficient in available K. The acid sulphate soils of Kerala, West Bengal, Andaman islands, etc. are highly deficient in available P and application of organic manures along with lime and higher doses of P fertilizers are very effective for higher productivity. Due to reduced root volume of plants, presence of excess amount of salt cations and anions in root zone soil and lack of scope for proper water management the efficiency of fertilizers are low on coastal soils. Hence, the fertilizer management of coastal soils need special attention. Regular application of organic manures improves the microbial properties, soil quality and efficiency of fertilizers which leads to sustainable higher crop yields. Application of amendments like gypsum, paper mill sludge, sugar mill spent wash, green manure, FYM, etc. showed significant improvement in yield of crops on the alkali soils of the coastal Tamil Nadu, Maharashtra and Gujarat. The yield of rice on alkali soils increased significantly with increase in N levels and more so when nitrogen was applied with gypsum and Gypsum + FYM. Application of inorganic fertilizers in combination with organic manures have been found to be very beneficial in stabilizing the productivity of coastal soils. The integrated use of organic and inorganic sources of nutrients along with biofertilizers has been found to be very effective in maintaining higher sustainable productivity through providing favourable, physical, chemical, biological and biochemical conditions in soils for better crop growth.

***(Key words:** Coastal saline soils, Nutrient management, Integrated nutrient management, Soil characteristics)*

The coastal region is the transitional zone or the interface between the land and the sea and it has no clear boundary or demarcation. The region is diverse in function and form and is highly dynamic in nature with a fragile ecology. The coastal agroecosystem in India spreads over a narrow strip of land along the 8129 km coastline of the country, extending over the coastal belts of the states/union territories of West Bengal, Orissa, Andhra Pradesh, Tamil Nadu, Kerala, Karnataka, Maharashtra, Gujarat, Pondicherry, Goa, Duman & Diu, Andaman & Nicobar islands and Lakshadweep & Minicoy islands. The coastal agriculture has a unique characteristic of co-existence of agricultural crops and aquaculture. No uniform nutrient management practice for the coastal region can be prescribed as the soils are of widely different characteristics and distributed over diverse agroclimatic conditions. The nutrient management for coastal soils are essentially location specific. However, in the following paragraphs broad outlines on nutrient management of coastal soils have been presented.

Characteristics of coastal soils

Out of 10.78 million ha of land under the coastal agroecosystem in India about 3.1 m ha of land is saline which poses further greater problems to agriculture (Velayutham *et al.*, 1999, Yadav *et al.*, 1983). The coastal soils vary widely in their characteristics depending on their physiographic locations, climatic conditions, parent materials, soil forming processes, characteristics of groundwater at the proximity of the soil surface, etc. The management problems of coastal soils at different locations, therefore, vary greatly (Sen *et al.*, 2000). All the coastal saline soils have common characteristics of presence of saline ground water table at shallow depth. Some of the major problematic soils found in the coastal region of India are saline soil, saline-alkali soil, alkali soil, acid sulphate soil, eroded soil, marshy soil, waterlogged and impeded drained soil, rocky soil, muddy flat, coastal sandy beach, etc., which are formed on the major soil types of deltaic alluvium, red & lateritic, and black soil. Taxonomically majority of coastal soils (Table 1) are of the order of Entisols and Inceptisols (Bandyopadhyay *et al.*, 1998) indicating that the soils are in the initial stages of formation.

The coastal soils also vary widely in their textural class from sandy to clay but majority are under heavy textured (Bandyopadhyay *et al.*, 1987) soil classes. Singaravel and Balasundaram (2001) studied the coastal saline soils of Tamil Nadu and found that the textural class of the soils varied from sandy to sandy clay. Polara *et al.* (2004) studied the coastal soils of northwest Gujarat and found that most of the soils were sandy to sandy loam in texture and contained considerable quantity of $CaCO_3$ (6.4%). Dominant exchangeable cations were Ca^{2+} and Mg^{2+}, followed by Na^{+} and K^{+}. Bandyopadhyay *et al.* (2003) found that coastal soils of West Bengal were mostly heavy textured silty clay loam to clay.

The coastal soils have also widely variable pH and base saturation varying from very acidic (pH<3.5) acid sulphate soils to highly alkaline (pH >10) sodic soils (Table 2). However, most of the soils are near neutral in pH (Bandyopadhyay *et al.*, 1987). Highly acidic soil horizons (surface or subsurface) with characteristics of acid sulphate soils are found at places in the coastal states/union territories of Kerala, West Bengal, Orissa and Andaman & Nicobar group of islands (Bandyopadhyay and Bandyopadhyay, 1984a, Bandyopadhyay and Maji, 1995). The salinity of coastal soils varies with the season, highest being in summer and lowest in monsoon season. The salinity (ECe) of coastal also

Table 1. *Coastal areas in India and the soil types*

State/Union Territory	Coast Line (km)	Coastal area (Mha)	Saline soils (Mha)	Major soil types
West Bengal	157.5	1.4152	0.820	Vertic Haplaquepts, TypicFluvaquents
Orissa	476.4	0.7900	0.400	Aeric Tropaquepts, Vertic Tropaquepts
Andhra Pradesh	973.7	3.5500	0.118	Chromic Haplusterts
Tamil Nadu	906.9	3.5500	0.100	Psammentic Paleustalfs
Kerala	569.7	0.7719	0.026	Typic Sulphaquents
Karnataka	280.0	0.7424	0.086	Aquic Ustifluvents
Maharashtra	652.6	1.0000	0.063	Udic Paleustalfs
Goa, Duman & Diu	160.0	0.0200	0.018	Fluventic Ustropepts
Gujarat	1214.7	1.7465	0.714	Typic Natrargids, Typic Calciorthids
Andaman Islands	1962.0	–	0.015	Typic Hapludolls, Haplic Hydraquents
Lakshadeep Islands	132.0	0.0026	-	Typic Ustipsamments,
Pondicherry	30.6	0.0003	0.001	Typic Ustorthents

Table 2. *General characteristics of some coastal soils in India*

$pH_{2.5}$	CEC(me/100g)	BS(%)	OC(%)	Av.P	Av.K
W. B.:Dist.- Medinipur: Fine, mixed, hyperthermic, Vertic Haplaquepts					
6.3	19.5	70	0.5-0.8	M-H	H-VH
W.B.: Dist.- 24 Pargs (S) : Fine, loamy, hyperthermic, Typic Fluvaquents					
7.2	12.6	78	0.5-0.7	M-H	H
Orissa: Dist. Balasore: Fine, loamy, Arirc Tropaquepts					
6.7	12.8	75	0.3-0.5	L-M	H
Orissa: Dist. Puri: Very fine, Vertic Tropaquepts					
4.5	35.1	49	0.2-0.4	L	H-VH
A.P.: Dist. –Godavari:Very fine , Chromic Haplusterst					
8.1	16.8	97	1.1	L-M	H
TN: Dist.: VOC: Sandy , mixed, isohyperthermic Psammentic Paleustalfs					
5.1	6.6	71	0.1-0.2	L-M	M
Kerala: Dist. Alappuzha: Fine, mixed, Typic Sulfaquents					
3.2	26.4	57	9.2	L	H
Kerala: Dist. KannurClayey-skeletal, kaolinitic,Ustpxic Humitropepts					
5.6	6.0	56	2.6	L	L
Karnataka:Dist. Kannada: Aquic Ustifluvents					
5.2	4.6	35	1.2	L	L
Maharashtra:Dist. Ratnagiri:Fine, mixed, isohyperthermic, Udic Paleustalfs					
6.8	20.8	72	0.7	M-H	H
Goa: Dist. North Goa: Loamy-skeletal, Fluventic Estropepts					
5.4	3.5	53	0.6	L	L
Lakshadweep:Chetlat island: Carbonatic, isohyperthermic, Typic Usti psamments					
8.5	5.9	100	0.5	M	H
Gujarat: Bhal region: Fine, Typic Chromusterts					
8.2	-	98	0.1	M	H
Gujarat: Sosia region: Fine, Typic Chromusterts					
8.0	-	93	0.5	M	H
Gujarat: Lakshpat region: Fine, Typic Natrargids					
8.7	-	100	0.3	M	H

L, low; M, medium; H, high; VH, very high

varies from 0.5 to 50.0 dS m^{-1} or more in summer. In saline soils of the coastal region soluble salts are primarily of chlorides and sulphates of sodium, magnesium, calcium and potassium in the decreasing order of preponderance. Bicarbonates are present in traces while carbonates are usually absent (Bandyopadhyay *et al.*, 1998, 2003). In sodic soils carbonate and bicarbonates of sodium and magnesium are the dominant soluble salts.

Organic carbon and microbiological properties *vis-à-vis* fertility of coastal soils

The organic matter is one of the primary sources and sinks of plant nutrients in soil (Doran and Parkin, 1994) besides its considerable influence on several physical, physicochemical and microbiological properties of soil. Das *et al.* (1992) observed that the organic matter content of coastal soils increased with increase in rainfall and decreased with increase in temperature. Cation exchange capacity alone and in combination with water holding capacity of soil showed significant positive correlation with organic matter content in coastal soils. The C:N ratio of organic matter indicates its stage of decomposition. Undecomposed organic matter may temporarily fix plant nutrients making it unavailable to plants. Well decomposed organic matter in soil have C:N ratio around 1:10 The C: N ratio of coastal soils usually varies between 1:12 and 1:22 (Pal *et al.*, 1991, Patil and Power, 1995) but it may extend up to 30 or more if there is high content of partially decomposed organic matter.

Red and lateritic soils of coastal region of Goa and other light textured soils rich in sand usually show lower organic matter content than the clay soils (Mondal and Singh, 1981, Bandyopadhyay *et al.*, 1987, Sen and Maji, 1994). Highly saline coastal soils in the low rainfall zones of Maharashtra and Gujarat show very poor contents of organic matter in soil. High content of organic matter was occasionally observed in lower horizons of soils developed under mangrove vegetation (Bandyopadhyay *et al.*, 1998). Maji and Bandyopadhyay (1996) observed that the organic carbon content of coastal soils of Balasore district of Orissa varied from 0.37 to 0.97 percent. Maji *et al.* (1998) reported that the organic carbon content of coastal soil of Sagar Island in Sundarbans delta of West Bengal varied from 0.69 to 0.78 percent.

Like organic carbon, the microbial activities and microbial biomass carbon content of soil are among the most important soil quality parameters determining the soil productivity. Chander *et al.* (1994) measured microbial biomass and microbial activities in a field experiment where irrigation water of different sodicity was applied for nine years. The amount of microbial biomass carbon in soil with 16 RSC (residual sodium carbonate) water was only one-third to that with 2.8 RSC water. Soil salinity also decreases microbial activity and microbial biomass in soil. Tripathi *et al.* (2006) observed that microbial biomass carbon was much less in salt affected coastal soils. High salinity also interferes with the mineralization of the soil organic matter (Bandyopadhyay and Bandyopadhyay, 1983), microbial population (Sah *et al.*, 2006) and symbiotic and non-symbiotic nitrogen fixation in soil. Reitz and Haynes (2003) found that both salinity and sodicity of soil greatly affected the microbial properties of soil. Batra and Manna (1997) found that microbial biomass carbon decreased at higher soil salinity, negatively correlated with salinity and positively correlated with organic matter content of soil. Sardinha *et al.* (2003) observed much reduced microbial biomass in acid soils and in saline soils and concluded that salinity was one of the most stressing environmental conditions for soil micro-organism. Bandyopadhyay and Bandyopadhyay (1983) observed decrease in the rate of mineralization of organic matter with increase in soil salinity. Tripathi *et al.* (2007) concluded that the soil productivity and microbial activities of coastal soil was better maintained when balanced fertilizers were applied. Soil productivity and microbial activities of coastal soil were much higher when inorganic fertilizers were applied in combination with organic manures.

Fertility management of coastal soils

In view of the present trend of intensification of crop cultivation in the coastal areas with the replacement of natural vegetation efficient fertility management of coastal soils are becoming more and more complex as the soils are already suffering from various soil related constraints and nutrient imbalances. Ganeshamurthy and Bandyopadhyay (1999) showed that there was a considerable decrease in soil fertility when a virgin soil was brought under common agricultural cropping (Table 3). The loss is more with field crops than under the agro-forestry and plantation crops. The loss of nutrients due to cultivation of crops (Table 4) are to be compensated for maintenance of soil fertility.

The coastal soils are, generally, medium to very high in available K status. (Bandyopadhayay *et al.*, 1985, Polara *et al.*, 2006) Light texture soils with low cation exchange capacity have relatively less available K status. The soils are usually low in available nitrogen and organic carbon, low to medium in available P and high in available K (Bandyopadhyay *et al.*, 1987, Joshi and Kadrekar, 1987, Bandyopadhyay, 1990, Sen and Maji, 1999). The available P status of highly acidic acid sulphate soils is very poor (Bandyopadhyay and Maji, 1999). Such soils fail to grow good crops unless heavily fertilized with phosphatic fertilizers (Burman and Bandyopadhyay, 2007). The coastal soils are usually rich in all the micronutrients except Zn (Maji amd Bandypadhyay, 1991, 1992) and in some cases, particularly, in highly acidic and waterlogged soils it may contain toxic content of availability of Fe and Mn (Maji and Bandyopadhyay, 1991, Maji and Bandyopadhyay, 1996).

Table 3. Changes in nutrient status in an Alfisol of Andaman due to replacement of virgin forest with single crop cultivation

Soil depth	Nutrients (kg ha^{-1})			Exch. Cation (me/$100g^{-1}$)	
	Total N	Av. P	Av.K	Exch. Ca	Exch.Mg
			Virgin forest		
Surface	3002	5.04	234.0	16.2	8.5
Subsurface	1557	4.20	203.8	20.5	9.6
			Groundnut		
Surface	1098	9.5	17.5	8.5	4.1
Subsurface	549	9.0	79.5	9.4	4.5
			Paddy		
Surface	560	1.10	132.5	9.2	5.1
Subsurface	427	1.68	108.6	10.1	6.6

(Soruce: Ganeshmurthy and Bandyopadhyay, 1999)

Table 4. *Nutrients removed (kgha^{-1}) by some field and plantation crops*

Crop	N	P	K	Mg	Ca	S
Eucalyptus	30.0	1.0	38.0	5.0	31.0	-
Coconut	46.0	5.1	28.4	8.5	23.0	-
Rice	123.0	21.4	120.0	27.0	32.0	9.0
Sorgum	103.4	23.2	125.8	14.9	30.6	7.0

(Soruce: Ganeshamurthy and Bandyopadhyay, 1999)

Most of the coastal soils are highly responsive to nitrogen fertilizers but the fertilizer use efficiency is very poor due to salinity and low organic matter content. Reduced quantity of organic matter in soil with the reduced root volume of plants in salt affected soils lead to very poor fertilizer use efficiency. Presence of excess amount of salts in root zone soil considerably aggravates the existing nutrient imbalances in coastal soils. Major portion of applied N fertilizer is lost through volatilization and the loss increases with increase in soil salinity (Sen and Bandyopadhyay, 1987). Volatilization loss from soil can be substantially reduced through placement of N fertilizer at shallow soil depth (5cm) (Sen and Bandyopadhyay 1986), by combined use of organic manures and nitrogen fertilizer and by increasing the number of splits of N application. The use efficiency of nitrogen fertilizers are considerably increased when applied in conjunction with organic manures (Subba Rao and Mohanty, 2006) with neem cake or neem oil (Bandyopadhyay *et al.*, 2006, Prasad *et al.*, 2006, Patil *et al.*, 1999). Subba Rao and Mohanty (2006) also reported high increase in yield of crops on coastal saline soils of West Bengal, Orissa and Andhra Pradesh when NPK fertilizers were applied in conjunction with green manure.

Integrated nutrient management

There is a strong consensus emerging now that integrated nutrient management system is essential for sustainable crop production in salt affected soils. The integrated use of inorganic fertilizers with organic manures and biofertilizers have a great scope for coastal soils. Use of green or farmyard manure improved the N fertility status of soil with gradual increase in yield of crops while the use of inorganic N fertilizers showed hardly any residual effect (Bandyopadhyay and Bandyopadhyay, 1984b). Higher doses organic matter are required for salt affected soils due to lower microbial activity in the soil. With the application of farmyard manure and green manure it has also been possible to prevent the occurrence of Zn deficiency in rice growing alkali soils (Swarup, 1991) and to increase the yield of crops on acid sulphate soils (Burman and Bandyopadhyay, 2007) and sodic soils (Singaravel and Balasundaram, 1999). Since, efficient use of applied fertilizers is one of the most important requirements for sustainable increase in the yield of crops on coastal soils nutrient supply through organic manures/green manure alone or in combination with inorganic fertilizers is extremely important for the sustainability of crop yields on salt affected soils.

Suvarna Lata and Sankara Rao (2001) observed that sustainable higher yield of crops on coastal saline soils could be achieved through judicious and integrated use of available organic sources of plant nutrients along with inorganic fertilizers (Table 5). Bandyopadhyay *et al.* (2006) reported that application combined sources of nutrients (inorganic and organic) are highly beneficial for sustainable yield of crops on coastal salt affected soils. The use of biofertilizers also turned to be very efficient, particularly in dry seasons. Dubey and Verma (1999) observed that integrated use of organic manures and fertilizers improved soil fertility and produced synergetic effect on the yield of crops on coastal soils. Prasad *et al.* (1984) reported that besides addition of nutrients to soil the application of organic manners enhanced the release of native sources of nutrients and reduced fixation of nutrients in soil. In an exhaustive review, Bandyopadhyay and Rao (2001) observed that the fertilizer use efficiency was low in coastal soils when chemical fertilizers were used alone. 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 were improved due to application of organic material to soil (Rao and Pathak, 1996). Besides improving nutrient status, regular application of organic materials has been reported to improve the organic matter status as well as several other physical, chemical and biological properties of soil which are highly important for sustainable yield of crops on salt affected soils (Rao and Pathak,1996, Wang *et al.* ,1988). The application of organic manure is beneficial not only for increasing the N use efficiency on coastal soils but also for reclamation of alkali soils and acid sulphate soils of the coastal region. Singaravel and Balasundaram (1999) observed that application of FYM / green leaf manure alone and in combination with gypsum substantially reduced the pH and ESP of coastal alkali soils of Tamil Nadu and increased the yield of crops (Table 6). Yield of crops on coastal acid sulphate soils is very poor due to high acidity and very low available P status of soils. Although lime is a common amendment for reclamation of acid soil, application of lime along with green manure are highly beneficial for higher and

Table 5. *Effect of combined use of inorganic fertilizers and organic manures on yield of crops on some coastal soils of eastern India*

Location	Treatment	1994-95		1995-96	
		Rice *(Kharif)*	Rice *(Rabi)*	Rice *(Kharif)*	Rice *(Rabi)*
West Bengal	NPK	1.8	4.6	2.8	5.1
(Medinipur)	NPK + GM	2.3	5.1	3.2	6.1
Orissa	NPK	4.0	1.6	3.1	4.2
(Puri)	NPK + GM	5.4	2.0	3.5	4.5
Andhra Pradesh		Rice	Groundnut	Rice	Groundnut
	NPK	3.1	2.4	3.1	3.2
	NPK + GM	3.4	3.3	4.0	2.8

(Source: Subba Rao and Mohanty, 2006)

Table 6 . *Effect of gypsum and organic manure on a sodic soil of coastal Tamil Nadu*

Gypsum ($dS\ m^{-1}$)	Org. manure	Rice grain ($kgha^{-1}$)	pH	EC_2	ESP (%)
Initial soil: Nagapattinum Dist. (TN): pH 8.9, $EC_2$4.8 (dSm^{-1}), ESP 35.9%					
Nil	FYM @ 15 tha^{-1}	2587	8.3	2.9	20.9
	Green leaf @ 5 tha^{-1}	2970	8.3	2.2	12.4
	Nil	2393	8.8	3.9	33.5
50% GR	FYM @ 15 tha^{-1}	3420	8.0	2.2	10.4
	Green leaf @5 tha^{-1}	3650	7.8	2.1	10.1
	Nil	2990	8.4	3.0	15.7

(Soruce: Singaravel and Balasundaram,1999) sustainable yield of crops on acid sulphate soils of the coastal region. Burman and Bandyopadhyay (2007) reported that efficiency of lime and phosphate increased considerably and the yield of crop was much higher when lime and phosphate fertilizers were applied in combination with green manure. Similar observations were also recorded by Bandyopadhyay and Maji (1999). Subba Rao and Mohanty (2006) also reported the positive effect of organic manure in increasing the yield of crops on acid sulphate soils of Kerala.

CONCLUSION

Foregoing discussions indicate that the coastal soils are extremely variable in terms of their physico-chemical properties, hydrological characteristics and agroclimatic conditions. The nutrient management problems are extremely complex due to the complex association of salinity, alkalinity, acidity, and variable hydrological and climatic conditions. For sustainable and productive land management, soil organic matter is one of the critical factors in most of the coastal soil types and agroclimatic situations. Besides the soil nutrient supply the soil organic matter reflects soil moisture retention, resilience to several removals/ imbalances and as the substrate for most soil biological activity. Under the complex soil fertility management of the coastal region the integrated nutrient management with application of organic and inorganic sources of nutrients along with biofertilizers might be the appropriate answer for sustainable higher yield of crops.

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Invited Paper

Status and Future Prospects for Use of Saline Water in Coastal Agriculture

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The coastal ecosystem is highly fragile and vulnerable due to human interferences, sea level rise and other anthropogenic activities. Though the coastal region in India have high potential of shallow ground water, about 15 to 40% of the aquifers are rated as of low quality due to seawater intrusion and toxicities of As, F, etc. Further, tidal waves and inundation of soil by tidal water, seawater intrusion and periodical cyclones change the ground water quality. The areas are specifically endangered with seawater inundations as a consequence of climate change. Though there are several other constraints to agriculture productivity in the coastal regions, there is a tremendous scope to improve the productivity by way of enhancing water supplies through rainwater harvesting and utilization in dry period and also sustainable exploitation of marginal quality waters. Various skimming well configurations such as single, multi-strainer radial collector and scavenger wells have also been proposed to selectively abstract fresh water from thin layers overlying saline ground water. Conjunctive or cyclic use of harvested rainwater and saline surface or subsurface water for crop production and integrated nutrient management for sustainability are the other options. Seeding and other agronomic practices to enhance performance and use of agrochemicals for minimizing alkalinity would provide an opportunity to tide over the anticipated water scarcity problem without detriment to land and water resources. Use of various microirrigation systems with mulch for higher productive functions is the viable technology for saline water use. Floriculture, growing *Prosopis* as energy plants and xerophytes with medicinal value are some alternative land users with poor quality waters in degraded soils. Integration of rice-fish-prawn cultivation and crop diversification/ alternative farming instead of monocropping of rice has tremendous scope in the coastal areas. It seems that time is ripe for pursuing some policy changes towards education of the stakeholders especially regulations governing incentives to encourage sustainable use of valuable saline water resources.

***(Key words**: Saline water use, Conjunctive use, Crop tolerance limits to salinity, Rainwater management, Ground water skimming, Microirrigation, Agroforestry, Policy changes)*

The coastal region of India stretches over a length of 8219 km having an area of 10.78 million hectare. Lack of good quality irrigation water, high soil salinity, influence of tidal waves and periodical inundation of soils by tidal water, and shallow ground water table enriched with salts are the characters of the ecosystem. Poor surface and subsurface drainage conditions, intrusion of seawater due to global warming and frequent occurrence of the tropical and endemic cyclones during both pre-monsoon and post-monsoon, followed by torrential rains cause irreparable damage to the crops and changes of the ground water quality. Though there are several other constraints, there is tremendous scope to increase agricultural productivity in the coastal regions.

Session 4 : Hydrology and Water Management

Rainwater management

Rainwater harvesting and management should form the most important strategy in this region. Excess rainwater available during monsoon period should be stored in dugout farm ponds and can be used in cyclic or mixed mode with poor quality waters to improve irrigation efficiency. There is considerable scope for conservation of excess rainwater in on-farm reservoirs which can be used for crop production in *rabi/* summer season. This also improves surface drainage and thus provides scope for cultivation of high yielding rice varieties in rainfed humid lowlands. Growing of vegetables and beekeeping on peripheral *bunds* around these ponds can fetch additional income.

Combined use of saline and canal water for irrigation

Various combinations of good and poor quality underground waters could be used for sustainable irrigation without much effect on crop growth and soil properties. Conjunctive or cyclic use of harvested rainwater and saline surface or subsurface water for crop production is one option. Results reveal that multi-quality water should preferably be used in cyclic modes. The use of lower salinity/ canal water during the initial stages including the pre-sowing irrigation allows use of higher salinity waters at later stages of crop growth. At Gangawati, early sowing of cotton (1st week of June) with four saline water irrigations (ECwi 5.0 dSm^{-1}) before switching over to canal water during August produced 75% higher cotton yield as compared to normal sowing in August after release of canal water. Though marginal build-up of soil salinity over years has occurred, it is still within threshold limit of the crop. Cotton - Wheat and Pearlmillet -Mustard under Hisar conditions showed that, for the combined use of saline and canal water, opting for irrigation with canal water at early stage was better. Cyclic use of two waters was also superior to their use by mixing in similar proportions. Mixing of canal and alkali waters (RSC 15 mel^{-1}) in the ratio of 2:1 at Agra produced similar yield as with canal water alone. However, alkali waters as such caused a reduction of 34 and 32 percent in the yield of potato and sunflower, respectively.

Effect of saline waters on soil and crop growth

For proper crop management in saline/alkaline environments, salt tolerant limits for major crops have been established, their sensitive stages identified and tolerant cultivars have been screened. Depending on the salinity of water and the soil type, appropriate crops could be chosen. In general, oil seed crops requiring less water can tolerate higher levels of ECiw, whereas most of the pulses and vegetable crops are sensitive. Similarly, late sown and summer grown crops show relatively less tolerance to ECiw than the timely sown and monsoon grown crops. Thus, for sustaining productivity with saline water irrigation, choice of crops should fall on the tolerant ones requiring less number of irrigation (Tables 1 & 2).

Ground water skimming

Various skimming well configurations such as single, multi-strainer radial collector and scavenger wells are possible to selectively abstract fresh water from thin layers overlying saline ground water. Single well is used in unconfined aquifers in most parts of India, while multi-strainer well with relatively shallower penetration than single well can be used for water table control with diminished upconing in fresh layer of restricted depth. There are sporadic reports on the use of these systems in marginally saline regions of Haryana, Rajasthan, Andhra Pradesh and Tamil Nadu in India. Scavenger wells involve simultaneous abstraction of fresh and saline waters through two wells having screens in different quality zones for controlling the rise of interface. Radial collector wells consisting of an open well and input radial drains on one or more sides involve shallower penetration than a single vertical well operating at the same discharge. Since the radial drains collect water from shallow depths, upconing of saline water from lower depths is prevented.

Large diameter open skimming wells with sump based *Doruvu* technology is operated on a large scale in coastal sandy soils of Andhra Pradesh. The system popularly known as "Improved *Doruvu* Technology" is becoming popular among the farmers

***Table 1**. Sensitivity of growth stages to salinity for different crops*

Crop	Growth stages in order of sensitivity	Crop	Growth stages in order of sensitivity
Wheat	Germination > Flowering > Milking > CRI	Black gram	Flowering to maturity > Seedling
Barley	CRI > Germination > Flowering	Green gram	Seedling > Pod development
Maize	Silking > Tasseling > Germination	Groundnut	Germination > Pegging > Pod
Rice	Seedling > Flowering	Sunflower	Germination > Bud initiation > Grain filling
Italian millet	Transplanting -Primodia > PF to flowering	Indian mustard	Seeding > Flowering
Pigeon pea	Germination > Flowering > Pod		

Table 2. *Evaluation of crop varieties for tolerance to use of saline water for irrigation*

Crop	Salt tolerant varieties/lines
Rice	Deepthi, NLR-30981,NLR-145, NLR- 33641, Surekha, Prakash, Chaitanya, Swarna, Rasi, Jaya,Vijetha,MTU2716 ,CSR23,30,36 & 13
Blackgram	LBG-22, LBG-402, LBG-623, LBG- 611, LBG-738 and LBG-726
Cotton	G.Cot DH-7, NHB-12, NHH-302 and Hy-4
Chillies	X-235, CA-960 and G-4
Groundnut	ICGV-87189 & 86309 (ECe 8 dS/m), Girnar-1, ICGS-1, ICGS-5, ICGS-65, ICGS-44 (ECe 6 dS/m)
Gingelly	Gowri
Castor	SHB-18, 48-1 and Gauch-1
Safflower	HUS-305, T-65 (upto ECiw 8 dS/m) and Bhima (upto ECiw 6 dS/m)
Mustard	CS52 and CS54
Sugarcane	83V15,81V48,CO7219 and CO8368
Bengal gram	Karnal Chana1
Green manure crops	Dhaincha (CSD123 & CSD137)
Fodder grass	Karnal grass and Paragrass
Medicinal plants	Aloe veera and Isabgol
Aromatic plants	Matricaria
Fruit crops	Amla
Plantation crops	Eucalyptus, Casuarina and Subabul
Fence plants	Prasofis, Opuntia, Acacia, etc.

of coastal Andhra Pradesh. This *Doruvu* system coupled with sprinkler/ drip was found to yield sufficient water for irrigating 3 ha of field crops and 4.5 ha of plantation. Using skimming water, the farmers are raising paddy, tobacco, chilli nurseries, vegetables, flowers plants and groundnut using *jerries* which can reduce water drop effect on tender plants. Besides this, the system also could supply water for dairy and drinking in rural areas.

Microirrigation system

The water use efficiency and yield of crops were higher with microirrigation system compared to conventional method of irrigation. Moderate saline water can be safely used for irrigation using drip/ sprinklers. Organic mulching further increased the yield of vegetables grown with saline water using drip method of irrigation. The biological clogging of drippers in subsurface with sewage water can be effectively cleaned using 100 ppm chlorine waters.

Use of agrochemicals for minimizing alkali hazards

Soil application of gypsum and alkali water passing through gypsum bed increased the seed yields of sunflower and pearlmillet. The application of 2/3 neutralized RSC water also showed significant improvement in the yields of crops. The grain yield of clusterbean was also improved by neutralizing the RSC water upto 4.0 mel^{-1} of alkalinity. Drip irrigation of gypsum bed treated water in combination with soil application of gypsum @ 50% GR reduced the soil pH, ESP and increased sugarcane yield. The data on chemical characteristics of soil after harvesting of crops indicated that addition of gypsum in soil as per GR and RSC neutralization decreased the pH of soil. Thus addition of gypsum not only reduced the alkalinity of soil but also prevents its further degradation with use of high RSC waters.

Use of urban and industrial effluents in agriculture

Farmers in peri-urban areas depend largely on urban and industrial effluents for irrigation. Evidences show that irrigation with different dilutions of sewage/ sewage mixed with industrial effluents can be effectively utilized to enhance productivity. Irrigation of forest species grown for the non-edible products, like fuel and timber with wastewater is another approach, which can help in overcoming health hazards associated with sewage farming. These systems of agroforestry which have come to be known as HRTS (high transpiration rate systems) are the land use systems based upon the high transpiration capacity of tree species. It promotes the treatment of wastewater using living soil filter in order to enable recycling and reuse of wastewater. They conserve nutrient energy into biomass thereby bringing multiple benefits to society such as fuelwood, timber, environmental sanitation and eco-restoration.

Use of arsenic contaminated water for irrigation

The toxicities of arsenic and fluorine are very common in coastal region. The drinking of arsenic contaminated water, consumption of crops and vegetables grown with arsenic contaminated irrigation water/soil is a potential source of arsenic intake in human/animal body. The management of arsenic contaminated soil/water is important for controlling its contamination in human and animal food chain. Crops show high specificity of arsenic uptake, and when arsenic toxicity is combined with salinity, it may cause stunted growth with phytotoxic symptoms. Edible parts of leafy vegetables and root crops contain high arsenic compared to grain/fruit crops, while uptake has been found to decrease with the application of higher dose of Fe and Zn.

CONCLUSION

Dwindling resources of water, increasing demand of water in the domestic and industrial sectors, degradation of water quality as a result of pollution and economic liberalization, etc. would force the agricultural sector to release a part of the fresh water for other sectors of economy that would be able to pay more for the first use of fresh water. Agriculture sector besides bridging this gap in the supply would also need to cope up with the increasing demand of water. Besides other sources, agriculture needs therefore to tap naturally occurring poor quality ground water for its use using advanced and well tested technologies. This might require some policy changes towards education of the stakeholders especially regulations governing the incentives to encourage sustainable use of valuable saline water resources.

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Invited Paper

An Overview of Natural Resource Degradation in the Coastal Ecosystem of A&N Islands

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In India the coastal ecosystems which extend over a length of 8,000 km support a large percentage of human population. Impoverished soil, ecologically unsound agricultural and forestry practices often threaten the livelihood security of the people as well as stability of the ecosystem. The harsh and climatically challenging environment in A & N Islands, coupled with demographic pressures, make resource degradation. The Andaman and Nicobar Islands have limited land area and as such proper usage of the same and minimization/ halting of land degradation are very important. In addition, *tsunami* on the 26th December 2004 had left a pronouncing and devastating effect on human life and natural resources of A&N Islands. Hence, there is a pressing need to generate innovative knowledge and adoptive technologies, create facilities on indigenous system to increase food production and conserve the resource base. This paper focuses on the major causes of natural resource degradation in these pristine Islands so that proper and timely decisions can be taken to modify the management practices to achieve food security while safeguarding the ecosystem as well.

*(**Key words:** Andaman & Nicobar Islands, Soil & water resources, Land degradation, Tsunami impacts, Future strategies to mitigate damages, Ecological sustainability)*

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 in nature, 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. A distinction is made between the terms 'coastal zone' and 'coastal area'. The term 'coastal zone' would refer to the geographic area defined by enabling legislation for coastal management, while 'coastal area' would be used more broadly to refer to the geographic area along the coast that has not yet been defined as a zone for management purposes.

Physical features of coastal ecosystems, such as reefs and belts of mangrove, are important for the mitigation of the effects of natural disasters, such as storm tide surges, shoreline retreat or floods. These features also play an essential role in natural processes, such as land accretion, and help to control coastal erosion and other damages arising from wind and wave action. At present, one-quarter of the world's population of some 5.9 billion live in coastal areas and most of the largest urban concentrations are on the coast. In India, the coastal agroecosystem covers an area of about 10.78 million ha over a length of 8,129 km along with the marine jurisdiction in the seas measuring 2.02 km^2 area and, in turn, supports a large percentage of the human population. The Andaman and Nicobar Islands constitute a group of 572 Islands in the Bay of Bengal, and represents a unique coastal ecosystem.

Current scenario of agriculture and allied sectors

Paddy is the lifeline cereal of these Islands presently (2002-03) grown in 10885 ha of lowlying valley areas. Vegetables are cultivated only in 4,244 ha with a total production of 25465 tonnes. Among the tropical fruits, banana and papaya are predominantly grown in these Islands. Fruit crops are generally grown as homestead gardens in the backyard of the houses. Among the plantation crops, coconut occupies 50 percent of the total cultivated

Session 11 : Mangrove, Wetland, Dunes

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area. Large areas under coconut still remain in the tribal dominated Nicobar groups of Islands, like Car Nicobar, Katchal, Kamorta and Great Nicobar. However, the productivity of coconut (15-25 nut per palm per year) is the lowest among the coconut growing states in India. Arecanut occupies the second most important place among the plantation crops in order of its area, production and economic importance. Spices like cinnamon, clove and black pepper are also grown, mostly as intercrops with coconut and arecanut plantations.

The livestock population in these Islands consists of non-descript cattle, buffaloes, pigs, goats, poultry and ducks. As per the 1997 census, these Islands possess a total livestock population of 188311, which include buffaloes, cattle, goats and pigs. These Islands also have about 5400 crossbred cattle. The total milk production is 22,930 litres with per capita availability of 226 ml per day. The indigenous cattle contributes more than 90% of the total production. Due to continuous inbreeding and indiscriminate breeding, none of the germplasm is in pure form. This is also one of the reasons for their poor productivity. The average per day yield is 1.5 litres in cow and 1.5-2.0 litres in buffalo. The total poultry population in these Islands is 800950 of which 85% are native birds including Nicobari fowl and local non-descript.

The total coastline of the Andaman and Nicobar group of Islands is 1912 km. The Exclusive Economic Zone (EEZ) is 0.6 million km^2. Nine fishing zones have been demarcated by the Administration of Andaman and Nicobar Islands for organized fishing in these Islands. Some of the important species as per their landings are sardines, perches, silver bellies, carangids, mackerel, seer fish, mullets, prawns and other crustaceans. About 19 species of penaeid prawns belonging to six genera and 6 species of lobster also occur. Among the molluscs, the most important are trochus, turbo shells, pearl oysters, giant clams, mussels and oysters (Dorairaj and Soundararajan, 1998). Freshwater fishes like catla, rohu and mrigal are also being cultivated in ponds. In general, the annual landings in these Islands have increased gradually from a meagre 44 tonnes in 1950 to 27442 tonnes in 1998-99.

Soil and water resources of A & N Islands

Soil and water are the vital natural resources on whose proper use depend all life support systems and socioeconomic development of a region. Maintaining quality of the natural resource base is therefore a key issue in ensuring agricultural sustainability. The soils of Andaman and Nicobar Islands have developed under the dominant influence of vegetation and climate over diverse parent materials. The uplands under forest cover are intensely leached, but runoff is very high wherever forest cover has been removed. Such soils have been severely eroded and support only scant grassy vegetation. Even though deforestation is relatively a recent phenomenon such soils have suffered changes in important physicochemical properties. The valley floors comprise of depositional landforms and have been termed as lowlands, which have developed from outwash of parent material from the surrounding hills. These soils are medium to heavy textured, moderately well drained, and subjected to seasonal fluctuations in ground water.

An extensive survey was conducted in the revenue area of inhabited Islands; samples were collected and analyzed for various physicochemical properties. Based on this information the soils were classified into three orders, seven suborders and established eight series (Singh *et al.*, 1988). The soil series are found to occur either as a single entity or as an association of two to three series in a mapping unit. The terrain is undulating ranging from steep slopes to coastal plains. Physiographically these soil series are grouped into soils on flat lands and soils on the hill slopes.

Physicochemical characteristics

The major soil texture (0-15 cm) of Andaman and Nicobar Islands is sandy clay to clay loam encompassing 75% of the area. The remaining area is sandy to clayey. The coastal plains and beaches have sandy soil in most of the Islands whereas the acid sulphate soils and some parts of Tushnabad in South Andaman are clayey. The soils of Andaman and Nicobar Islands have been grouped into four depth classes generalized as 0-25 cm, 25-50 cm, 50-100 cm and > 100 cm for broad recommendations. The coastal plain lands and some of the hill soils have deep soils with depths exceeding 100 cm. The soils on tablelands and hills are moderately deep (50-100 cm). The soils on hill slopes and foothills are however severely eroded and hence are shallow (25-50 cm) or very shallow (<25 cm). The available water holding capacity of the soils vary widely from very low in coastal beaches and coastal plains to very high in clay soils. Generally the hilly areas have medium to high available water holding capacity, ranging between 100 mm m^{-1} to 200 mm m^{-1}. The acid sulphate soils and some parts of Tushnabad area in South Andaman have high water holding capacity. Contrarily, the littoral forest area and non-saline lowland paddy soils have low water holding capacity.

Organic carbon content in soils of Andaman and Nicobar Islands is usually more than 0.5 %. Studies conducted by Singh *et al.* (1988) revealed that most of the soils of these islands have medium to high organic matter status (organic carbon status > 0.5 %). Some parts in South and Middle Andaman have low organic carbon status mainly because of severe erosion of the surface soil caused due to extensive deforestation and complete neglect of the deforested area.

The commonly encountered pH range in our soils is 5.5 to 8.5; however pH lower than 4.5 and higher than 9.5 are also observed in strongly acidic and alkaline soils, respectively. In general, the major soil types are moderately acidic with pH ranging from 5.5 to 6.5, covering the hill slope. Slightly alkaline soils with pH ranging from 7.5 to 8.0 mainly occur in Neil, Havelock, Makka Pahar area of S. Andaman, Little Andaman and the Nicobar Group. Coastal marshy soils are potential acid soils, which on drying during summer months become extremely acidic and are called acid sulphate soils. These soils are not suitable for cultivation without reclamation. In general, fertility status reveals that soils here are generally medium in available N and low in both available P and K.

For the purpose of crop planning the soils of these Islands were grouped into:

- Heavy textured lowland valley soils: School Line series
- Medium to heavy textured upland soils: Tushnabad series
- Coarse to medium textured well drained soils: Pahargaon and Garacharma series
- Coastal saline and acid sulphate soils: Dhanikari series
- Coastal and inland marshes: Dhanikari series
- Coastal sands and coraline deposits: Rangachang series
- Severely eroded hill soils: Wandoor series
- Slightly to moderately eroded hill/foothill soils: L.Andaman series

Since the U.T. of Andaman and Nicobar Islands has limited land area proper usage of the same and minimization/halting of land degradation is very important. In recent times, the rapid increase in population and development of tourism industry has put land and water resources in these fragile Island ecosystem under tremendous pressure. Soil erosion by water due to high intensity rainfall in soils with poor surface structural stability is the most obvious form of land degradation. The other forms of degradation are salinization and inundation. Land degradation may be due to natural factors like occurrence of *tsunami*, floods, etc. leading to erosion and tidal action. It may also be partly due to human factors like improper agricultural practices in terms of excessive usage of fertilizer, pesticides, monocropping, deforestation, industrial activity, overgrazing, over-exploitation, etc.

Natural causes of land degradation in A&N Islands

Water erosion

The A & N Islands receive 3100 mm rainfall annually through both SW and NE monsoons. The topography of Andaman Islands is hilly undulating and rolling with narrow valleys encircled by the spurs given out from the main hill ranges. Mismanagement of land both on the hills and in the valleys has led to severe soil erosion. Hence, excessive soil and water loss is posing a serious threat to the fragile ecosystem of these Islands.

The study on the effect of land use on annual runoff and soil loss in A& N Islands revealed that greatest rates of runoff and soil loss were measured in denuded tropical forest area (average soil loss 45 t ha^{-1} y^{-1}). Area cultivated with vegetables is sensitive to erosion, especially during active monsoon season, generating higher amounts of runoff and soil loss (34 t ha^{-1} y^{-1}), while the area under arecanut canopy has registered soil loss of 28 t ha^{-1} y^{-1}. However, the area under tropical rainforest with dense vegetative ground cover has recorded the lowest runoff and soil loss (15 t ha^{-1} y^{-1}). (Ghoshal Chaudhuri *et al.*, 2007). Therefore, for any environmentally sound planning it is essential to develop a surface reflecting the 'Relative Erosion Potential' (REP) of the Islands. The REP for Andaman Islands ranged from as low as 0.5 in the evergreen and semi-evergreen forests under 1-2% slope area to as high as 1606 in the revenue area with 15-30 % slope (Ganeshamurthy *et al.*, 2002).

Soil salinization

In humid region of Andaman & Nicobar Islands salt affected soils may develop under the appropriate conditions of saline ground water table present at shallow depth. The ground water reaches the soil surface through capillary rise, evaporates from the soil leaving salts behind, finally making the soils saline and unproductive for agricultural crops. The water table in soil may also rise due to nearness to sea and brackish water estuary, which leads to the development of coastal saline soils along the sea coast, while in the delta regions originating from geological weathering, the salts are transported and accumulated in the soil profile as a result of water movement.

Anthropogenic causes of land degradation in A&N Islands

Improper agricultural practices : Includes a wide variety of agricultural activities such as insufficient or excessive use of fertilizers, use of poor quality irrigation water, improperly timed use of heavy machineries, absence of anti-erosion measures on land susceptible to water erosion, etc.

Deforestation : Clearing of natural vegetation for agricultural purposes, introduction of large scale commercial forestry, construction of roads and urbanization may lead to soil erosion.

Industrial activity : This directly relates to the pollution of land arising from the disposal of effluents and hazardous wastes into the soil and water. Extraction and processing of minerals may also degrade the land.

Over-grazing : This may not lead to the degradation of vegetation as such but may cause soil compaction and thereby water erosion.

Over-exploitation : Utilization of the vegetation for domestic purposes such as fuel, energy and fencing may lower the capacity of the vegetation to protect the soil against erosion.

Impact of *tsunami* on the coastal ecosystem of A&N Islands

Until recently occurrence of large scale soil salinity due to natural disaster like *tsunami* was thought to be a rare phenomenon. However, the nature's fury in the form of massive *tsunami* waves triggered by the massive earthquake on 26th December 2004 has created devastation not only in terms of human lives and loss of infrastructures in coastal areas of A & N Islands, but they also caused complete submergence of adjoining agricultural fields and other plantations, and rendered the soils and water resources, including ponds and dugwells, salt affected. The direct environmental impact of *tsunami* varied according to various factors, notably bathymetry and geomorphology of the coastline. Thus, areas adjacent to relatively steep continental shelves were generally less damaged than coast with excessive shallow continental shelf.

Agricultural lands : The coastal areas of A&N Islands affected by the *tsunami* present highly diversified human activities from inland fresh water rice based systems to mangrove and coastal strips used primarily for fishing. The *tsunami* has affected the cultivated lands surrounding the coastal areas with severe impact on the eastern coast. Rice is cultivated in the coastal lowlying areas where drainage is often difficult due to lack of slope (flat lands). Seawater ingression due to *tsunami* waves has led to different situations in the agricultural lands of A & N Islands, *viz.* (1) seawater intruded into the cultivated land during *tsunami* and receded completely, (2) seawater intruded during high tide and receded during low tide, and (3) coastal areas where there was permanent stagnation of seawater depth of impounding increased with high tide. So, the farmers of A & N Islands faced a situation in which they have either lost their farmland completely or dealt with the problem of soil salinity, which seriously hampered the crop production.

In this context, soil and water sample collection-cum-analysis was undertaken at periodic intervals, i.e. immediately after *tsunami* (February, 2005), after one rainy season following *tsunami* (February, 2006), and after two rainy seasons following *tsunami* (February, 2007) in order to assess the changes occurring in soil physicochemical characteristics and water quality and to formulate rehabilitation strategies. Based on regular soil and water sampling and analyses carried out at various locations of South Andaman, Middle Andaman, Little Andaman and Car Nicobar, it has been observed that most of the agricultural lands in South Andaman were still suffering with various degree of soil salinity, sodium absorption ratio (SAR), soluble sodium, calcium, magnesium, chloride and sulphate content. However, Middle Andaman, Little Andaman and Car Nicobar soils were having no/ very low degree of salinity except a few places where seawater stagnation continued. In case of water resources, immediately after *tsunami* fresh water sources like surface ponds and dugwells located near coastal areas got contaminated due to direct ingression of seawater, but the salinity level came down in most cases after two rainy seasons.

Ocean floor : The rolling of ocean floor has absolutely changed the ocean bed characteristics. Much of the unconsolidated sediments were detached and brought to the shore. The changes in seabed affected bottom inhabitants.

Landscape (erosion and accretion) : Recurring, disastrous *tsunami* was labeled as a contributing mechanism for geomorphic alteration in coastal landforms. The blow of *tsunami* waves on coastlines was distinct from that of storm waves since the former had bigger wavelengths and wave interludes.

A change in coastal morphology led to inundation in several coastal wetlands which distressed the supportive capacity of young marine life. There has been widespread erosion of coastline in some areas, including the complete abandonment of sandy beaches in South Andaman, Little Andaman and Nicobar Group of Islands. In general, sediments of coastal areas became finer in character after the *tsunami*. The colour of coastal dunes changed and became dull due to sticky nature of soil.

Dumping of debris : The vigour of the *tsunami* demolished all structures that it came in contact with, resulting in too much debris. This debris was then dumped on the coast by the action of the waves. Coastal dumping contaminated the coastal waters.

Sea level rise : The worst scenario projected a sea level rise of 95 cm to 1.00 m at Campbel Bay. The impacts of sea level rise were expected to be more local than global. The relative change of sea and land was the main factor. Even more significant than the direct loss of land caused by the sea rising were the associated indirect factors, including erosion patterns, damage to coastal infrastructure, salinization of wells, suboptimal functioning of the sewage system with resulting health impacts, loss of littoral ecosystems, and loss of biotic resources. In coastal areas, and particularly deltas, factors such as modified ocean circulation patterns (and their impact on building and erosion of the coast), climate change in the catchment basin, and change in coastal climate were observed.

Mangroves : Mangroves, which stretch out in the inter-tidal region between sea and land, assist to shield and stabilize coastlines and enrich coastal waters. They are more useful than tangible barriers in dipping erosion, trapping sediments and squandering the energy of breaking waves. Mangrove forests were themselves victims of the power of tidal waves, particularly young saplings. Some of the larger trees were totally uprooted as water entered these regions.

In Andaman Group of Islands about 3850 ha of mangroves were totally lost and 7750 ha were damaged. In Nicobar Group, about 855 ha were lost and 3900 ha were damaged. Mangroves act as bioshields. Due to these indemnities their accommodating capacity was significantly reduced. The mangrove ecosystem in Little Andaman was largely damaged and submerged.

In the Nicobar Group of Islands, mangrove areas were affected to the extent of 335.70 ha (51%) in Camorta and 339.03 ha (69%) in Katchall. In Andaman & Nicobar Islands due to upward tilting of the west coast of South Andaman and entire Middle & North Andaman, the mangroves remained 1 m above the high tide line in creeks, leading to mangrove strands drying and sliding into creeks.

Coral reefs : Coral formations act as buffers during storm surges and tidal waves. When giant *tsunami* waves smashed onto shores, the massive backwash returned to sea carrying a deadly cargo that could destroy the region's vital coral reefs. The coral in nearby shallow areas were destroyed, crushed and shrouded to debris. Coral reefs were mainly affected due to siltation as a result of *tsunami*. Siltation led to choking and death of the live corals reefs in Andaman & Nicobar Islands.

Coral reefs were either completely eroded or sand and mud were deposited over it. In some parts they were smashed and crushed. In Andaman & Nicobar group about 40,000 ha of reef were affected. The tectonic movement affected the coral reefs in Nicobar and South Andaman resulting in the reefs suddenly sinking up to 4 meters deeper in the water. The opposite was the case for the reefs of North Andaman, where some reefs were lifted 4 meters above their previous position. Coral reef in several areas of Nicobar and South Andaman (for example, Jolly Buoys, Redskin and Alexandra) has been extensively damaged. In the reef flats, sand and silt have been deposited on the coral reefs.

The extent of reef area affected was 41% at Camorta, 49% at Katchall, 53% at Nancowry, and 59% at Trinkat. On the day of *tsunami* and after, extensive silt laden turbid waters were seen all over the reef area. Such turbid waters were mapped using satellite imageries and they were observed to cover an area of 400.71 ha in Nancowry and about 552.44

ha in Trinkat. The effect has decreased after 10 days but all the silt and mud were found to be deposited on the reef area.

Biodiversity : Changes in the physical environment and in the chemical properties of water affected biodiversity. For example, in addition to the phenomena explained above muddy coasts became sandy in nature and *vice versa*. Fish populations were greatly affected due to the vibrations and shock. Extensive damages have occurred to seaweeds and sea grass beds in Andaman & Nicobar Islands. These were habitats of several commercially important marine organisms.

Fisheries : The *tsunami* caused heavy damages to the fishing industry. The changes in the coastal environment, i.e. accumulation of debris and silt in the estuaries and backwaters caused mortalities in the juvenile populations of commercial species of fin and shell fishes, including *P.monodon* (black tiger), which may subsequently have considerable impact on the recruitment of juveniles into the adult stages (broodstock). Since most of the broodstock of *P.monodon* were supplied from Andaman waters, the ecological damages which took place in Andaman had serious adverse effect on its supply.

Salinization of aquifers : Increases in salinity were noticed in *tsunami* affected areas of Andaman due to seawater inundation. The *tsunami* tidal waves transported large volumes of seawater into inland water bodies and also created large tidal pool of seawater which percolated into coastal freshwater aquifers and salinized them.

CONCLUSION

In order to meet the ever increasing demand for food, fibre and fuel for the growing population, efficient and scientific management of land and water resources will continue to play a pivotal role in agricultural production of these Islands. Apparently, land and water are the basic natural resources for agricultural growth and development and agricultural growth cannot sustain on a deteriorating resource base. Hence, it is imperative to strengthen the management for its conservation and improvement. The *tsunami* has introduced a serious risk factor in balancing the equation for the coastal environment on equity and/or sustainability basis between ecology, on the one hand, and productivity linking land uses, tourism and related industries, adaptation to climatic change, anthropogenic disturbances, etc., on the other. Hence, there is a need for ecologically sound agricultural systems and judicious use of biodiversity to our approach to sustainability. The twin necessities of enhancing agricultural productivity and building sustainable agroecosystems call for a "paradigm shift" towards an agricultural system that is knowledge based, technology intensive, and information rich. It is therefore imperative to focus on total ecosystem quality management and coupling economy with ecology and equity while ensuring food security.

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Invited Paper

Indian Mangroves: Status, Management and their Plausible Benefits for Livelihood Security

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Mangroves are restricted in their distribution to the tropics and subtropics (approximately between 32°N and 38°S) and encountered along the seacoasts in backwater creeks and river estuaries between approximately mid-tide to the extreme high water mark along the coasts of Africa, Australia, Asia and America. The mangrove biota or ecosystem consists of the inter-tidal flora and fauna dominated by evergreen sclerophyllous broad leaved trees with stilt roots or negative geotropic pneumatophores and viviparous seedlings. The mangrove forests are comparatively very rich in biodiversity. It has been experienced clearly in the past during the *tsunami*, supercyclone or any other form of natural calamity, that the damage to the coast was minimized whenever there was a barrier of mangroves. Its complex root system not only protects the shoreline, the roots and branches have other functions also to trap nutrients in the form of litter, and further these serve as shelter and food for a large number of organisms including a number of orchids, ferns, lichens, mosses, algae, fungi, ciliates, nematodes and amphibians. Mangroves are essentially in the food chain of several animals, such as salt water crocodiles, turtles, water monitor lizards, snakes, wild pigs, monkeys, deer, tiger (in Sundarbans), several indigenous and migratory birds, mud skippers, mollusks, insects and several crustaceans. In recent years, however, attention is being paid worldwide to accommodate the salt tolerant species of industrial importance for highly saline degraded areas including coastal marshes. Many mangrove species have been tested for their useful chemical ingredients. There are many of them useful also for fruit, forage, oil, medicinal and fuel wood purposes. The scopes of many of these species of high economic value for their management and utilization in coastal saline ecosystem have been discussed in this paper. The most disturbing factor is that these most strategic and fragile ecosystems are being depleted mostly due to anthropogenic factors. Many plant and animal species (including soil microflora) might have become extinct even before reported and many of them are on the verge of extinction. There is urgent need of managing existing mangrove stands and rehabilitating the degraded stands with most suitable species for the livelihood security of the dependent coastal population.

*(**Key words:** Distribution & biodiversity of mangroves, Utilization, Ecological security & anthropogenic factors, Strategies for future development & management, Climate change & impact)*

Distribution and biodiversity of mangroves

Mangroves are restricted in their distribution to the tropics and subtropics (approximately between 32°N and 38°S) and encountered along the seacoasts in backwater creeks and river estuaries between approximately mid-tide to the extreme high water mark along the coasts of Africa, Australia, Asia and America. A wide variety of plant species can be found in mangrove habitats but of the recognized 110 species only 54 species in 20 genera belonging to 16 families constitute the "true mangroves" that occur almost exclusively in mangrove habitats and rarely elsewhere (Hogarth, 1999). However, International Union for Conservation of Nature and Natural Resources (IUCN) documented 60 exclusive mangrove species (13 in Western hemisphere and 51 in Eastern hemisphere) and 23 non-exclusive (8 from Western hemisphere and 18 from Eastern hemisphere) mangrove species (Table 1) distributed over 1,68, 810 km^2 area in the world (Saenger *et al.*, 1983). The distribution of various species in different zones is shown in Table 1. Two species (*Rhizophora* x *annamalayana* and *Heritiera kanikensis*) have been documented from India (Banerjee *et al.*, 1989, EISC, 2002), which make total 62 species of true mangroves. Out of 62 species, 22 are common in both Asia and Oceania regions, while 15 are found exclusively in Asian region and 5 in Oceania. Nine species are found distributed in Asia, Oceania and East Coast of Africa and the Middle East. Three species (*Avicennia bicolor, A. tonduzii* and *Pelliciera rhizophorae*) are restricted to only West Coast of Americas and *Avicennia tomentosa* is only found in East Coast of Americas. *Avicennia germinans, Laguncularia racemosa* and *Rhizophora harrisonii*, besides those two areas, are also distributed along West Coast of Africa; while *Rhizophora mangle* is the only species, which besides the above three regions, is also found in Oceania region (Table 1).

The mangrove forests of Australia are among the richest in their floral biodiversity in the world with 22 species of true mangroves. The Malaysia/ Guinea zone comprises all the mangals from Burma to Guinea and from the Philippines to South Japan with maximum number (up to 42) of mangrove species. The first 'World Mangrove Atlas' (Spalding *et al.*, 1997) provided the opportunity to evaluate for a realistic assessment of existing mangroves (the total mangrove area reported to be 1,82,305 km^2) and their evolutionary trends, both at global and at a local scale.

Table 1. *Distribution of various mangrove species in different regions of the world*

Mangrove species	Region of occurrence	Total no. of species
Acanthus ebrateatus, ilicifolius, Aegiceras corniculatum, Avicennia alba, officinalis, Bruguiera cylindrica, hainesii, parviflora, sexangula, Camptostemon schultzii, Ceriops decandra, Cynometra iripa, Excoecaria agallocha, Lumnitzera littorea, Osbornia octodonta, Rhizophora apiculata, R x lamarckii, stylosa, Scyphiphora hydrophyllacea, Sonneratia caseolaris, ovata, Xylocarpus australisicus	1,2	22
Acanthus volubilis, Aegialitis rotundifolia, Avicennia intermedia, lanata, Camptostemon philippinensis, Cynometra ramiflora, Heritiera fomes, kanikensis, Kandelia candel, Phoenix paludosa, Rhizophora x annamalayana, Sonneratia apetala, griffithii, Xylocarpus gangeticus, parviflorus	1 (exclusively)	15
Aegialitis annulata, Avicennia eucalyptifolia, rumphiana, Bruguiera exaristata, Rhizophora x selata	2 (exclusively)	5
Avicennia marina, Bruguiera gymnorhiza, Ceriops tagal, Heritiera littoralis, Lumnitzera racemosa, Rhizophora mucronata, Sonneratia alba, Xylocarpus granatum, moluccensis	1, 2, 6	9
Avicennia bicolor, tonduzii, Pelliciera rhizophorae	3(exclusively)	3
Avicennia tomentosa	4(exclusively)	1
Avicennia germinans, Laguncularia racemosa, Rhizophora harrisonii	3,4,5	3
Conocarpus erectus, Rhizophora racemosa	4, 5	2
Nypa fruticans	1, 2, 5	1
Rhizophora mangle	2, 3, 4, 5	1
Total	–	**62**
Some Important non-exclusive species		
Acrostichum aureum, Hibiscus tiliaceus	1, 2, 3, 4, 5, 6	2
Thespesia populnea	1, 2, 4, 5, 6	1
Acrostichum speciosum, Barringtonia racemosa, Pemphis acidula	1, 2, 6	3
Acrostichum danaefolium, Mauritia flexuosa	3,4	2
Brownlowia argentata, Cerbera manghas, Clerodendrum inerme, Cynometra manii, Dolichandrone spathacea, Maytenus emerginata, Thespesia populneoides	1, 2	7
Brownlowia tersa, Hibiscus hamabo, Oncosperma filamentosa	1	3
Myristica hollrungii	2	1
Dimorphandra oleifera, Pterocarpus officinalis	4	2
Cynometra mannii	5	1
Thespesia acutiloba	6	1
Total	–	**23**

Source: Modified from " Global Status of Mangrove Ecosystems" (Saenger *et al.*, 1983)

Geographical zones indicated 1-6 are depicted as: 1, Asia; 2, Oceania; 3, West coast of the Americas; 4, East Coast of the Americas; 5, West Coast of Africa; 6, East Coast of Africa and the Middle East

As per Forest Survey of India report (FSI, 2003) mangrove forest area in India is only 4461 km^2, which is 0.14% of total geographical area of the country. The mangrove area of Sundarbans in India is 47.5% of total area, while of Gujarat and Andaman and Nicobar Islands 21.5% and 15%, respectively. On the western coast of the Indian subcontinent 22 species of true mangroves are found in different mangal areas (Banerjee *et al.*, 1989, Dagar, 2003, Dagar and Singh, 2007).

The mangrove vegetation, the associate flora and fauna, and microorganisms form a complex but very interesting food web. Chauhan *et al.* (1980) isolated 60 species of fungi from sediments of mangroves of Andamans, out of which species of *Aspergillus, Penicillium, Trichoderma, Fusarium* and *Rhizoctonia* were the most frequent.

Prabhakaran *et al.* (1987) isolated 31 fungi species from sediment and 27 from decaying leaves of Cochin mangroves, while 48 species from sediments, dead woods and prop roots of Pichavaram mangroves were reported (Nair *et al.*, 1991, Ravikumar and Vittal, 1996). In Maharashtra coast 41 species of Ascomycetes, 2 of Basidiomycetes and 12 of Deuteromycetes have been reported from mangrove wood (EISC, 2002).

The mangroves support rich faunal resources and are inhabited by several interesting animals such as salt water crocodiles, turtles, water monitor lizards, snakes, wild pigs, monkeys, deer, tiger (in Sundarbans), several indigenous and migratory birds, mud skippers, molluscs, insects and crustaceans (Chaudhuri and Chakrabarti, 1989, Das and Dev Roy, 1989). Among invertebrates, more than 500 species of insects and Arachnida, 229 species of crustaceans, 212 species of molluscs, 50 species of nematodes, and 150 species of planktonic and benthic organisms are known from Indian mangroves while vertebrate fauna is represented by 300 species of fish, 177 species of birds, 39 of reptiles and 36 species of mammals (Gopal and Krishnamurthy, 1993, Jagtap, 1994, EISC, 2002). Das and Dev Roy (1989) reported several animal species such as polychaetes (8), earthworm (2), molluscs (100), crustaceans (59), echinoderms (6), insect-mites (35), amphibians (2), fishes (35), reptiles (7), birds (53) and mammals (8) in association with mangroves of Andaman and Nicobar Islands – a good number of them being endemics. Naskar and Guha Bakshi (1987), Mandal and Nandi (1989) and Ghosh *et al.* (1990) have recorded various faunal species from Sundarbans.

The mangroves also serve as wildlife sanctuaries especially in Sundarbans and Andaman & Nicobar Islands. The Javan Rhinoceres (*Rhinoceros sondaicus*), swamp deer (*Cervus dauvaceli*) and wild buffalo (*Bubalus bubalis*), which were once the pride of Sundarbans no longer exist, however, Sundarbans is well known for the Royal Bengal Tiger (*Panthera tigris*) and Chital deer (*Cervis/Axis axis*), which are protected here. Crocodile (*Crocodylus porosus*) in Mahanadi delta and Bay Islands, Olive Ridley turtle (*Lepidochelys olivaceae*), dolphins (*Platenista gangetica*), monkey (*Macaca mulatta*) in Andamans, and endangered wild ass (*Asinus hemionus*) in Kachchh are other important wildlife species.

Utilization of mangrove forests

With increasing urbanization and industrialization, particularly in developing countries like India, the mangrove areas can be judiciously explored for meeting the demands for food, fuel wood, thatching material, and increasing the productivity of coastal water for marine resources including fish and shrimp production with little disturbance to the mangrove forests. The coastal degraded saline areas near seacoast may be brought under mangrove and other useful halophytic vegetation such as *Salvadora persica* and *Salicornia bigelovii* to augment the economy at many fronts. These are highly valuable resources. Some of the natural benefits and utilizations of these resources in the scenario of their management aspects have been highlighted in brief.

Stabilization of the coasts and beaches

Mangroves have unique mode of adaptation to saline environment. Their prop and knee like dense root systems forming web protect the coastline from erosion. The root systems enable the mangroves to trap sediments and provide the seabed a shallow slope. Many species have mechanism of producing viviparous mode of seedlings, when seeds germinate while fruit is attached on the mother plant. Thus, the germinating radicals when matured fall in the substratum and produce new seedlings. The dense roots help the mangroves to absorb the energy of waves and tidal surges, thus acting as a shield for the hinterland. The trees form a barrier against winds and play a vital role during cyclones and *tsunami* like disasters. The creepers and trailers on sandy beaches also keep the sand intact. During *tsunami*, areas in Pichavaram and Muthupet with dense mangroves suffered fewer human causalities and less damage to property compared to areas without mangroves (Padma, 2004).

Ecological role in food chain and life support system

One of the most important roles of the mangroves is formation of detritus in the form of litter, which is converted into nutrients by microorganisms for wide range of animals (Odum and Heald, 1975) to help in recycling of carbon, nitrogen and sulphur. It is perhaps the only biotic system that recycles sulphur in nature and makes it available in an assimilable form to other organisms (Chapman, 1976). Therefore, these waters are rich in organic and inorganic nutrients. Mangrove water is rich in production of planktons, which play primary role in food web. Mangroves provide breeding and nursery ground for the juveniles of many types of fish, shrimps, crustaceans and other fauna including turtles (Saenger *et al.*, 1983), which come onshore to lay eggs beneath sand along the beaches. Dense mangrove roots serve as shelter for almost all the groups of animals including fungi, cyanobacteria, bacteria, ciliates, nematodes and amphipods which colonize and feed on litter and form food for many juvenile fishes (EISC, 2002). Many animals are associated with mangrove habitats and play part in complex food web and energy flow.

Aquaculture in the vicinity of mangroves

The fact, that mangrove communities are nursery grounds for fish and crustaceans through primary food chain, has been suitably exploited in South-East Asia by constructing aquaculture ponds behind mangroves, and shallow lagoons or creeks are being managed for aquaculture, particularly where the fresh water from upstream merges with seawater. Availability of fish and prawn seeds in natural mangrove waters is critical and very important factor in aquaculture development. The fish seeds of economic value available in Bay Islands include species of *Mugil, Anabas, Caran, Lactarius, Lates, Sillago*, etc., and among prawns, *Penaeus marguensis, Metapenaeus ensis, M. dobsoni* and *M. brevicornis*.

Biofertilizer

The nitrogen fixation by many microorganisms found in mangrove substratum has been worked out and encouraging results have been found (EISC, 2002). N fixing bacteria like *Azotobacter* and cyanobacteria (viz. *Aphanocapsa, Nodularia* and *Trichdesmium*) are quite common in sediments of mangroves (Ravikumar, 1995). Interestingly the cyanobacterium *Phormidium tenue* was found to have potential to enhance the growth and production and protein contents of shrimp and the cultures of many of these can be used as biofertlizer (Palaniselvam and Kathiresan, 1998).

Food resource

Many types of fish, shrimp, crustaceans and other coastal animals inhabit mangroves and associated ecosystems, which are also used as food by the coastal population. Besides these animals honey is also collected from mangrove stands. Many plant species also contribute towards food.

Fodder resource

In many coastal areas (including Rann of Kachchh) where mangroves occur sporadically and there is scarcity of fodder, the cattle, goats and camel are found browsing on mangroves and the foliage of many mangroves and associates, such as species of *Avicennia, Ceriops, Bruguiera, Rhizophora, Kandelia, Sonneratia, Cynomitra, Terminalia, Hibiscus, Salvadora* and many others (Dagar, 2003).

Fuel wood

In coastal areas the mangroves and their associates are widely used for fuel wood and timber, often leading to deforestation of these habitats. Species of *Rhizophora, Bruguiera, Ceriops, Kandelia, Avicennia, Sonneratia, Xylocaprus, Heritiera, Lumnitzera* and *Excoecaria* are excellent fuel wood and also used for making charcoal. *Avicennia marina* is one of the most widely distributed species throughout the mangaı stands of the world.

Building and thatching material

In many mangrove stands wood is extracted to construct jetties and shelters. The log is also used for minor constructions such as poles, beams, electric poles, shafts, and agricultural implements. Poor coastal population frequently uses the leaves of *Nypa, Pandanus, Licuala* and *Phoenix* as thatching material. Bark fibre of *Pandanus* and *Hibiscus tiliaceous* is commonly used for cordage, ropes and mats.

Tannin

The extraction of tannin from the bark of majority of mangrove species (mainly species of *Rhizophora, Brugueria, Ceriops, Kandelia, Sonneratia, Exoecaria, Xylocarpus*) is one of the major uses of mangrove trees and most of Indian mangroves contain about 35% tannin in their bark (CSIR, 1986).

Medicinal and aromatic plants

There are many reports on the medicinal uses of halophytes including mangroves and their associates. Some common medicinal halophytes found in coastal areas include: *Acanthus ilicifolius, A. volubilis, Barringtonia acutangula, B. racemosa, Calophyllum inophyllum, Cerbera manghas, Clerodendrum inerme, Cressa cretica, Cynometra ramiflora , Heritiera fomes, H. littoralis, Pandanus odoratissimus, Xylocarpus granatum* and *X. moluccensis*. Recently in India, the cultivation of medicinal and aromatic plants has gained more importance and the trade in products of these plants is estimated to be over US $ 3000 million per annum. Utilization of degraded wastelands including salt affected coastal areas is a viable option for cultivation of medicinal and aromatic plants.

Other salt tolerant plants of economic value

Seed oil from *Salicornia bigelovii* and coastal *Terminalia catappa* is reported to be edible (CSIR, 1986). Seeds of *Salvadora oleoides* and *S. persica* contain 40-50% fat and are good source of lauric acid and purified fat is used for soap and candle making (CSIR, 1986). Among other products perfume from male flowers of *Pandanus spp.*, beverages from mangrove palm *Nypa fruiticans*, pulp and fibre from *Pandanus tectorius, Hibiscus cannabinus, H. tiliaceous, Urochondra setulosa*, and many others, and bioactive compounds from *Calophyllum inophyllum* and *Salsola baryosma* are worth mentioning (CSIR, 1986).

Socioeconomic development

The mangroves help in socioeconomic development of coastal communities through employment generation, providing shrimp/ fish seeds for aquaculture as well as for traditional sources of medicines, food, honey, fodder, thatching material, fuel wood, etc. Coastal fishery is highly dependent on mangrove ecosystem, therefore, the system provides direct employment to more than half million fisher folk (EISC, 2002). Besides the capture fishery, culture fishery is also prevalent and dependent on mangrove rich areas (Achuthankutty, 1990).

Anthropogenic impacts on mangroves

The total wetland area in India converted to other uses has been estimated to 40 million ha (Untawale, 1992). The major problems associated with indiscriminate use of coastal wetlands are increasing soil acidification (acid sulphate soils), loss of nutrients, soil erosion and decreasing fishery potential (Dagar *et al.*, 1993), which, in turn, have led to many ecological and economic problems along the coast (Untawale, 1992). Traditionally man has exploited the mangrove forest products in the form of firewood, charcoal, housing material and fishing gear, tannin, food and drink, medicine and aquatic products such as for various kinds of fish and shrimps, molluscs, crabs, lobsters and other animals (Chapman, 1976, Tesoro *et al.*, 1984, Vannucci, 1989, Dagar *et al.*, 1991, Dagar and Dagar, 1999, Dagar, 2003). Human settlement in mangrove areas is another but more serious exploitation of these resources. Our country has already lost 40% of mangrove area of what existed a century ago (Upadhyay *et al.*, 2002). The fast destruction and degradation of the mangroves have already caused coastal erosion, destruction in soil and water health and loss of life and property. The fish and shrimp resources have declined drastically (Padmavathi, 1991). The freshwater inflow in estuaries is necessary for seed germination and establishment of mangrove seedlings (Scott, 1989). Tree felling for domestic uses, cattle grazing, hyper-salinity, heavy sedimentation, pest problems, unsustainable fishing practices, unauthorized hunting and collection of animal products, and lack of peoples participation, particularly for rehabilitation of mangrove areas are specific issues that need to be addressed immediately.

Strategies for development and management of mangrove forests

The following strategies may be adopted to utilize mangrove resources on a sustainable basis to reduce the level of conversion to other land uses and declare certain mangrove areas, especially those with pristine resources, as conservation and preservation zones (Untawale, 1992, Alagarswami, 1995, EISC, 2002).

Ecosystem approach for protection and conservation of mangrove forests

Mangrove ecosystem is a complex and open ecosystem, composed of various interrelated elements in the land/ sea interface zone and further intervened with other natural systems in the coastal zone such as corals, sea grasses, coastal fisheries and beach vegetation (Chapman, 1976). It is imperative, therefore, that mangrove management should be pursued in an integrated manner and not in isolation. All efforts should be made to stop various anthropogenic interferences including pollution, dumping of waste material, grazing, and deforestation in these stands. Natural regeneration should be promoted.

Afforestation of denuded areas

It has been estimated that approximately 1,00,000 ha of barren inter-tidal mangrove area are immediately available for afforestation programme (Untawale, 1992) and about 1, 62, 300 ha area consists of open mangrove forest (FSI, 2003), which needs to increase in density through planting of suitable tree saplings.

India has a long tradition of mangrove forest management. The Sundarbans mangroves and mangroves of East Coast were the first mangroves in the world to be put under scientific management (Chaudhuri and Chaudhury, 1994). Recognizing the importance of mangroves, the Government of India set up the National Mangrove Committee under the Ministry of Environment and Forests in 1976, and subsequently a scheme was introduced for mangrove conservation, protection and promotion of research with the following agenda.

Aquaculture with mangroves intact

Mangroves are good nursery ground for fish and shrimp culture; therefore, these should be explored for aquaculture keeping the mangroves intact. Untawale (1992) suggested brackish water fish farming as a potential use for the open degraded mangrove areas and a range of uses including fishing, navigation, transport, recreation and research for the estuarine waters fringing the mangroves. Wherever possible aquaculture, especially oyster culture, may be adopted in mangrove creeks (Dagar *et al.*, 1991). The agri-silvi-aquacultural system of *tumpang sar* approach of Indonesia and building the shrimp ponds behind the mangroves (landward), as is done at some places in Brazil, appears to be the ideal approach (Vannucci, 1989), where mangroves are least disturbed.

Impact of climate change on mangroves

There is emerging consensus that changes in coastal wetlands, especially mangroves and coral reefs, are consequences of steadily rising of marine temperature (Singh, 2000). Mass coral bleaching has already been reported and some 27% of the world's coral reefs are effectively lost (Worldwatch Institute, 2002). Scientists have documented that due to greenhouse gases and increase in temperature a 10-20 cm rise in global average sea levels over the past century (Worldwatch Institute, 2002) has taken place. It is expected that future rises in relative sea level will be more than one meter in 100 years (Clough, 1994).

Following mitigation measures may help to manage mangroves against sea level rise.

- Strict protection of existing mangroves against encroachment and cutting
- Expansion of mangroves by regenerating potential inter-tidal areas
- Rehabilitation of degraded mangrove area planting with site-specific suitable species after raising them in nursery (in tidal areas)
- Management interventions through regeneration of threatened species, which may not adapt to climate change
- Preparing area specific plan for all the 32 mangrove areas as already identified for their conservation and further development and increasing their biodiversity.
- Scientific studies and consistent monitoring of mangrove areas, species distribution and ecological changes, sea level rise and climate change
- Providing adequate space behind mangrove for their natural landward expansion
- Special research efforts for conservation and protection of biodiversity of Island mangroves
- Estimation of real mangrove status and identification of fresh area for rehabilitation
- Accountability for implementation of mangrove programmes

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J. Indian Soc. Coastal agric. Res., 26(2), 129-131, 2008 **Invited Paper**

A Suggestive Methodology to Measure the Coastal Livelihood - Empirical Evidences from East Coast

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Coping strategies, in short term, in response to climate change should be addressed to secure a livelihood system in the face of periodic stress during extreme events like drought, flood, cyclone, etc. Livelihood should be socially sustainable which can cope with and recover from stress and shocks in order to provide for future generations. Coping mechanisms can be visualized as a network to maximize the utility of resources from fisheries, livestock rearing to agriculture and related commodities. The paper aims to establish a methodology in order to measure the coastal livelihood.

The empirical evidences assessed the present livelihood status and identified the key factors which contributed positively or negatively towards the sustainable coastal livelihood. It suggested that the adopted strategies and coping mechanisms depended on households' perception on extreme events and the problems associated with it. The problems included fishing day's loss, crop failures, concomitant decline in income and employment opportunities, low yields, escalation of food prices, hunger and malnutrition, decrease in grazing land and fodder adequacy, and loss of properties and life. The strategies practised to reduce the coastal vulnerability are classified into four groups, namely (1) common strategies for any extreme events in general, (2) specific strategies to reduce drought, and impacts of (3) flood and (4) cyclone. The challenge is to identify the activities dependent on climatic conditions and to find out how to tackle them when climate changes.

***(Key words**: Coastal livelihood, Composite index, Measurement, Adoptive strategies & coping mechanism, Economic & climatic stress)*

Notwithstanding the remarkable performance of agriculture in producing food and also attaining some degree of resilience, inter- and intra-year fluctuations in agriculture production will continue as long as agriculture depends on weather. Such fluctuations cause serious damages to crops, animals and livelihood of people when they attain the level of natural calamities like droughts, floods, cyclones, earthquakes, etc. The primary impact influences the physical and biological environment, while secondary impact reflects on the economic livelihood of farmers and their families. With the onset of climate change, it is predicted that soil erosion, salinity and waterlogging are inevitable and the coastal area will be worst affected.

Coping strategies, in short term, in response to climate change should be addressed to secure a livelihood system in the face of periodic stress during extreme events like drought, flood, cyclone, etc. Livelihood should be socially sustainable which can cope with and recover from stress and shocks in order to provide for future generations. Coping mechanisms can be visualized as a network to maximize the utility of resources from fisheries, livestock rearing to agriculture and related commodities.

To meet the emerging climate change in the coastal area where the questions of food security lies with scarce resources, farmers cannot afford to invest on sustainable agricultural practices as it may lead to a low yield, although in the long run, the gains might offset the expenditures made. Hence, through different adaptive strategies the individuals, households and communities changed their productive activities, and modified their community rules and institutions over time in response to economic or environmental shocks or stresses, and thereby meet the livelihood needs in the coastal areas. The paper will address these issues on measuring livelihood under stress prevalent in the coastal areas in East India.

MATERIALS AND METHODS

For establishing the methodology, to measure the coastal livelihood, five different criteria were used to construct the composite index which was expected to influence the coastal livelihoods across the target population and the region. These were:

1. Food Security (X_1)
2. Efficiency (X_2)
3. Equity (X_3)
4. Sustainability (X_4)
5. Asset/Capital resource parameters (X_5)

In establishing the relative importance of each criterion in setting priorities, some explicit weighing procedure is necessary. It was assumed that all the five criteria should have been given equal weight since each of them received strong emphasis as far as its contribution to coastal livelihood was concerned. In fact, in this case each of the criteria addressed a fundamental goal and possibly none could be ranked in preference to others.

The additive model could be specified as below:

$$CRLI_i = X_{1i} + X_{2i} + X_{3i} + X_{4i} + X_{5i}$$

where, $CRLI_i$ = Composite Coastal Rural Livelihood Index for i^{th} farmer, X_{1i} = value of food security criterion, X_{2i} = value of efficiency criterion, X_{3i} = value of equity criterion, X_{4i} = value of sustainability criterion, and X_{5i} = value of capital resource criterion.

Based on it, this paper tried to answer the following key questions for coastal livelihood.

- What were the livelihood resources, institutional processes and livelihood strategies which were important in enabling or constraining the achievement of sustainable livelihoods for different groups of people?
- How could one assess as to who achieved a sustainable livelihood and who did not? In other words, what were the relevant outcome indicators?
- What were the practical, operational and policy implications of adopting a sustainable livelihood approach?

RESULTS AND DISCUSSION

Our empirical evidences assessed the present livelihood status and identified the key factors which contributed positively or negatively towards the sustainable coastal livelihood. From the empirical evidences, we arrived at various suggestions on where to make intervention to improve the livelihood and accordingly suggest planning and activities with rational expectation. Our empirical evidences suggested that the adopted strategies and coping mechanisms depended on households' perception on extreme events and the problems associated with it. The problems included fishing day's loss, crop failures, concomitant decline in income and employment opportunities, low yields, escalation of food prices, hunger and malnutrition, decrease in grazing land and fodder adequacies, and loss of properties and lives. However, the coping mechanisms varied according to the nature and degree of events.

The strategies practised to reduce the coastal vulnerability were classified into four groups, namely (1) common strategies for any extreme events in general, (2) specific strategies to reduce drought, and impact of (3) flood, and (4) cyclone.

The possibilities for any large scale adaptation programmes by governments should, in fact, be few because of resource constraints and execution and development problems that the country faces. Therefore, efforts by those who felt the impacts of climatic changes, such as farmers and households, should have been crucial in ameliorating the potential adverse impacts of climatic changes. The challenge was therefore to identify the activities dependent on climatic conditions and to find out how to tackle them when climate changed.

It was possible to develop an understanding of the local factors and linkages found in the wide range of rural locations subject to different socioeconomic and ecological conditions. With a view to secure livelihood we therefore should focus on decisions of community, households and individuals. We need to adopt a local contemporary lens. An investment for long term measures calls for climate friendly agricultural practices, such as conservation agriculture, homestead farming, crop diversification, etc. Building up stocks and inventories are also essential particularly for minimizing risk both for individual as well as for community. Institutional support is a pre-condition for it.

The paper finally raises the following issues:

- The government policy frameworks and regulation are often inconsistent with required policies for the climatic changes and subsequent mitigation goals.
- Policies and regulations need to be identified that are relevant to generate incentives and to remove barriers towards adaptation to climatic changes.
- Avenues should be explored to help influence the market and guide farmers' choice towards farm management and energy use, selection of relevant agricultural inputs and natural resources.
- System of farming to be encouraged that does not require inputs based on imperfect market mechanisms, and frontier technology should be encouraged.
- An inbuilt infrastructure, which would make an efficient use of the existing technologies, local knowledge and traditional practices through a decentralized institutional system of governance and diffusion policy, should be developed.

J. Indian Soc. Coastal agric. Res., 26(2), 132-134, 2008

Invited Paper

Coastal Vulnerability Mapping – A New Method Suggested in Indian Context

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The coastal zone of India is thickly populated and is vulnerable to high gales, storm/ tidal surges, *tsunami*, erosion, accelerated sea level rise, subsidence, etc. Thus, it has become expedient to classify the coastal zones according to different vulnerability intensities. Western USA coast adopted the indicators like geomorphology, shoreline change rate, coastal slope, relative sea level change, mean significant wave height, and mean tidal range. In India the Central Ministry of Environment and Forests (MoEF) adopted the same parameters. In this article the authors have proposed that the indicators adopted by MoEF will not reflect a clear picture of the vulnerability of the coast if population density of the coast and their economic status *vis-a-vis* the coastal hazards are not taken into consideration. Moreover, in the instant case the rate of erosion/ accretion had to be studied/ delineated on area specific basis. In support of this case the example of Digha-Sankarpur area for which an Integrated Coastal Zone Management Plan has been prepared by the School of Oceanographic Studies, Jadavpur University, Kolkata has been taken into consideration to demonstrate the vulnerability of the region.

(**Keywords:** *Integrated Coastal Zone Management Plan, Sea level rise, Coastal Vulnerability Index*)

Coastal areas are vulnerable to natural and man made hazards. The population density of the coasts is increasing day by day. It has now become expedient to draw and demarcate the coastlines according to its relative vulnerability to natural hazards. Such mapping was done in Western US Coast based on geomorphology, shoreline change rate, coastal slope, relative sea level change, mean significant wave height, and mean tidal range (Pendleton *et al*, 2004).

Western US coast is not very thickly populated like India, neither the people live below poverty line. Therefore, the density and poverty level of the coastal population were not taken into consideration as proposed by IPCC (Inter-Governmental Panel for Climate Change, 1992). In the Indian context the population density and the financial status of the coastal population need specific consideration in order to cope up with the hazard situation and for arriving at a useful mapping methodology. Further, since the coastal areas of the world are abodes of denser human population it is essential to have a proper demarcation of the setback lines in order to facilitate various socioeconomic activities for sustainable development. The Ministry of Environment and Forest, Govt. of India has, however, taken up a decision to map the vulnerability of different coasts of India and draw the vulnerability lines according to Swaminathan Committee following only the US guidelines of vulnerability study.

Vulnerability lines may be drawn, however, on the basis of rate of erosion/ accretion and return periods of devastating cyclones, surges and *tsunami* as 50 year and 100 year setback lines. Since 50 year is the normal expected life of masonry structures in India, 50 year setback line may be suggested to be more restrictive for future developmental projects.

MATERIALS AND METHODS

The vulnerability indices followed in Western USA (Gornitz *et al.*, 1994) were taken as the guidelines. The population density in Western USA is very low and poverty situation is much less than in India. But in India these two factors should be given priority for determination of vulnerability.

School of Oceanographic Studies, Jadavpur University has mapped these vulnerability lines for Digha-Sankarpur Development Area (DSDA) and parts of Sundarbans. DSDA lines were mostly found coterminus with the 500 m buffer line from HTL (Anon., 2006).

It was suggested for the Indian coastal region from the Integrated Coastal Zone Management Plan that the erosion and accretion rate was > 5 m per year denoting high vulnerability areas and < 2 m per year as low vulnerability areas, details given overleaf.

Variable	High risk	Moderate risk	Low risk
Erosion/ accretion rate	> 5 m/y	2 to 5 m/y	< 2 m/y
Coastal slope	< 1.2 %	2 to 1.2 %	> 2 %
Rate of sea level rise	> 3 mm/y	1.8-3 mm/y	< 1.8 mm/y
Mean wave height	> 1.25 m	1.25 – 0.55 m	< 0.55 m
Tidal range	> 6 m	1 – 6 m	< 1 m
Population density	> 800 / km²	800 – 500 / km²	< 500 / km²
BPL %	> 50 %	20 – 40 %	< 20 %

'Mean significant wave height' was used here as a proxy for wave energy which drives the coastal sediment budget. Wave energy was directly related to the square of wave height: $E = 1/8\ \tilde{n}\ gH^2$, where E was energy density, H was wave height, ñ was water density, and g was acceleration due to gravity. Thus, the ability to mobilize and transport coastal sediments was a function of wave height, and the latter was an important component of vulnerability index determination.

RESULTS AND DISCUSSION

The vulnerability of the coastal zones was so long guided in India on the basis of our CRZ Regulations, 1991 with its various amendments. In Western USA vulnerability mapping has been done on the basis of following factors.

1. Geomorphology
2. Shoreline change rate
3. Coastal slope
4. Relative sea level change
5. Mean significant wave height
6. Mean tidal range

These variables can be divided into two groups, viz. (a) Geologic variables and (b) Physical process variables.

The geologic variables are geomorphology, historic shoreline change rate, and coastal slope. These variables account for a shoreline's relative resistance to erosion, long term erosion/ accretion trend, and its susceptibility to flooding, respectively. The variables of physical process include significant wave height, tidal range, and sea level, all of which contribute to the inundation hazards of a particular section of coastline over time scales from hours to decadal scales.

Taking cue from the report of the same Swaminathan Committee formed under the Ministry of Environment and Forests, Government of India accepted almost the same set of parameters to be implemented in case of India as listed below.

1. Elevation (data were obtained from Survey of India maps)
2. Geology
3. Horizontal shoreline displacement
4. Geomorphology (landforms and bathymetry)
5. Sea level trend
6. Tidal range
7. Wave height

IPCC's (1992) Common Methodology for vulnerability determination included these factors. In fact, density of coastal population and population living below poverty line (BPL) who cannot cope with the vagaries of coastal hazards copiously need also to be considered in India. IPCC Common Methodology considered, however, only the following 5 indicators to assess the vulnerability.

1. Number of people at risk
2. Capital value loss
3. Land area loss
4. Wetland loss
5. Protection/ adoption cost

USGS used the following method of calculating Vulnerability Indices by assigning numerical variability values as given in the previous section. Actual variable values were assigned a vulnerability ranking based on value ranges, whereas the non-numerical geomorphology variable was ranked qualitatively according to the relative resistance of a given landform to erosion. Shorelines with erosion/ accretion rates between -1.0 and +1.0 m y^{-1} were ranked as moderate in USDA. Increasingly higher erosion or accretion rates were ranked as correspondingly higher or lower vulnerability. Regional coastal slopes ranged from very high risk, < 1.2 % percent to very low risk at values > 2 percent. The rate of relative sea level change was ranked using the modern rate of eustatic rise (1.8 mm y^{-1}) as very low vulnerability. Since this was a global or 'background' rate common to all shorelines, the sea level rise ranking reflected primarily local to regional isostatic or tectonic adjustment. Mean wave height rankings ranged from very low (< 0.55 m) to very high (> 1.25 m). Tidal range was ranked such that macrotidal (> 6 m) coasts were very highly vulnerable and microtidal (<1 m) coasts had very low vulnerability.

Assigning scores of 3 for High risk, 2 for Moderate risk, and 1 for Low risk we may get the Vulnerability values for each variable. Once each section of coastline is assigned a vulnerability value for each specific data variable, the Coastal Vulnerability Index (CVI) was calculated as the square root of the product of the ranked variables divided by the total number of variables (Pendleton *et al.*, 2004).

Thus, Coastal Vulnerability Index C.V.I. = (Product of the variable scores / Number of the indicator variables)$^{1/2}$.

Further, we may assume that the maximum possible risk value for our seven indicators was $3^{3.5}/7 = 6.7$. Thus, the areas having more than the 50 % of the maximum value can have:

Coastal Vulnerability Index (CVI) > 3.5	- High vulnerable stretch
CVI > 1.6 – 3.5.	- Moderate vulnerable stretch
CVI > 1.6	- Low vulnerable stretch

It would be possible now to map the area following the above mentioned categories of Vulnerability Indices.

The return period of severe cyclone, storm surges and *tsunami* may be taken as 50 year since the normal life for masonry structures is taken as 50 year. The 25 year return period lines should be considered as High Risk lines for practical application. This was determined by the National Coastal Zone Management Authority for the 'High Vulnerable' coastlines. Similarly, 'Moderate' and 'Low' risk zones will be delineated along the coast depending on the CVI values determined as above.

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Water Management Strategies for Increased Productivity on Tsunami Affected Salty Lands of Andaman and Nicobar Islands

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Long-term production and productivity of agricultural lands in Andaman and Nicobar islands was at stake following unprecedented damage of land and water resources besides human/ animal loss and infrastructure damage due to tsunami. A team comprising of CSSRI/CARI and ActionAid International joined hands for putting in place some land and water management models for reclamation of these lands in the islands. These included design of peripheral dykes (bunds) with one-way sluice gates to ensure adequate drainage to agricultural lands and to avoid seawater encroachment. Besides design of drainage channels and farm ponds were prepared to drain and utilize excess rainwater during monsoon season. An optimal size of the farm pond was worked out at 15% of the land holding. Multi-enterprise agriculture was advocated with farm pond as a central unit. A low cost semi-permanent check dam using waste coal tar drums was made available. Leaching and potential of salt tolerant rice varieties such as CSR 23 and CSR 36 over conventionally grown varieties was demonstrated for quick recovery of livelihood source of the poor farming communities. The technologies of water management described in the paper have vast replication potential in island and coastal ecologies often battered by natural calamities.

(**Key words:** *Tsunami, rainwater management, farm ponds, drainage, salt tolerant rice varieties, one-way sluice gates*)

The natural disasters visit coastal areas and Islands almost regularly compounding the hardships being faced by the farming community. It was on 26th December 2004, that a disaster improperly named as tsunami in the Indian context lashed the eastern coast including the group of Andaman and Nicobar islands. It caused unprecedented vast scale human/animal loss, infrastructure damage and geared out the agricultural and fishing operations, the major livelihood sources of the farming and fisheries communities. In agriculture, not only the standing crops and plantations were damaged due to sheer physical force but also impacted the soil and water resources turning them saline. Fearing that such a colossal damage would have long-term implications on production and productivity of agricultural lands, Central and State Governments initiated reclamation activities providing physical inputs besides financial resources and psychological succor but there was lack of expertise. A collaborative effort was put in place by Action Aid International to draw upon the expertise of CSSRI and CARI in land reclamation and allied activities so that agricultural activities in the Andaman and Nicobar islands could be put back to normal. Various activities taken up by this team of experts from CSSRI/CARI are listed as follows:

- Design of peripheral bunds along with provision of one-way sluice gates
- Design of drainage channels to allow drainage of excess rainwater
- Design of farm ponds and check dams for *in-situ* rainwater harvesting
- Leaching of salts from agricultural fields by ponding of rainwater
- Cultivation of salt tolerant rice cultivars in moderate saline land

This paper briefly describes these activities and their impact on agricultural production in Andaman and Nicobar Islands.

MATERIALS AND METHODS

About the site

The A & N islands comprise of a chain of 572 islands, islets, reefs and isolated rock exposures spread in the Bay of Bengal. The total land area is

8249 square kilometers, 86% of it being under reserve and protected forests. The topography of the islands is flat to rolling with low range hilly mountains to narrow valleys at the foothills resulting in an undulating terrain ranging from steep slopes to coastal plains. Local variations with steep (>45°) to moderate slopes (<10°) are discernible, where crops are cultivated. The tropical ecosystem of Andaman and Nicobar islands is very unique having diverse species with wide range of genetic diversity in varying density. High rainfall, extremely humid climate, undulating terrain, deep islets and creeks are very conducive for faunal and floral species diversity. Evergreen and littoral forests, mangroves and coral reefs are important components of the existing ecosystems prevailing in the islands.

The annual rainfall of these islands varies from 3100-3500 mm distributed erratically over a period of 7-8 months in a year. Both the southwest and northeast monsoons occur in these islands from May to October and November to January, respectively. Nearly 95% of annual rainfall is received during May to December (2250 mm in May-Sep. and 685 mm in Oct.-Dec.) and remaining four months from January-April are dry (90 mm). The numbers of rainy day in these months hardly exceed three. Agriculture badly suffers during this period due to severe moisture stress. Being near to the sea, water even during the excess period is hardly available since most of it runs through to the sea. In spite of the fact that there is no other source of irrigation or freshwater or groundwater in the area, the rainwater is not fully exploited.

An extensive survey-cum-soil/water investigation of the Tsunami affected area was carried out over a period of two years. For the purpose of the study designs were prepared for various interventions and limited actions were initiated to implement the programme for the following two situations prevailing after the tsunami.

(i) Seawater only intruded during tsunami and receded completely thereafter

(ii) Seawater continued to intrude during high tides and recede during low tides

No action was initiated for the third situation prevailing in the area i.e. coastal areas and depressions where seawater stagnated permanently and depth of stagnation increased with high tide.

RESULTS AND DISCUSSIONS

Impact on water resources

Both surface and groundwater resources were impacted by the tsunami waves. The water got salinized either due to mixing of the seawater or due to horizontal movement from the sea. Groundwater wells were also contaminated due to debris and silt brought in by the tsunami waves. The salinity levels were high in ponds located at lower sites in comparison to medium and upper sites of Guptapara. The salinity of stagnated water in farmer's fields (Manglutan and Chouldhari) was very high and ranged from 56.0 to 71.0 dS/m. However, stagnated water in Chuckchuka (Nicobar) was of low salinity and was safe for use with many crops. It was observed that reclamation of contaminated surface water resources was as difficult as that of the soils but to reclaim the groundwater wells could still be an uphill task. The reclamation could be undertaken primarily with rainwater.

Design of embankment

During the surveys it was noticed that for the reclamation of category (i) lands and to provide all weather mobility, large number of embankments were being constructed. It was realized that it would change the whole hydrology of the islands. To avoid such a situation, provision of sluice gates to facilitate adequate drainage during rainy season was recommended along with the construction of embankments. In low-lying areas, provision of one-way sluice gate would help to regulate drainage of rainwater and to obstruct seawater intrusion in agricultural land. Moreover, it was observed that lower elevated areas were receiving highly saline seawater due to seepage/leakage from these embankments. Mud crabs posed a great nuisance for dykes constructed with local earth. These crabs made holes through the bunds and large amount of water leaked into agricultural lands besides the seepage. Therefore, it was recommended to strengthen these embankments as per the design dimension shown in figure 1 to minimize leakage and seepage during high tide with appropriately located sluice gates. It was also suggested to form local farmers bodies that could take care of the maintenance of these dykes till stabilization and cleaning of sluice gates at some regular interval as the effective functioning of one-way sluice gates is hindered over time due to deposition of silts and shells.

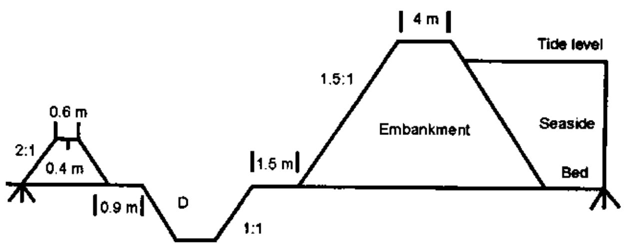

Fig. 1. Line diagram showing the dimensions of an embankment and related drainage channel

Agricultural land drainage

The impact of tsunami waves on agricultural land varied according to the topographical elevations of the land mass and the available drainage facility to quickly drain the seawater. The impact on agricultural lands was much less destructive in little Andaman as compared to south Andaman. Ideally, peripheral embankments with provision of adequate drainage all around the islands would minimize the damages due to disasters like tsunami (Gupta *et al.*, 2006).

In areas with high rainfall during rainy season and scanty rainfall during other cropping season, the objective of land drainage should be to optimally use the excess rainwater before its removal from the fields. The technology developed and experimented at CSSRI could be easily adopted in the Andaman and Nicobar islands. The technology consists of the following three components.

1. Rainwater (available during May- December) is allowed to accumulate and remain on the rice fields till such time and extent as will not be harmful to crop.
2. Excess rainwater from the fields is led to the dugout ponds of sufficient capacity. The stored water can be utilized subsequently during dry spells or for irrigating winter season crops.
3. Rainwater in excess of these two components of storage is led out of the area to the creeks/ sea through appropriately located one-way sluice gates/structures.

Design dimensions of the 2nd and 3rd components were worked out.

Design of dugout pond

On the basis of the calculations reported in Table 1, the optimal size of the farm pond was worked out at 15% of the land holding. In that case it would be possible to irrigate the remaining 85% area for summer crops. On this basis, the size of the farm pond was worked out as 39 m x 39 m with effective storage volume of 2500 m^3. The design dimensions of such a farm pond are given in Fig. 2 and its water balance in Table 2. It is expected that the loss of income due to the land converted into farm pond would be offset by generation of income from sweet water aquaculture and crop cultivation in remaining 85% area. This kind of rainwater management strategy has been proved from experiments at CSSRI, Canning and the practice is becoming quite popular in South 24 Parganas district of West Bengal (Ambast *et al.*, 1998).

Design of drainage channel

Since rainfall in the Andaman and Nicobar islands is quite high appropriate drainage provision must be made to drain the excess water. On the basis of valid parameters for the Andaman and Nicobar islands, the design dimensions of required drainage channel for 10 ha land were worked out. The run off was estimated using Rational Formula, which worked out to be 2.1 cumecs. The section of the field channel recommended to efficiently drain away the runoff is shown in Fig. 3. Similar designs for a 20 ha watershed and 100 ha watershed were prepared.

Table 1. *Crop evapotranspiration (ET_c), crop water, gross and net irrigation requirement (CWR, NIR, GIR)*

Crop	ET_{crop} (mm)	CWR (mm)	R_{eff} (mm)	NIR (mm)	GIR (mm)
Rice (Kharif)	468	1300	1200	150	215
Rice (Rabi)	447	1280	691	589	840
Groundnut (Rabi)	478	478	554	-	-
Maize (Rabi)	442	442	436	-	-
Sorghum (Rabi)	361	361	403	-	-
Vegetables (Rabi)	328	328	358	-	-
Pulses (Summer)	456	456	238	218	311
Vegetable (Summer)	429	429	180	249	356
Vegetables* (Cucumber)	358	358	112	246	351

*GIR should be calculated for each vegetable to be grown in *rabi*/summer season.

Table 2. Estimation of available water in the pond for agriculture

Item	Details
Dimension of the pond	39 m x 39 m
Depth of pond	3 m
Dead storage	0.5 m
Water losses (@5 mm/d for 100 days)	0.5 m
Effective rainfall during summer	0.1 m
Available depth for agriculture	2.1 m
Available storage for agriculture	2500 m^3
Extent of Irrigated area	0.85 ha

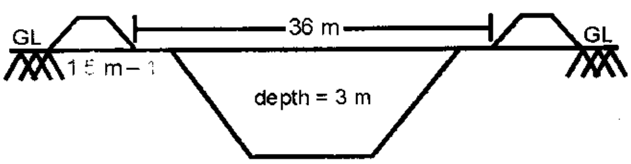

Fig. 2. A schematic diagram of farm pond showing important dimensions

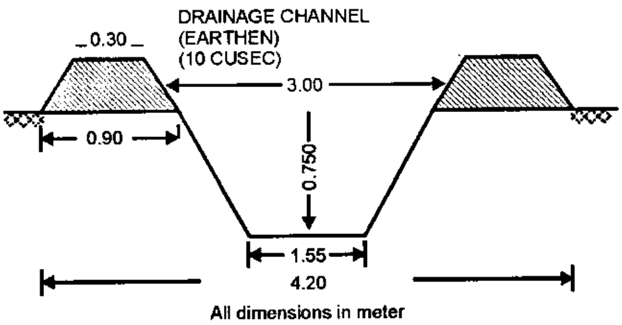

Fig. 3. Section of a typical field drainage channel for a watershed of 10 ha

Check dams

Three low cost check dams were constructed in series with the farmer's participation using locally available materials like mud, bamboo mat, wooden pegs and other indigenous materials at CARI farm at Garacharma costing about Rs 2400/- each. Vegetables like okra, cowpea, bitter gourd, cucumber, ridge gourd could be sown on residual soil moisture following rice on both sides of the check dams by providing life saving irrigations. In all 13-14 supplemental irrigation were given to the vegetable crops while surveying the area, few permanent check dams could also be observed. Considering the investments, a semi-permanent check dam consisting of used coal-tar drums was designed and the design made available to the Action Aid and Administration for use in the islands (Fig. 4).

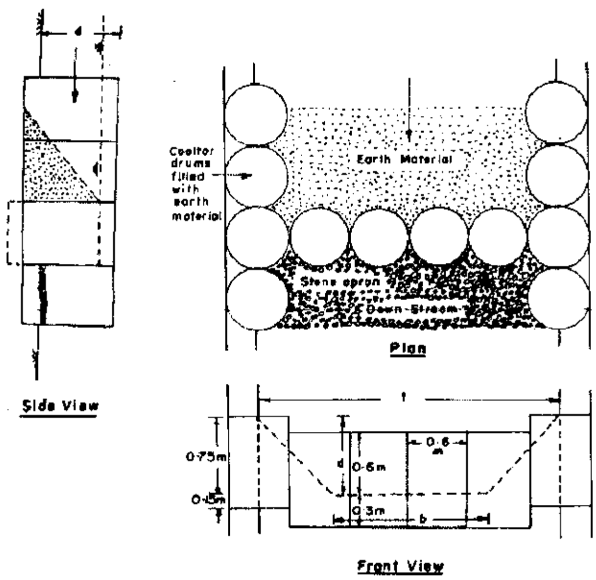

Fig. 4. Design dimensions of a low cost semi-permanent check dam made of used coal tar drums

Model building at Pilot areas

Some of the proposed technologies were put to test at two demonstration sites, namely New Manglutan and Loha Barrack in south Andaman as part of the model building exercise. Before technological interventions, at both the sites, situation II prevailed in lower areas adjacent to seashore as seawater ingression was occurring during high tide especially during new moon and full moon days. In elevated portions above such areas, situation I was prevailing where land became saline due to seawater intrusion during tsunami but receded completely thereafter. Above these fields, unaffected agricultural fields were present (Fig. 5).

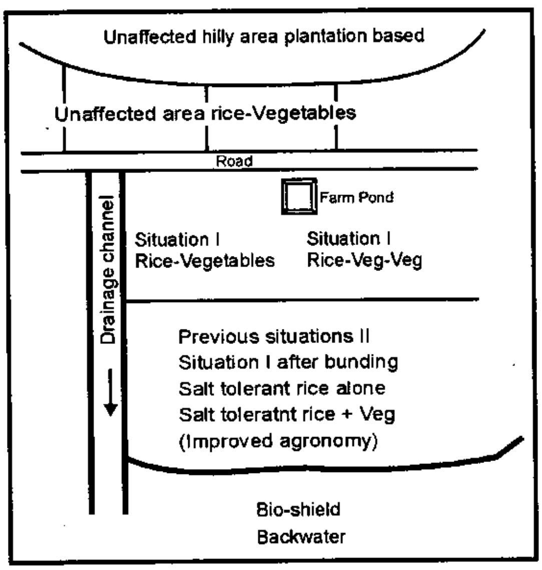

Fig. 5. Schematic view of the model sites showing various situations and interventions

Soil analysis made during March 2006 revealed that salinity level was high at both the places especially under situation II (Table 3). This was in spite of the fact that these areas received 3770 mm of rainfall after tsunami i.e. during 2005 monsoon season. This necessitated the combination of engineering measures like peripheral bunding and provision of one-way sluice gates in order to arrest the ingress of seawater, rainwater management, drainage and agronomic measures like introduction of salt tolerant rice varieties with improved agronomic practices. For this purpose seeds of CSR 23 and CSR 36 were procured from CSSRI, Karnal for demonstration on the farmers fields. The data revealed that tsunami affected the land quality and as a result yield of all the varieties was affected (Ambast *et al.* 2007). However the salt tolerant varieties out yielded the conventional high yielding varieties grown in the Andaman and Nicobar islands (Table 4). Considerable improvement in soil salinity status was noticed in March 2007 after the interventions were imposed.

Table 3. *Soil salinity dynamics at model sites following annual rainfall*

Situation/place	Sampling depth (cm)	March 2006		March, 2007	
		pH	EC_e (dS/m)	pH	EC_e (dS/m)
Situation I					
Loha Barrack	0-15	6.5	7.2	6.5	4.8
	15-30	6.6	5.6	6.3	4.1
New Manglutan	0-15	5.7	4.1	5.6	0.9
	15-30	5.5	3.7	5.5	0.6
Situation II					
Loha Barrack	0-15	6.5	9.4	6.6	5.9
	15-30	6.4	8.7	6.8	5.3
New Manglutan	0-15	5.4	4.5	5.8	3.9
	15-30	5.6	6.2	5.5	3.7
Unaffected land					
Loha Barrack	0-15	6.6	0.8	6.7	0.9
	15-30	6.0	1.0	6.3	0.7
New Manglutan	0-15	6.3	0.2	6.1	0.3
	15-30	5.9	0.1	5.6	0.4

Table 4. *Yield of paddy of different varieties under different situations at model sites*

Situation/Location	Varieties			
	CSR 23	CSR 36	BTS 24	Jaya
Loha Barrack				
Unaffected land	2.88	3.15	2.57	2.48
Situation I	2.49	2.83	2.24	1.84
Situation II	1.64	1.89	1.26	1.02
New Manglutan				
Unaffected land	2.83	3.43	-	2.52
Situation I	1.89	2.21	-	1.27
Situation II	1.57	1.76	-	0.95

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Long-term Impact of IPNS Technology on Crop Productivity and Sustainability with Rice-Rice System in Alfisols of Coastal Kerala

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Rice – rice is an important cropping system of coastal region of India. The soils of coastal region belong to Alfisols which are poor in buffering capacity and also sensitive to management practices. Owing to this, sustainability is of paramount significance. Therefore in order to monitor the sustainability, a long-term fertilizer experiment is in progress since (1996) last nine years at Pattambi (Kerala) with *kharif* rice (rainfed) and *rabi* rice (irrigated) as test cropping system. The continuous use of NPK+FYM (IPNS) gave maximum yield of rice in both the seasons. The higher agronomic efficiency for N, P and K in both the rice crops was recorded when the crop received nutrient through conjunctive use of NPK and FYM or green manure compared to optimal (100% NPK) and super optimal (150% NPK) chemical fertilizer alone. The largest sustainable yield index (SYI) of 0.69 and 0.95 was found under NPK+FYM in both the seasons during *kharif* and *rabi*, respectively. Integrated use of fertilizer and organic also improved the nutrient status of soil compared to initial and other treatments as well. Thus the results obtained revealed that integrated use of NPK+FYM not only sustained crop productivity and (SYI) but also helped to maintain soil fertility status.

***(Key words:** Alfisol, Coastal region, IPNS technology, Long-term, Rice, Sustainable yield index)*

In India, 89.9 million ha of land is under acid soil and Kerala constitutes nearly 4.2% of this area. Rice is one of the predominant crops in these soils. In Kerala rice is grown on 0.289 m ha with productivity of 2301 kg ha^{-1}. Its area and production are declining every year due to socioeconomic constraints. Depending upon the season and toposequence, rice in Kerala is grown under a variety of agronomic conditions. In high rainfall region, the sequential cropping of rice-rice is the main cropping system. However, the productivity is low due to poor water and nutrient management. To deal with the problems of nutritional disorders and toxicities of Fe and Cu in rice-rice cropping system, IPNS technology is adopted to sustain crop production by integrating nutrient need of crop through FYM, crop residues and green manure along with inorganic fertilizers (Vurghese and Rani, 2003). In India, many workers used SYI for evaluation of sustainable technology for different crops and cropping systems (Wanjari *et al.*, 2004). Here an attempt is made to monitor the changes in crop productivity, soil fertility and sustainability under continuous application of plant nutrient inputs through fertilisers and organic sources under rainfed and irrigated rice-rice cropping systems in poorly managed Alfisols of coastal area of Kerala.

MATERIALS AND METHODS

The Long-Term Fertilizer Experiment (LTFE) is in progress since 1996 at the Regional Agricultural Research Station, Kerala Agricultural University, Pattambi. The soils of LTFE field is classified as Typic haplustalf and belongs to Vadanamkurissi series. Initial soil status of N was 304, P 15.5 and K 173.2 kg ha^{-1}, with pH of 5.4, and organic C of 0.93 % in the surface 0-15 cm. Collected soil samples were analysed for pH, EC, organic carbon, easily mineralisable N by alkaline permanganate and exchangeable K. The experiment is laid out in randomised block design with four replications with a plot size of 125 m^2. The treatments under study consist of control (unmanured), 100% N, 100% NP, 100% NPK, 150% NPK, 100% NPK + lime @ 0.6 Mg ha^{-1}, 100% NPK + in situ green manuring of *Sesbanea aculata* in *kharif* rice only, 100% NPK + FYM @ 5 Mg ha^{-1}in *kharif* rice only. The nutrients N, P and K were applied through urea, SSP and muriate of potash at the rate of 90, 20 and 38 kg per ha to both *kharif* and *rabi* rice, respectively. The sulphur has gone by default as P was supplied through SSP. The *kharif* season crop was planted during first week of June and harvested in the first week of September. The *rabi* season crop was planted and harvested during the last week of

September and December, respectively each year. The agronomic efficiency (AE) of fertilizer (kg of produce per kg of plant nutrient) and the sustainable yield index [SYI = $(\check{y} - \sigma_{n-1})\ y_m^{-1}$, where, $\check{y}$ = mean yield, σ_{n-1} = standard deviation and y_m = maximum yield obtained under a set of management practices] for the experiment were calculated.

RESULTS AND DISCUSSION

Soil properties and fertility

Results (Table 1) showed that treatment has significant effect on soil pH and EC after 9 years. Imbalanced use of nutrients (100% N, 100% NP) resulted in more decline of both soil pH as well as EC, whereas application of lime (100% NPK + lime) resisted decline in soil pH. Thus, it is imperative that lime addition has helped to maintain pH. Though change has been observed in EC over the years but is within the permissible range. It is interesting to note improvement in soil organic C (SOC) irrespective of treatments compared to initial value but the impact of balanced application of nutrients in IPNS mode was more pronounced (Table 1). Green manuring with *Sesbania* and regular application of FYM @ 5 Mg ha^{-1} in combination with 100% NPK has helped much in improving organic C content in soil. The high organic C content in almost all treatments is due to incorporation of stubbles and root biomass during each harvest continuously over the years. The larger increase in SOC in 100% NPK, 100% NPK + lime, 100% NPK +FYM/green manuring is due to the incorporation of large amount of C as a result of higher yield and addition of C through FYM/GM in these treatments. The initial soil N, P and K status are low to medium. With continuous application of N, P and K the soil available nutrient status did not increase appreciably due to prevalent higher leaching/surface runoff loss due to high rainfall. In spite of continuous mining of K larger than supplied, increase in available K status is probably due to movement of K of decomposed forest litter occurred at higher topography and supplied K through irrigation water which is harvested from that area during rainy season. The larger increase in K in FYM plot is obviously due to its addition through FYM.

Nutrient uptake

A perusal of data in table 2 indicated that *rabi* rice removed greater amount of N, P and K compared to *kharif* rice which is due to larger yield during *rabi* as a result of more sunshine hours. The range of nutrients uptake by both *kharif* and *rabi* rice varies from nutrient to nutrients. The *kharif* rice removed 29.3 - 78.3 kg N, 3.7-5.4 kg P and 30.2 – 68.9 kg K per ha while *rabi* rice mined about 38.1 – 91.0 kg N, 4.2-6.9 kg P and 43.2 – 75.3 kg K per ha. In both rice crop greater amount of uptake of N, P and K is observed in treatments having integrated use of 100% NPK either with FYM @ 5 Mg ha^{-1} or *Sesbania* green manure which is again due to larger yield in these treatments. Thus, the results clearly showed that IPNS technology resulted in larger nutrient uptake in both the crops.

Agronomic efficiency

A data on agronomic efficiency (Table 3) indicated that rice crops showed differential response in utilizing nutrients from soil. The agronomic efficiency for N (AE_N), P (AE_P) and K (AE_K)

Table 1. *Impact of fertilizer and manure use on soil properties, and available N, P and K status in long-term fertilizer experiment at Pattambi (Kerala, India)*

Treatments	pH	EC (dS m^{-1})	Organic C (%)	Available nutrients (kg ha^{-1}) N	P	K
Control	4.9	0.045	1.01	198	10.8	34.4
100% N	4.9	0.078	1.04	225	11.3	37.2
100% NP	4.7	0.056	1.07	222	14.5	36.4
100% NPK	5.0	0.078	1.16	201	12.8	45.3
150% NPK	4.6	0.070	1.34	212	13.4	47.8
100% NPK+ Lime	5.2	0.078	1.06	212	12.6	40.7
100% NPK+GM	4.9	0.080	1.20	204	13.3	46.6
100% NPK+FYM	4.9	0.065	1.37	231	15.5	51.3
Initial	5.4	-	0.90	304	15.5	35.1
CD (at 0.05)	0.31	0.012	0.11	7.8	1.10	2.17

GM= *In situ* green manuring with *Sesbania aculata*

Table 2. *Impact of fertilizer and manure use on average nutrient uptake (kg ha^{-1}) by rice in long-term fertilizer experiment at Pattambi (Kerala, India)*

Treatments	*Kharif* Rice			*Rabi* Rice		
	N	P	K	N	P	K
Control	29.3	3.7	30.2	38.1	4.2	43.24
100% N	45.9	4.3	46.0	64.1	5.0	51.10
100% NP	50.7	4.8	47.0	65.6	6.3	58.89
100% NPK	56.2	4.8	55.7	66.2	5.7	67.16
150% NPK	56.3	4.7	57.7	66.6	6.6	68.42
100% NPK+ Lime	47.1	4.4	52.2	66.1	5.8	69.30
100% NPK+GM	56.0	5.4	67.7	81.0	6.9	69.12
100% NPK+FYM	78.3	5.1	68.9	91.0	6.5	75.38
CD (at 0.05)	8.40	0.7	2.08	9.70	0.78	13.90

GM= *In situ* green manuring with *Sesbania aculata*

Table 3. *Effect of continuous cropping and manuring on agronomic efficiency of N, P and K in long-term experiment at Pattambi (Kerala, India)*

Treatments	*Kharif* Rice			*Rabi* Rice		
	AE_N	AE_P	AE_K	AE_N	AE_P	AE_K
Control	-	-	-	-	-	-
100% N	7.8	-	-	9.7	-	-
100% NP	8.0	0.9	-	9.8	0.3	-
100% NPK	9.4	7.4	3.4	11.5	7.9	4.0
150% NPK	8.7	4.2	1.8	12.6	13.0	6.7
100% NPK + Lime	5.7	-9.4	-5.4	9.3	-2.2	-1.3
100% NPK + GM	12.9	23.2	11.7	14.5	21.5	11.1
100% NPK + FYM	13.6	26.1	13.3	17.5	35.1	18.3

AE_N, AE_P and AE_K = Agronomic efficiency for N, P and K respectively; GM= *In situ* green manuring with *Sesbania aculata*

was maximum when the crop was subjected to receive nutrients through integration of NPK and FYM or green manure compared to chemical fertilizer alone (100% NPK). The super-optimal dose of NPK (150% NPK), however, found less efficient in producing grain per unit of nutrient compared to optimal NPK dose (100% NPK) in *kharif* rice. But *rabi* rice proved to produce higher amount of grain per unit of nutrient applied with super-optimal dose of NPK. The increase in agronomic efficiency during *rabi* is due to higher yield due to larger sunshine hours and the crop has got opportunity to express the potential of the treatment.

Yield sustainability

Nine year's average yield data indicated different trend in *kharif* and *rabi* (Table 4). Application of N resulted increase in yield (43%) during *kharif* and (38%) in *rabi*. Both the rice did not respond to P application whereas response of K was observed in *rabi* rice only. This is due to larger yield during *rabi* rice. Moreover, during *rabi* season movement of K along with water from forest was not added to the

Table 4. *Effect of continuous cropping and manuring on average grain yield (kg ha^{-1}) and SYI over the years in long-term experiment at Pattambi (Kerala, India)*

Treatment	*Kharif* Rice		*Rabi* Rice	
	$\check{y}$	SYI	$\check{y}$	SYI
Control	1624	0.38	2266	0.53
100% N	2324	0.54	3143	0.75
100% NP	2341	0.54	3149	0.76
100% NPK	2471	0.55	3300	0.79
150% NPK	2408	0.59	3403	0.84
100% NPK + Lime	2136	0.53	3099	0.69
100% NPK + GM	2787	0.67	3572	0.82
100% NPK + FYM	2846	0.69	3844	0.95
SD	386.4	0.10	461.1	0.12

$\check{y}$ = Average grain yield; SYI = Sustainable yield index; GM = *In situ* green manuring with *Sesbania aculata*

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Effect of Gypsum and FYM Application on Leachate Composition and Soil Properties at Varying Leaching Levels on Saline-Sodic Soils

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Pot experiment was conducted to study the effect of application of gypsum and FYM at varying leaching levels on leachate composition and soil properties under saline-sodic soils. Results revealed that cumulative removal of cations (Ca^{2+} + Mg^{2+}, Na^{+}) and anions (CO_3^{2-} + HCO_3^-, Cl^-, SO_4^{2-}) through leachate were higher under higher levels of leaching (L_3), gypsum (G_4) and FYM (F_1). Soil EC, ESP and pH were, however, found to decrease considerably with increase in the levels of leaching, gypsum and FYM during both the crop growth periods.

*(**Keywords:** Leaching, Gypsum, FYM, Leachate composition, Soil properties)*

The gypsum and FYM have been found to be beneficial and proved more effective in reducing EC and ESP level in soil under higher levels of leaching. Information on the effect of soil amendments under varying leaching levels on leachate composition and soil properties in saline-sodic soils is rather limited. Present investigation is undertaken to address the issue.

MATERIALS AND METHODS

A pot experiment was conducted on a saline-sodic soil (ECe 8.2 dS/m and ESP 28) with three levels of leaching (L1:50 to 100% WHC, L2: 50 to 150% WHC and L3: 50 to 200% WHC), two levels of FYM (F0 : 0 and F1 : 25 Mg/ha) and five levels of gypsum application (G0: No gypsum, G1 : 25% GR, G2 : 50% GR, G3 : 75% GR and G4 : 100% GR) in a factorial completely randomized design by growing wheat (*rabi*) and fodder sorghum (summer) in sequence as test crop. A measured quantity of good quality water was applied to crops as per treatment i.e., L1 = 2.66, L2 = 4.00 and L3 = 5.32 liters per pot. The crops were irrigated when water-holding capacity reached up to 50 per cent (18.5% moisture). Important physical and chemical characteristics of the experimental soil are reported elsewhere (Polara *et al.* 2002). First leachate was collected after initial irrigation and remaining leachates were collected at 30 and 60 days after sowing (DAS) of wheat and sorghum crops, respectively along with the soil samples. The leachate samples were analyzed for anions and cations content; while soil samples were analyzed for pH, EC and ESP (Jackson, 1973).

RESULTS AND DISCUSSION

Results (Fig. 1 and 2) showed that the cumulative removal of Na^+, Ca^{2+} + Mg^{2+}, CO_3^{2-} + HCO_3^-, SO_4^{2-}, and Cl^- was higher with gypsum (G), FYM (F) and leaching (L) treatments than with the control (F_0 and G_0); the highest removal of Ca^{2+} + Mg^{2+}, however, observed with G_4. All the levels of Gypsum application caused higher cumulative Na+ removal than those by the FYM and leaching levels (Fig.1). The cumulative rate of leaching of CO_3^{2-} + HCO_3^- was linear with time; but for Cl^- and SO_4^{2-}

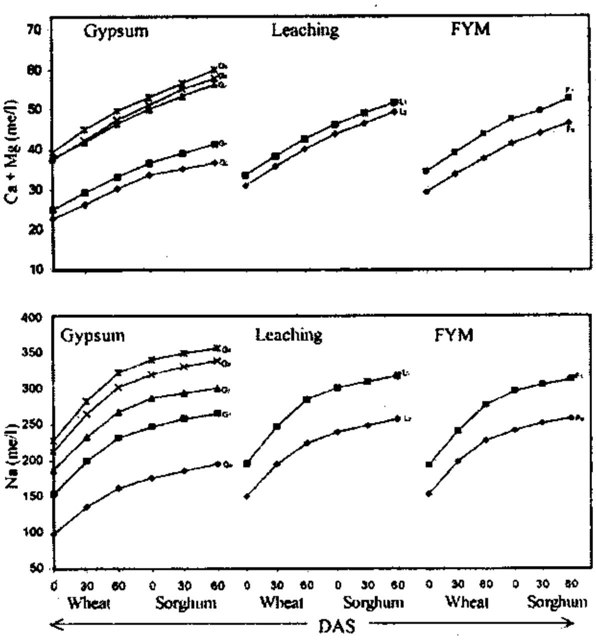

Fig. 1. Effect of different treatments on cumulative loss of Ca + Mg and Na through leachate

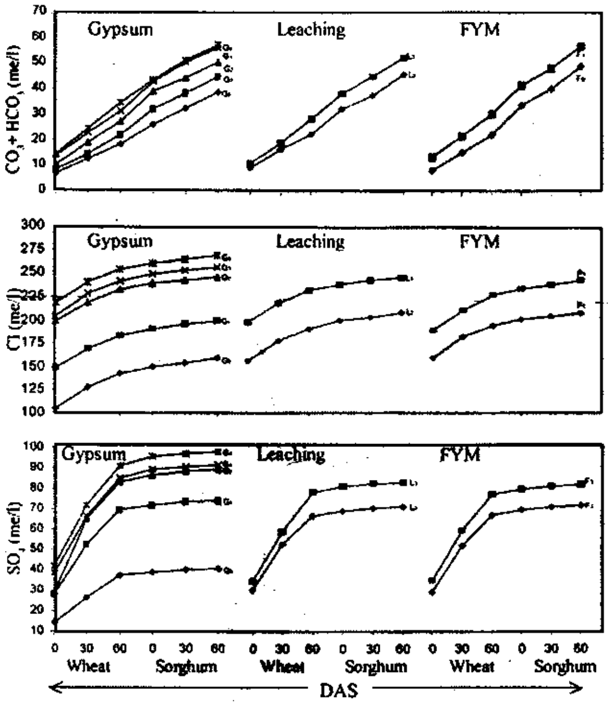

Fig. 2. Effect of different treatments on cumulative loss of CO_3+HCO_3, Cl and SO_4 through leachate

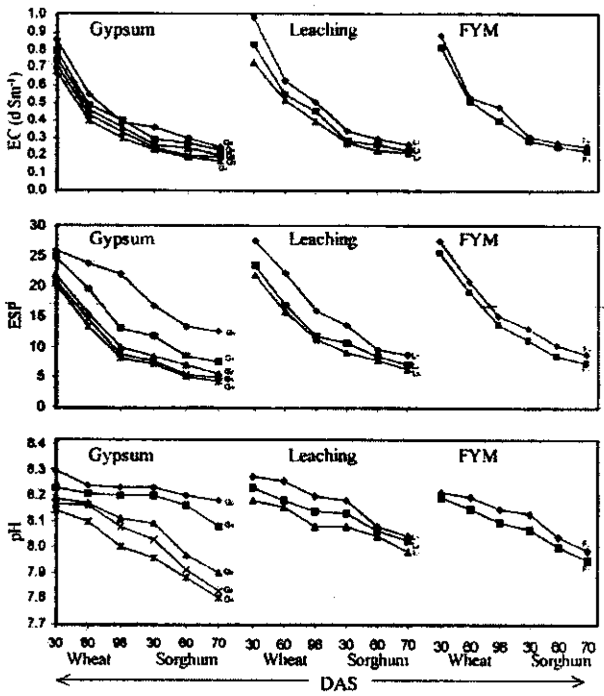

Fig. 3. Main effect G, L and F on periodic change in $EC_{2.5}$, ESP and $pH_{2.5}$ of soil

the rate of loss was more during the first 98 days as compared to latter periods. The highest amount of CO_3^{2-} + HCO_3^- removal through leachate was obtained with F1 and those of Cl^- and SO_4^{2-} with G_4. These results are in agreement with the finding of Patel and Singh (1991). The EC, pH and ESP (Fig. 3) of the soils were found to decrease significantly with an increase in the levels of leaching (L), FYM (F) and gypsum (G) at all the sampling dates during both the crop growth periods. Leaching level produced significant impact on $pH_{2.5}$ at 30 and 98 DAS of wheat and 70 DAS of sorghum. Application of gypsum @ 100 per cent GR (G_4) significantly reduced the EC and ESP of the soil (Fig. 3). The soil EC, ESP and pH was significantly decreased with the application of FYM @ 25 Mg/ha over its no application (F0) (Fig. 3). This could be due to improvement in soil physical properties (increase in infiltration rate at decreased bulk density of soil) due to addition of FYM.

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Comparison of Path Behaviour of Some Healthy and *Phomopsis* Blight affected Brinjal Genotypes

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An investigation was carried out at the Regional Research Station, Kakdwip of Bidhan Chandra Krishi Viswavidyalaya, West Bengal with fifteen brinjal genotypes during spring-summer seasons of 2003-2005 to observe the direct and indirect contributions of each character to yield of healthy and *Phomopsis* blight infested genotypes through path analysis. Out of fifteen growth and yield attributing characters, fruit number per plant, with or without protection for *Phomopsis* blight, recorded highest and positive significant effects on fruit yield. This has been proposed to be one of the prime considerations for recommending a variety for the growers.

***(Key words:** Brinjal, Path analysis, Phomopsis)*

Brinjal/Aubergine [*Solanum melongena* L.] is an economically important vegetable crop grown extensively in many Asian and African countries. India being its place of origin a great array of variability exists in the country. *Phomopsis* blight of brinjal, caused by *Phomopsis vexans* (Sacc & Syd) is a serious disease of brinjal in India, particularly in humid, coastal saline belts, reducing fruit yield to a considerable extent. Fruit yield being an interactive result of many growth variables and yield attributing characters, superiority of a genotype should be judged on the basis of growth and /or yield attributing characters highly correlated with fruit yield. Therefore, the present study was carried out to identify the highest yield contributing parameters with diverse genotypes (both elite and indigenous cultivars) under disease free and diseased (*Phomopsis* blight, one of the major biotic stresses) conditions, by means of path analysis.

MATERIALS AND METHODS

Two sets of experiments involving a healthy plant block (with plant protection) and a *Phomopsis* affected block (natural occurrence without plant protection) were carried out at the Regional Research Station (Coastal-Saline Zone), Kakdwip of Bidhan Chandra Krishi Viswavidyalaya, West Bengal during the spring-summer seasons of 2003-05. The experiments were laid out in randomized block design with three replications, involving 15 diverse genotypes viz., KB-13, Sagar Local, KS-224, Pusa Kranti, Shyamal, Pusa Purple Long, AB-1, B-B-16-2, Madanpur Local, KB-22, Milky White, Puli, KS-223, Muktajhuri and Orissa Green. The plants were spaced at 90 x 60 cm and recommended cultural practices were followed. Bavistin (Carbendazim) @ 1.0 g per litre was applied at 15 day intervals to protect the crop from *Phomopsis* blight. Path analysis was done on growth and yield characters (Table-1); observations were recorded on the basis of average performance of five plants/plot. Eight morphological and seven yield attributing characters were recorded separately from both the sets of experiments (diseased and protected).

RESULTS AND DISCUSSION

Under disease-free (protected) condition, fruit length, fruit stalk length and numbers of fruits per plant showed positive correlation with fruit weight per plant. Among these three characters, number of fruits per plant, however, exhibited highest direct positive contribution to yield as compared to fruit length and stalk length characters. Similar findings have been recorded by Praneetha (2006). Significant contribution of fruit length to yield was due to indirect positive effect of fruit breadth and number of fruits per plant. The fruit stalk length does not have any significant direct effect on yield but exerted a significant indirect effect via fruit number per plant. Under disease free condition, fruit number per plant should be the best additional criterion beside varietal disease response and fruit yield for selection.

Under diseased (*Phomopsis* blight) condition, however, number of fruits per plant and fruit length were the only two parameters which showed positive correlation with yield (Table-2) having stronger correlation with fruit length. Number of fruit indirectly influenced fruit yield via fruit length in a positive manner but strong indirect negative effect had also been apparent via fruit breadth. The same trend was observed in case of fruit length and fruit breadth where fruit length had strong direct positive effect on yield and influenced fruit breadth to produce strong indirect negative effect. For selection of better genotypes against *Phomopsis* blight, fruit length and fruit number per plant are the two varietal characters to be given emphasis. However, comparing the results of path analysis, between the healthy and diseased plants, it can be concluded that number of fruits per plant is the most important additional parameter beside varietal response (disease) and fruit yield for selection of *Phomopsis* blight resistant genotypes of brinjal. This finding is in tune with the results obtained by Mohanty (1999) and Pathania *et al.* (2005).

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Integrated Management Approach of Chilli Leaf Curl Caused by Thrips (*Scirtothrips dorsalis* Hood)

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A field experiment was conducted in order to identify the appropriate combination of both organic manure and inorganic fertilizer *vis-à-vis* pesticides with a view to maximize the fruit yield and manage the chilli leaf curl caused by thrips (*Scirtothrips dorsalis* Hood) during 2005-06 and 2006-07 under coastal saline zone of West Bengal. Imidachlorpid (17.8% SL) @ 0.005% with recommended dose of chemical fertilizers showed the best result with respect to reduction in leaf curl symptoms, growth and yield attributing parameters leading to maximum yield (41.60 q ha^{-1}). This was followed by use of vermicompost or FYM along with 75% of the recommended dose of fertilizer in combination with Imidachlorpid or neem based botanical pesticide.

(**Key Words** : *Integrated approach, Organic manure, Botanical pesticide, Imidachlorpid, Chilli leaf curl, Thrips, Scirtothrips dorsalis Hood)*

Chilli (*Capsicum frutescens* L.) is an important remunerative cash crop of coastal zone of West Bengal. Thrips (*Scirtothrips dorsalis* Hood) infestation causing leaf curl is one of the major constraints of low chilli productivity in the region. The yield losses vary form 60.5 to 74.3% (Patel and Gupta, 1998). Injury due to infestation by *S. dorsalis* results in the upward curling of young top leaves in a boat shaped manner and leaf lamina on both sides of the midrib become corrugated. Leaves become smaller, thickened, brittle and plants becomes stunted (Karmakar, 1995).

An attempt is made in the present study to identify appropriate combination of both organic manures and inorganic fertilizers *vis-à-vis* pesticides for maximizing chilli yield through management of chilli thrips infestation.

MATERIALS AND METHODS

Field trials were laid out in randomised block design at the Regional Research Station, Bidhan Chandra Krishi Viswavidyalaya, Kakdwip, West Bengal during 2005-06 and 2006-07 to test the efficacy of chemical and botanical pesticides alone and in combination with inorganic fertilizer and organic manure for the control of leaf curl disease of chilli for maximization of yield. Four weeks old seedlings of chilli (cultivar: Beledanga) were transplanted at 50 cm x 50 cm spacing in the 2nd week of January during both the years. The organic manure used were farm yard manure (FYM) and vermicompost. The recommended dose of chemical fertilizer was 60 kg N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1}. Among the pesticides Imidachlorpid 17.8SL (0.005%) and neem based botanical pesticide (2%) were used. The treatment combinations were: T_1 = 100% of the recommended dose of chemical fertilizer (RD) (in the form of urea, single suuperphosphate and murate of potash); T_2 = 75% of RD, T_3 = 75% of RD + Vermicompost @ 5t ha^{-1}; T_4 = 75% of RD + FYM @ 10t ha^{-1}; T_5 = 100% of RD + 0.005% Imidachlorpid; T_6 = 100% of RD + 2% Neem pesticide; T_7 = 75% of RD + Vermicompost @ 5t ha^{-1} + 2% Neem pesticide; T_8 = 75% of RD + FYM @ 10t ha^{-1} + 2% Neem pesticide; T_9 = 75% RD + Vermicompost @ 5t ha^{-1} + 0.005% Imidachlorpid; T_{10} = 75% of RD + FYM @ 10t ha^{-1} + 0.005% Imidachlorpid. Insect damage incidence were recorded by visual rating on five randomly selected plants in each plot. The damage by thrips on the terminal, newly grown leaves was recorded based on the 0 - 4 scale : (0 = no curling, 1 = low curling, 2 = moderate curling, 3 = heavy curling, 4 = very heavy curling). The ratings were pooled together and average rating in all treatments was worked out. The data on the height of plant, number of branches plant^{-1}, number of chilli plant^{-1} and yield of red chilli were recorded and analyzed for statistical significance.

RESULTS AND DISCUTION

The results (Table 1) revealed that the treatment comprising of recommended dose of chemical fertilizers along with Imidachlorpid 0.005% resulted into highest growth and yield attributing parameters

***Table 1.** Effect of different treatments on height of plant (cm), number of branch plant^{-1}, leaf curl av. Rating, number of chilli plant^{-1} and yield (q ha^{-1}) of chilli.*

Treatments	Height of Plant (cm)	Number of branch plant^{-1}	Leaf curl av. rating	Number of chilli plant^{-1}	Yield (Q ha^{-1})
T_1 = 100% of RD**	38.1	7.40	2.55	43.4	23.5
T_2 = 75% of RD	34.1	6.65	3.05	29.3	21.9
T_3= 75% of RD + Vermicompost @ 5t ha^{-1}	37.6	7.40	1.85	35.9	26.2
T_4= 75% of RD + FYM @ 10t ha^{-1}	37.2	7.15	1.90	36.7	26.5
T_5 = 100% of RD + Imidachlorpid 0.005%	45.3	8.35	0.45	64.1	41.6
T_6 = 100% of RD + 2% Neem pesticide	43.7	8.10	0.50	50.8	36.2
T_7 = 75% of RD + Vermicompost @ 5t ha^{-1} + 2% Neem pesticide	39.5	7.70	0.90	48.4	27.0
T_8 = 75% of RD + FYM @ 10t ha^{-1} + 2% Neem pesticide	38.6	7.65	0.95	43.5	26.9
T_9 = 75% of RD + Vermicompost @ 5t ha^{-1} + 0.005% Imidachlorpid	43.7	8.26	0.55	51.2	35.0
T_{10} = 75% of RD + FYM @ 10 t ha^{-1} + 0.005% Imidachlorpid	42.1	7.85	0.85	48.8	29.5
S. Em (±)	2.64	0.41	0.16	2.69	1.07
CD at 5%	NS*	NS	0.46	8.27	3.31

* NS = Not significant, ** RD = Recommended dose of chemical fertilizer (N, P_2O_5 and K_2O @ 60 kg, 30 kg and 30 kg ha^{-1}).

***Table 2.** Economics for management of chilli leaf curl caused by thrips.*

Treatments	*Total cost Rs. ha^{-1}	Yield q ha^{-1}	Increased yield over 75% RD q ha^{-1}	Value of additional produce	Net profit Rs. ha^{-1}	Cost benefit ratio
T_1	445**	23.50	1.60	6400	5955	1 : 13.38
T_2	-	21.90	-	-	-	-
T_3	-	26.20	4.30	17200	17200	1 : 17.2
T_4	-	26.50	4.60	18400	18400	1 : 18.4
T_5	2245	41.60	19.70	78800	76555	1 : 34.1
T_6	2170	36.20	14.30	57200	55030	1 : 23.36
T_7	1725	27.00	5.10	20400	18675	1 : 10.83
T_8	1725	26.90	5.00	20000	18275	1 : 10.6
T_9	1800	35.00	13.10	52400	50600	1 : 28.1
T_{10}	1800	29.54	7.64	30560	28760	1 : 15.98

* Total cost = cost of insecticides + labour charges; ** Cost of 25% RD; Cost of insecticides: (i) Imidachlorpid (Confidor) @ Rs. 270/100ml, (ii) Neem pesticides @ Rs. 380/lit.; Cost of fertilizer: (i) Urea @ Rs. 6/kg, (ii) Single superphosphate @ Rs. 4/kg, (iii) Murate of Potash @ Rs.5/kg; 500 litre spray solution required for spray of ha^{-1}; Labour charges: 3 labour ha^{-1} x 3 spray =9 x 65 = Rs. 585. Sale price of red chillies in Kakdwip, West Bengal market @ Rs. 4000 q^{-1}

leading to maximum yield (41.6 q ha^{-1}) with minimum value of leaf curl average rating (0.45) and higher cost benefit ratio of 1 : 34.1 (Table 2). This was followed by use of 100% RD + neem pesticide (1: 23.4) and 75% RD + vermicompost/FYM + Imidachloropid/neem based botanical pesticide in order. These treatments, however, are significantly superior over that of the treatment T_2 (75% of recommended does of inorganic fertilizers alone) contributing lowest yield and highest thrips infestation. The cost benefit ratio of 75% of RD + vermicompost/FYM (1: 17.2 & 1 : 18.4) was higher than 100% of RD alone (1: 13.4).

The neem based pesticide is comparable with Imidachlorpid under 100% RD. FYM/vermicompost can also be substituted for 25% of recommended inorganic fertilizers, under situations of availability of organic manures for better maintenance of soil health.

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Characteristic features of Garole sheep with special emphasis on Worm infestations

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Garole sheep is reputed for multiple births and can thrive well in the coastal agro-climatic zone of Sundarban. They are also habituated with knee-deep grazing in waterlogged area with high disease resistance property. Coat colour of the breed is mostly creamy white and often black patches are seen in the face, belly and leg. Distribution of the breed according to their ear size viz. rudimentary (1 to 3 cm), medium (4 to 8 cm) and long (more than 8 cm) are 16.9, 62.8 and 20.2% in ram and 12.0, 47.1 and 40.9% in ewe respectively. The study also revealed that they attain 10-13 kg body weight within a year. They have single, twin, triplet and quadruplet birth for 37.7, 46.8, 14.6 and 0.93% of their population respectively. The age of puberty is noticed within 7-24 months of age and the length of gestation period ranges from 145-160 days. The post partum oestrus generally occurs within 60-180 days and the birth weight of the lamb varies from 0.9 -1.5 kg. Observation on worm infestation revealed that 87.3% samples were positive. Faecal sample examination revealed that 68.7, 51.7, 14.0, 10.7 and 56.3% are positive with *Amphistome, Strongyle, Strongyloides, Trichuris* and *Coccidia Oocyst* respectively; they are, however, not infected with *Fasciola*.

(***Key words:*** *Garole, litter size, reproductive performance, worm infestation*)

Sheep rearing plays an important role in Indian rural economy particularly for the landless, small and marginal farmers. The production potentiality of Indian seep is low due to scarcity of grazing land, disease incidence, and lack of organized efforts for genetic improvement. Most of the Indian sheep breeds have evolved naturally through adaptation to agro-ecological conditions. Garole sheep of Sundarban, West Bengal, India is one of such sheep breed which is well adapted to harsh climate. Besides agriculture, farmers of the Sundarban rear garole sheep as an alternative source of income. Garole sheep is reported for multiple births and can thrive well in the coastal agro-climatic zone of Sundarban. They are also habituated with knee-dip grazing in waterlogged area (Ghosh *et al.*, 1999). Due to its high prolificacy and disease tolerance, the sheep may provide a subsidiary income to farmers during economic stress and crop failure. The present study was carried out to find out some breed characteristics of garole sheep and worm infestation of naturally grazing garole without deworming.

MATERIALS AND METHODS

The study was undertaken in five blocks viz., Joynagar-I, Joynagar-II, Mathurapur-I, Mathurapur -II and Pathar Pratima of a coastal district (South 24-parganas) in West Bengal. Five villages from each of the blocks and 10 respondents from each of the villages totaling 250 were selected randomly. Data were collected through face-to-face interview and also direct measurement of different parameters. Ear length of garole sheep was measured at 10-12 months of age. Birth weight of lambs was documented by directly interviewing the respondents. A total of 645 lambs were considered for the calculation of birth pattern. Sixty faecal samples from each block were collected in a moisture tight container and fixed by mixing with 10% formalin and subsequently examined for the presence of parasitic eggs through sedimentation by gravitation method and floatation by levitation method following Willi's technique (Solusby, 1968).

RESULTS AND DISCUSSION

Of the studied population, 16.9, 62.8 and 20.5% of ram and 11.9, 47.1 and 40.9% of ewe had rudimentary, medium and long type of ears respectively. On average, the length of the rudimentary type of ear in ram and ewe were 1.57 and 1.88 cm; while the same for medium and long type were 6.73 and 6.87 cm and 6.83 and 9.32 cm respectively. Results also showed that length is more in case of ewe than in ram for all the three types of ear. This might be due to a hormonal effect in the breed. Bose (1996) also found similar trend in distribution of ear sizes in the breed.

The birth weight of male and female lamb was 1.17 kg and 0.98 kg; however, their body weight on attaining the age of 10-12 months were 11.39 and

Table 1. *Average length and distribution of different types of ear in Garole Sheep*

Type of Ear	Male (242)			Female (684)			Pooled (926)		
	Length (cm)	Number of sample	Per-cent	Length (cm)	Number of sample	Per-cent	Length (cm)	Number of sample	Per-cent
Rudimentary (1-3 cm)	1.57	41	16.9	1.88	82	11.9	1.78	123	13.3
Medium (4-8 cm)	6.73	152	62.8	6.87	322	47.1	6.83	474	51.2
Long (more than 8 cm)	9.32	49	20.5	9.61	280	40.9	9.57	329	35.5

Table 2. *Mean body weight of Garole Sheep at the time of birth and at 10-12 months of age*

Age	Male		Female		Pooled	
	Average	Range	Average	Range	Average	Range
Birth Weight (kg)	1.17 (154)	0.95-1.50	0.98 (158)	0.90-1.40	1.07 (312)	0.90-1.50
10-12 months age(kg)	11.39 (137)	10.50-13.00	10.88 (187)	10.00-12.50	11.10 (324)	10.00-13.00

Figures in the parenthesis indicate the number of samples

10.88 kg respectively. The difference in body weight between the two sexes of garole sheep might be due to the effect of growth hormone. Nimbkar *et al.* (1998), however, found higher body weight of the garole at the time of birth and at one year of age than those values of ours. Pan and Sahoo (2007), on the other hand, reported 10.37 $\pm$ 0.14 and 10.88 $\pm$ 0.14 kg at 12 months age of the sheep like ours.

Thirty seven point seven (37.7), 46.8, 14.6 and 0.93% of the studied population had single, twin, triplet and quadruplet litter, respectively with an average of 1.78 (Fig. 1). Nimbkar *et al.* (1998) also observed that the distribution of litter size was 35% single, 57% twins, 7% triplets, and 1% quadruplets. Ghalsasi and Nimbkar (1993), however, reported 9% singles, 65% twins, 21% triplets and 5% quadruplets with average litter size of 2.23. These findings might indicate that the prolificacy of Garole sheep is in decline trend.

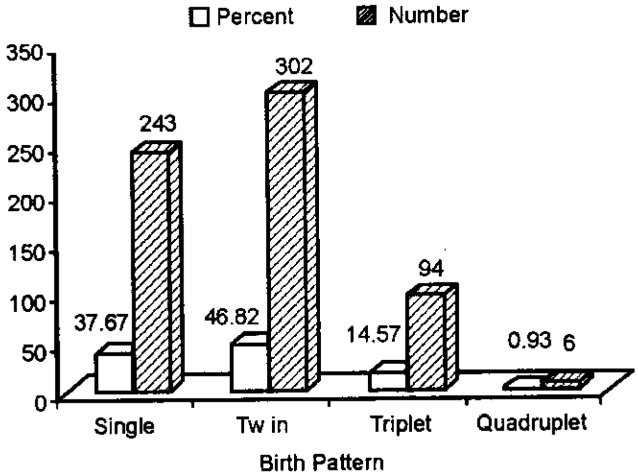

Fig. 1. Birth pattern of Garole Sheep

Results of the reproductive performance of the sheep showed (Table 3) that the age at puberty was within 210-730 days with an average of 272.8 days. This finding was in agreement with the findings of Mahanty and Mishra (1992) who reported that Ganjam and Bolangir sheep attained their puberty, on an average, at 280 $\pm$ 2.9 and 290$\pm$2.64 days respectively. Average length of gestation period of the sheep was 151.1 days with a range of 145 -160 days. Post partum oestrus generally occurred late but within 60-180 days with a mean of 92.36 days. A delayed puberty and post partum oestrus of the sheep might be due to some mineral and vitamin deficiency.

Table 3. *Reproductive performance of Garole Sheep*

Parameters	No. of observations	Mean (days)	Range
Age at puberty	126	272.85	210–730 days
Gestation period	134	151.14	145-160 days
Post partum oestrus	131	92.36	60-180 days

Table 4. *Worm infestation in naturally grazing Garole Sheep*

	Number	Percent
Positive	262	87.33
Negative	38	12.67
Amphistome	206	68.66
Strongyle	155	51.66
Strongyloides	42	14.00
Trichuris	32	10.66
Coccidia	169	56.33

While studying the prevalence of worm infestation in naturally grazing garole (Table 4) it was found that 87.3% of the faecal samples were positive. Of the infested sheep, 68.7, 51.7, 14.0, 10.7 and 56.3% were caused by *Amphistome, Strongyle, Strongyloides, Trichuris* and *Coccidia* respectively. Most of the naturally grazing garole were positive with Amphistome and Strongyle infestations. There was, however, no faecal sample infested with *Fasciola.* Nwosu *et al.* (2007) observed that nematode infestation in small ruminants of Nigeria varied with *Strongyles* sp. (22.5 percent), *Trichuries* sp. (5.9 percent) and *Strongyloides* sp. (4.9 percent).

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J. Indian Soc. Coastal agric. Res., 26(2), 156-157, 2008 **Short Communication**

Integrated Nutrient Management for higher Productivity of Confectionery Groundnut in Coastal Region of Maharashtra

The large seeded confectionery groundnut is important for direct consumption in India and abroad. It is an exhaustive crop compared to many other legumes. Biofertilizers and organic manures are applied as important components of integrated nutrient management for increasing productivity of this crop. Groundnut is grown on lateritic soil of Konkan region having low Ca and S along with major nutrients. In view of the above present investigation was carried out to find out the effect of integrated use of secondary nutrients and biofertilizers in combination with poultry manure and chemical fertilizers on yield and yield attributing characters of confectionery groundnut.

The field experiment was conducted during *rabi*-summer of 2004-05 and 2005-06 at the Agronomy Farm, College of Agriculture, Dapoli. The soil of the experimental plot was clay loam in texture, slightly acidic in pH, high in organic carbon, low in available nitrogen and phosphorus and moderately high in potassium. There were ten treatment combinations: 100% N through poultry manure (PM) and recommended dose of fertilizers (RDF) @ 50 kg N + 100 kg P_2O_5 ha^{-1}; sulphur and calcium were applied @ 25 kg and 2.5 t ha^{-1} through elemental sulphur and lime, respectively in a band. The fertilizer was mixed in surface soil and band was covred with soil. Transparent polythene mulch of 0.007 mm thickness having 90 cm width was used for mulching purpose. Holes of 25 mm diameter at a distance of 30 x 15 cm were punched. Then the polythene film was spread in plots before sowing. Effective Micro-organisms (EM-2) was prepared by the original EM-1 stock solution, Jaggary and clean water and kept in plastic bottle for

Table 1. *Effect of different treatments on growth and yield contributing characters, yield and economics of confectionery groundnut*

Treatments	Growth parameters		Yield contributing characters			Yield		Economics	
	No. of branches/ hill	Dry matter production/ hill (g)	Mature pods/hill	Wt. of pods/hill (g)	Dry pod yield (q/ha)	Haulm yield (q/ha)	Kernel yield (q/ha)	Net returns (Rs./ha)	B : C ratio
T_1-Control	9.53	21.65	20.55	31.35	52.44	52.05	38.40	58602.67	2.20
T_2-100% N through PM	12.57	26.76	22.93	41.87	61.60	60.62	45.29	72125.96	2.33
T_3-PM+EM+ PSM	13.58	27.84	24.55	44.42	65.98	63.16	48.63	79256.74	2.42
T_4-PM+EM+ PSM+S	14.07	30.34	27.71	46.61	71.84	66.96	54.36	87392.67	2.47
T_5-PM+EM+PSM +S+Ca	14.77	33.84	33.00	53.44	76.00	73.29	56.71	90482.18	2.39
T_6-RDF (50:100:0 kg/ha)	12.97	26.82	24.57	42.97	65.11	59.65	47.65	77675.74	2.40
T_7-RDF+EM+PSM	13.53	28.84	26.02	45.00	68.27	63.65	50.52	82849.37	2.46
T_8-RDF+EM+ PSM+S	14.07	31.15	27.43	47.32	73.29	67.15	54.59	89585.28	2.48
T_9-RDF+EM+PSM+ S+Ca	14.32	32.52	30.85	50.97	74.83	69.59	55.74	88100.01	2.36
T_{10}-PM+RDF+EM+ PSM+S+Ca	15.27	39.00	37.47	65.13	81.26	75.83	60.35	96990.83	2.40
SE (m) ±	0.32	1.14	1.03	1.65	0.56	0.52	0.51	—	—
CD 5%	0.96	3.39	3.05	4.92	1.67	1.55	1.51	—	—

PM, EM, PSM, RDF = Poultry manure, effective micro-organisms, phosphorus solubilizing micro-organisms and recommended dose of fertilizers respectively.

7 days before use. This EM-2 was used as per recommendation for soil inoculation. The seed kernels of confectionery groundnut (cv TPG-41) was inoculated with phosphorus solubilizing micro-organisms (PSM) in respective treatment plots. Two seeds per hill were dibbed in the soil through holes in the polythene mulch. Need based plant protection measures followed.

Application of PM+EM+PSM+S+Ca (T_{10}) produced the highest number of branches, dry matter, mature pods and weight of pods per hill (Table 1). The PM and RDF individually or in combination with biofertilizers, S and Ca produced significantly higher dry pod yield, haulm yield and kernel yield over the control. Application of integrated nutrient combination (T_{10}) consistently produced maximum dry pod, haulm and kernel yield. Integration of calcium (T_5 and T_9) and sulphur (T_8 and T_4) produced dry pod, haulm and kernel yield statistically at par with each other. Economic analysis of groundnut cultivation in terms of net profit showed the following trends: T_{10} (Rs. 96990 ha^{-1}) > T_5 (Rs. 90483 ha^{-1}) > T_8 (Rs. 89585 ha^{-1}) with the lowest associated with T_1 (Rs. 58603 ha^{-1}). Application of RDF and PM in combination with biofertilizers and sulphur (T_8 and T_4) proved highly remunerative in terms of return per rupee invested with B: C ratio of 2.48 and 2.47 respectively. Results also indicated that investment on sulphur in integrated nutrient supply system was more remunerative than that on calcium. Similar results were also reported by Madhiyazhagan *et al.* (2001).

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Short Communication

Effect of Land Configuration on Yield and Yield Attributes of Rainfed Bajra under Coastal Saline Soil Condition

Bajra is an important foodgrain crop for human and fodder for animal in coastal region of Gujarat. Its cultivation is done mostly under rainfed condition and its productivity is constrained by edaphic factors. The coastal tract of Saurashtra region of Gujarat is salt affected. Land configuration is an important technique to minimize salt level in root zone of crop and improve soil moisture status in saline soil. Keeping this in mind, a study was undertaken to investigate the effect of land configuration on yield and yield attributes of bajra grown under coastal saline soil condition.

A field experiment was conducted during *kharif* for four years (2003-04 to 2006-07) on coastal alluvial soil at Bajra Sub-Research Station, Junagadh Agricultural University, Mahuva, in split plot design consisting of 3 land configuration systems as the main plot treatments (flat system, ridge and furrow system and broad bed furrow system) and 2 sub-plot treatments (without mulch and mulching with straw @ 3 t ha^{-1}) with four replications. The experimental soil was of alluvial origin having silty loam texture, $EC_{2.5}$ 1.0 dSm^{-1}, $pH_{2.5}$ 8.1 and ESP 13.5 (Richards, 1954). Bajra (var. GHB 558) was sown in ten rows at spacing of 60 cm between rows with a seed rate of 3 kg ha^{-1}. Crop was fertilized with recommended doses of N: P_2O_5 : K_2O (80:40:40 kg ha^{-1}).

Results (Table 1) showed that the grain yield of bajra was significantly higher under Broad bed furrow system (M_3) compared to the others tested, the magnitude of increase being 23.5 and 12.7 per cent over the ridge and furrow (M_2) and flat bed sowing (M_1) system, respectively. Similar trend was also observed for fodder yield. The test weight (9.46 g/1000 seeds) and effective tillers (4.20/plant) were 4.1 and 11.1 per cent higher with broad bed furrow system (M_3) than that of ridge and furrow system (M_2), respectively. Plant height and length of ear-head were, however, found unaffected due to different land configuration systems. The grain yield of bajra was significantly affected by mulch treatment and it was 7.06 per cent higher with straw mulch practices @ 3 t ha^{-1} over no mulching (Table 1). Such mulching treatment had little effect on the straw yield of bajra. The test weight (9.50 g/1000 seeds) and effective tillers (4.07/plant) were, however, found significantly higher with straw mulch compared to no mulch.

Results thus indicated that under saline soil condition, broad bed furrow system of cultivation produced significantly higher yield of bajra. Application of straw mulch @ 3 t ha^{-1} in bajra produced significantly higher grain yield over no mulch.

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Table 1. *Effect of land configuration and mulch on yield and yield attributes of bajra*

Treatment	Yield (Kg ha^{-1})										Yield attributes			
	Grain					Fodder					Plant height (cm)	Length of ear head (cm)	Effective tiller/ plant	Wt. of 1000 seed (g)
	2003-04	2004-05	2005-06	2006-07	Pooled	2003-04	2004-05	2005-06	2006-07	Pooled				
Main plot treatment (M=Land configuration)														
M_1=Flat bed	2049	2972	3025	2717	2691	7002	6397	6439	6096	6483	186.8	21.58	3.89	9.36
M_2=Rid. & Fur.	1658	2839	2986	2337	2455	6173	6312	6235	5370	6022	184.8	21.73	3.78	9.09
M_3= Broad bed fur.	2160	3351	3589	3033	3033	6825	6235	7353	6497	6727	186.4	21.50	4.20	9.46
S. Em$\pm$	69.5	97.4	118.5	118	42.1	232	229	128	141	174.5	1.08	0.20	0.06	0.07
C.D. at 5%	240	337	410	403	123	NS	NS	444	487	509	NS	NS	0.18	0.20
Sub plot treatment (S=No mulch & Mulch)														
S_1= No mulch	1901	2910	3134	2588	2633	6546	6245	6438	6018	6312	185.3	21.44	3.84	9.11
S_2= Mulch	2011	3197	3265	2803	2819	6788	6384	6914	5957	6510	186.7	21.76	4.07	9.50
S. Em$\pm$	83.5	75.8	120.7	64.3	41.3	160	109	215	169	72.4	0.72	0.11	0.06	0.07
C.D. at 5%	NS	243	NS	206	119	NS	NS	NS	NS	NS	NS	NS	0.17	0.21

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Short Communication

Effect of Salinity and Potassium Levels on Yield and Nutrients Uptake by Groundnut

Majority of coastal saline soils of Gujarat under groundnut cultivation are poor in fertility. Under such situation, yield of groundnut is limited because of salinization and problem of K nutrition. Information on the effect of potassium and salinity levels on groundnut yield and its nutrients absorption is scarce. An attempt is made here to address the problem.

A pot experiment was conducted with four levels of salinity (S_1-2, S_2-4, S_3-8 and S_4-12 ECe dSm^{-1}) and four levels of potassium (K_1=0, K_2=25, K_3=50 and K_4=100 kg K_2O ha^{-1} applied as basal in the form of muriate of potash) in a factorial completely randomized design. The saline water of 2.0, 4.0, 8.0, and 12.0 EC dSm^{-1} were prepared by dissolving sulphates and chlorides of Na, Mg and Ca at 15:2:1 and of Cl : SO_4 at 2:1 ratio and added to soil in the pot frequently until the desired levels of salinity developed. The soil was silty clay loam with pH-7.9, ECe-0.5 dSm^{-1}, $CaCO_3$ 122 g kg^{-1}, Organic C 7.1 g kg^{-1}, available P-5.5 mg kg^{-1} and available K 45.5 mg kg^{-1}. Recommended doses of N (50.0 kg ha^{-1}) and P_2O_5 (100 kg ha^{-1}) were applied in each pot in the form of urea and diammonium phosphate. Ten seeds of groundnut (cv. G 4-2) were sown, thinned to five plants after germination and harvested at maturity. Yields of pod and haulm were recorded and representative samples were analyzed for nutrients content (Jackson, 1973).

Results (Table 1) showed that yield of both pod and haulm decreased significantly with increasing salinity levels, the magnitude being about 167.2 and 233.7 per cent with S_4 (ECe 12 dSm^{-1}) compared to S1. The uptake of N, P, K, Ca and Mg both by pod and haulm at harvest also decreased significantly with increasing salinity levels (Table 2). The uptake of Na, however, increased with increased salinity up to S_2.

Potassium application, on the other hand, increased significantly the pod and haulm yield with its increasing levels (Table 2). The uptake of N, P, K, Ca and Mg by pod and haulm also followed the same trends. The highest and the lowest yields of pod and haulm were recorded with S_1K_4 (25.20 and 43.33 g pot^{-1}) and S_4K_1 (5.37 and 8.57 g pot^{-1}, respectively) treatment combinations respectively. Similar effects of K and salinity on yield of groundnut was also reported by Mahi *et.al.*

Table 1. *Main and interaction effect of salinity and potassium levels on pod and haulm yield of groundnut*

Treatments	Pod yield (g pot^{-1})					Haulm yield (g pot^{-1})				
	Salinity levels					Salinity levels				
Potash levels	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
K_1	20.00	17.40	10.40	5.37	13.29	36.00	30.33	16.80	8.57	22.90
K_2	22.33	20.30	11.80	7.40	15.46	41.10	36.62	17.91	9.60	26.31
K_3	24.83	23.43	12.93	10.07	17.84	41.62	37.91	26.32	15.31	30.33
K_4	25.20	24.83	14.30	11.73	19.02	43.33	39.62	28.25	15.04	31.52
Mean	23.09	21.49	12.36	8.64		40.55	36.28	22.38	12.15	
	K	S	K x S			K	S	K x S		
S.Em. $\pm$	0.21	0.21	0.41			0.64	0.64	1.28		
C.D. P=0.05)	0.59	0.59	1.19			1.84	1.84	3.68		

Table 2. *Main effect of salinity and potassium levels on nutrients uptake (mgpot^{-1}) at harvest by pod and haulm of groundnut*

Treatments	Nutrient uptake in pod						Nutrient uptake in haulm					
	N	P	K	Ca	Mg	Na	N	P	K	Ca	Mg	Na
Salinity levels (S)												
S_1	305.42	83.49	145.79	96.51	73.93	64.08	343.25	95.61	409.64	350.06	256.84	297.12
S_2	284.81	72.89	131.00	89.04	63.93	74.42	317.48	87.16	354.59	280.72	213.17	284.34
S_3	164.75	42.64	57.02	46.96	31.40	48.60	174.73	44.10	192.81	153.88	128.86	211.64
S_4	117.25	28.13	31.30	26.18	19.94	39.04	91.06	18.59	94.76	60.32	62.31	175.64
SEM ±	4.48	1.53	1.45	1.64	1.82	2.26	7.26	3.52	7.52	6.81	6.06	6.86
CD (P=0.05)	12.89	4.41	4.17	4.74	5.25	6.50	20.90	10.14	21.65	19.61	17.46	19.74
Potash levels (K)												
K_1	174.27	43.99	65.11	45.61	41.91	54.77	185.54	40.31	201.41	154.79	120.90	232.59
K_2	204.72	53.15	82.20	57.63	46.35	57.71	220.24	57.17	245.42	190.85	149.55	240.25
K_3	237.65	62.76	101.78	70.82	50.19	59.15	258.98	75.03	287.82	224.56	185.21	253.91
K_4	255.58	67.25	116.01	84.61	50.75	54.51	261.75	72.95	317.15	274.79	205.52	242.00
SEM ±	4.48	1.53	1.45	1.64	1.82	2.26	7.26	3.52	7.52	6.81	6.06	6.86
C.D. (P=0.05)	12.89	4.41	4.17	4.74	5.25	NS	20.90	10.14	21.65	19.61	17.46	NS

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Response of Groundnut to Balanced Fertilizer under Coastal Saline-Sodic Soils of Saurashtra

Apart from inherent soil salinity, the problem of salinity ingress by seawater is acute in coastal belt of the Saurashtra. A decade ago, the yield potentiality of groundnut was about 5000 kg ha^{-1}, but now it has reduced to about 1000-2000 kg ha^{-1} because of saline groundwater associated with ingression of seawater. Nutrient management under such a situation is important for improving crop yield and soil health. Keeping this in view, a field experiment was undertaken to study the effect of K on yield, yield attributes and uptake of K by groundnut under coastal saline-sodic soil condition.

A field experiment was conducted on saline-sodic soils during *kharif* 2004 to 2006 in randomized block design having four replications in the farmer's field at Maktupur, Junagadh on groundnut (cv. GG-10). The experimental soil was silty clay loam having ECe-4.7 dSm^{-1}, pHs-7.99, ESP-22.04, $CaCO_3$-267 g kg^{-1}, organic carbon 7.10 g kg^{-1} and available N, P_2O_5 and K_2O - 140, 20.5 and 90 kg ha^{-1}, respectively. The treatments evaluated in this study included T_1: Control (recommended dose- 15.0: 30.0 kg N and P ha^{-1} in the form of urea and diammonium phosphate), T_2: T_1+K_{25} (25 kg K_2O ha^{-1}), T_3: T_1+K_{50} (50 kg K_2O ha^{-1}), T_4: T_1+K_{100} (100 kg K_2O ha^{-1}), T_5: T_4+Zn_{10} (10 kg $ZnSO_4$ ha^{-1}), T_6: FYM (10 t ha^{-1}), T_7: T_1+ Gypsum (50% of gypsum requirement) and T_8: T_6 + T_7. The groundnut crop was sown in rows of 60 cm apart using seed rate of 150 kg ha^{-1} after adequate rainfall. At maturity, pod and haulm yields were recorded separately and representative soil and plant samples were collected from each plot and were analyzed using standard methods (Jackson, 1973).

Results (Table 1) showed that application of gypsum @ 5 t ha^{-1} (T_7) produced significantly higher pod (3312 kg ha^{-1}) yield at par with T_5 (T_4+10 kg $ZnSO_4$ ha^{-1}) treatments. However, the haulm yield was not affected significantly by the treatments. Among the yield attributes, only mature pods per plant was significantly affected by the treatments recording higher values with T_4(13.6) and T_5 (12.7). Plant height, number of branches and immature pods per plant were also not affected due to the treatments. The uptake of K by pod was higher with treatment T_5 (22.3 kg ha^{-1}), T_4 (20.0 kg ha^{-1}) and $_7$ (20.5 kg ha^{-1}), but lower with T_6(15.6 kg ha^{-1}). Similar was the findings of Singh *et al.* (1987). Application of gypsum @ 5 t ha^{-1} along with FYM @ 10 t ha^{-1} (T_8) gave significantly higher values of EC 1.22 dSm^{-1} at par with treatment T_7 i.e. gypsum @ 5 t ha^{-1} (1.20 dSm^{-1}). In contrary, significantly lower value of soil pH was recorded with treatment T_8 (7.74) and treatment T_7 (7.81). Similarly, exchangeable sodium percentage (ESP) recorded significantly lower values with the T_7 and T_8. Overall, the higher values of EC and lower values of pH and ESP were recorded with treatment T_7 and T_8 than the other treatments because of gypsum application. The soil available K_2O of crop was higher with doses of K_2O application. Application of gypsum @ 5 t ha^{-1} (50 % GR) produced significantly higher pod yield and also reduced the ESP and pH in soils under coastal saline-sodic condition.

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Table 1. *Effect of different treatments on yield, yield attributes and uptake of K by groundnut and on soil properties (2004 to 2006 pooled)*

Treatment	Yield ($kg\ ha^{-1}$)		Yield attributes				Soil analysis				Potassium uptake ($kg\ ha^{-1}$)	
	Pod	Haulm	Plant height (cm)	No of Branches per plant	Mature pods per plant	Immature pods per plant	EC (1:2.5) dSm^{-1}	pH (1:2.5)	ESP	Av. K_2O ($kg\ ha^{-1}$)	Pod	Haulm
Control (Reco. dose of ferti.), (T_1)	2706	5535	46.7	5.73	11.0	1.52	0.75	7.93	26.4	252	17.5	57.6
T_1 +K_{25} (25 kg K_2O ha^{-1}) (T_2)	2645	5562	47.1	5.70	11.8	1.36	0.74	7.93	26.7	251	17.0	59.5
T_1 + K_{50} (50 kg K_2O ha^{-1}) (T_3)	2785	5700	48.2	5.55	11.7	1.50	0.68	7.93	26.2	265	18.7	61.2
T_1 + K_{100} (100 kg K_2O ha^{-1}) (T_4)	2761	5898	47.0	5.79	11.7	1.69	0.64	7.93	27.3	296	20.0	63.6
T_4 + Zn @ 10 kg $ZnSO_4$ ha^{-1} (T_5)	3083	6115	47.9	5.82	12.7	1.64	0.66	7.96	27.1	302	22.3	67.2
FYM (10 t ha^{-1}) (T_6)	2498	5634	46.7	5.38	11.5	1.29	0.78	7.96	26.9	261.2	15.6	59.6
Gypsum (50 % of GR) (T_7)	3312	6214	47.3	5.82	13.6	1.54	1.20	7.81	19.8	234	20.5	63.0
FYM (10 t ha^{-1}) + Gyp. (50 % of GR) (T_8)	2945	5780	48.9	5.61	10.8	1.41	1.22	7.74	19.9	233	18.4	59.3
SEm±	94	209	0.94	0.20	0.47	0.10	0.05	0.02	1.26	10.5	0.82	2.72
CD at 5%	265	NS	NS	NS	1.3	NS	0.13	0.07	3.8	29.8	2.3	NS

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Results and Discussion : With heading (Centre alignment), Upper case, Bold, 12 pt (Times New Roman) **Text**: Justified alignment, Double space, 12 pt. (Times New Roman) (**as: Results and Discussion**): **Table:** Title in italics at the top of the Table and Table number with a space (as: **Table 3.** *Characteristics of the soil profiles*): **Figure:** Title in italics at the bottom of the Figure and Figure number with a space (as: **Fig. 3.** *Salinity of groundwater in different months*)

References : With heading (Centre alignment). Upper case, Bold, 12 pt. (Times New Roman)

Journal articles: Sen, P.A., Roy, D. and Das, C. K. (2007). Characteristics of salt tolerant rice varieties for the coastal region. , **Journal name and volume:** Fully expanded name of the Journal. 12 pt (Times New Roman), italics with volume in bold number as: *Journal of the Indian Society of Coastal Agricultural Research* **25**: 45-52

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