ISSN 0972-1584

28 • No. 1 • 2010

Journal of the Indian Society of Coastal Agricultural Research

Advancement in Research on Coastal Agriculture

ISCAR

Publication of
Indian Society of Coastal Agricultural Research
www.iscar.org.in

ISSN 0972-1584

Journal
of
THE INDIAN SOCIETY OF COASTAL AGRICULTURAL RESEARCH

Volume 28 | 2010 | Number 1

INDIAN SOCIETY OF COASTAL AGRICULTURAL RESEARCH

CENTRAL SOIL SALINITY RESEARCH INSTITUTE, REGIONAL RESEARCH STATION

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OBITUARY

Padma Shri Dr. J.S.P. Yadav, the first President, Patron and Fellow of the Indian Society of Coastal Agricultural Research and a legendary figure in the field of Soil Science, breathed his last on 3 April 2010 at New Delhi. He had dedicated his entire professional life for the development of land and water management strategies under different cropping systems of inland and coastal salt affected soils regions and agro-forestry systems.

Dr. Yadav was born on 30 July 1922 in a village Akhaipur, Hathras, U.P. He had a brilliant academic record throughout his educational career. He did his B.Sc. (1946), M.Sc. (Ag.) (1951), Ph.D. (1958) and Post Graduate Diploma in Forestry (Soil), Oxford University, UK in 1959. He started his professional career as a lecturer in Govt. Agriculture College, Kanpur (1947-56) and occupied important positions as Soil Scientist and Senior Research Officer (Soil) Forest Research Institute, Dehradun (1956-69); Project Coordinator (1969-74) and Director CSSRI, Karnal (1974-82); Vice Chancellor, Haryana Agricultural University, Hisar (1982-83); Chairman, ASRB (1983-86); and Senior Programmer Specialist/ Project Officer USAID India (1987-91).

An eminent Soil Scientist of international repute, Dr. Yadav made outstanding contributions on soil and water management, leading to efficient and economic use of these two key resources. Based on an intensive investigation of Dr. Yadav, a salinity and alkali scale was prepared in 1956 to evaluate the salt-affected soils for crop responses. This scale has proved of immense practical value for adopting appropriate management practices for crops like rice, wheat, sorghum and barley.

The research initiated by Dr Yadav in 1970 after establishment of CSSRI on afforestation of sodic land helped rehabilitation of these problematic areas through agroforestry / social forestry. The publication of Dr. Yadav on 'Problems and Potentials of Reforestation of Salt-affected Soils in India' brought out in 1988 by FAO Regional Office Bangkok, received the wide recognition.

Dr. Yadav was the Vice Chairman, Commission VI and Sub-Commission on Salt-affected Soils of IUSS. Besides, he has been chairman/member of several professional/scientific committees, panels and meetings at State, National and International level. He served as the Editor of National Academy Agricultural Sciences. Dr. Yadav published more than 250 publications including research papers in foreign and Indian journals of repute, scientific reviews, books, bulletins, popular articles etc. The book co-authored by him on 'Saline and Alkali Soils of India' (1979) is still in great demand.

In view of his outstanding contributions, Dr. Yadav was conferred PADMA SHRI by the Govt. of India. He was also recipient, singly or jointly, of other important awards namely Guinness Award of Commonwealth Scientific Association, Hari Om Trust Award, Dr. Rajendra Prasad Award, Brandis Memorial prize, Schlich Memorial Prize, Honorary Member and Golden Jubilee honour of the Indian Society of Soil Science, USAID Award for Superior Performance, Samaj Gaurav Samman National Award, All India Pensioners Appreciation for meritorious service in ICAR, and D.Sc. (h.c.) by GBPUAT, Pantnagar. Dr Yadav was the Fellow of National Academy of Sciences, India; Chemical Society, London; National Academy of Agricultural Sciences; Indian Society of Agricultural Chemists; Indian Society of Water Management, and Soil Conservation Society of India. Dr. Yadav was President of Indian Society of Soil Science, Agricultural Society of India, Indian Society of Coastal Agricultural Research, Indian Society of Salinity Research Scientists, and Indian Society of Water Management. He was conferred honorary membership of the International Union of S Sciences in 2008. He visited several countries and served as the expert/consultant to FAO, USAID, World Bank, UN-ESCAP, UNDP, AFC, WAPCOS, PPCL and United Rice Land Ltd.

Members of the Indian Society of coastal Agricultural Research deeply mourn the death of most revered Dr. Yadav and pray to Almighty for peace to the departed soul.

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.

ISSN 0972-1584

JOURNAL
OF
THE INDIAN SOCIETY OF COASTAL AGRICULTURAL RESEARCH

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Published by the Hony. Secretary, Indian Society of Coastal Agricultural Research, Canning Town (743 329), WB and Printed by Media, Kolkata - 700 029, Phone : 98306 10609, E-mail : mediass60@yahoo.in

J. Indian Soc. Coastal agric. Res., 28(1), 1-7, 2010

Soil and Water Management Options for Enhancing Agricultural Productivity of Coastal Area of West Bengal

B. K. BANDYOPADHYAY*, SUBHASIS MANDAL, D. BURMAN and S. K. SARANGI

Central Soil Salinity Research Institute, Regional Research Station, Canning Town – 743 329, West Bengal

The coastal region of West Bengal primarily falls under the geomorphic sub-units of as *lower alluvial plain, deltaic flood plains, marshy/ inundated area, coastal sand dunes, coastal plains,* etc. Most of the coastal lands are low-lying (average 2-3 m above MSL) and many have elevation below the high tide mark of tidal rivers thus, they get easily submerged with rain/sea water. Taxonomically majority of these soils are in the order of *Entisols* and *Inceptisols*. The soils have *Hyperthermic* temperature and *Aquic* moisture regime. The soils are usually heavy textured varying from clay to silty loam. The economy of coastal areas of West Bengal is mainly dependent on agriculture (agriculture, fisheries, forestry, etc.) which influences the livelihoods of millions of rural households in the region. The agriculture in the coastal region is, as a whole, complex, diverse and risk prone. The cropping pattern is predominantly mono-cropped with low yield, growing traditional rice in almost 98% of the area in monsoon season as no other crops is possible during the period (*Kharif*) due to submergence of agricultural fields. But, the overall productivity of rice in the in the area is low, ranging between 2.2-2.6 t ha^{-1}. However, there lies plenty of scope of crop diversification towards high value fruits & vegetable crops by adopting suitable soil, water and crop management practices. The excess rain water in *Kharif* season (monsoon) goes waste into the sea as runoff water can be stored in farm with suitable land shaping for use as irrigation resource for growing multiple crops and integrated crop-fish cultivation. Several types of land shaping models has been suggested to meet the farmers' choice and land situation. The rainwater harvesting in the farm through appropriate land shaping also reduces salinity build up in soil and drainage congestion thus, making the land suitable for diversified crop cultivation.

(***Key words:*** *Coastal saline soil, Land shaping, Rainwater harvesting, Crop management, Integrated crop-fish cultivation*)

The coastal region of West Bengal lies between 87° - 25'E and 89°E latitude and 21° - 30'N and 23° -15'N longitude, spreading over mostly 3 districts viz. East Medinipur, South 24-Parganas and North 24-Parganas and covering an extensive area of land along the Bay of Bengal coast. The major part of the coastal area in West Bengal falls within the boundary of the districts of North 24 Parganas and South 24 Parganas, popularly known as Sundarbans. The total coastal areas under coastal agro-ecology in West Bengal is 14,152 sq km. The region belongs to the broad geographic unit Alluvial and deltaic plains of West Bengal. Under this region geomorphic sub-units such as lower alluvial plain, deltaic flood plains, marshy/inundated area, coastal sand dunes, coastal plains, etc. predominate. Most of the coastal lands are low-lying (average 2-3 m above MSL) and many have elevation below the high tide mark thus, they get easily submerged with rain/ sea water. In the Sundarbans region, the river Hugli (the Ganges) with its tributary systems meander severely in its confluence with the Bay of Bengal and are divided into number of branches, enclosing and intersecting the delta into large numbers island besides, the main land. The Bay of Bengal through the network of these rivers spreads its long arms, which are the chief sources of brackish water. The tides carry saline water and the tidal floods have, thus, great influence on the formation and development of coastal soils of the state. Most of the areas have very low elevations (average being 2-3 m above MSL) and a few areas are even below the sea level. In many cases, particularly in the Sundarbans region, the height of tide is above the mean elevation of the lands.

The soils of the coastal areas of West Bengal have developed on alluvium and taxonomically majority of these soils are under the order of Entisols and Inceptisols. The soils have Hyperthermic temperature and Aquic moisture regime. The soils are usually heavy textured varying from clay to silty loam. However, light textured soil i.e. sandy-to-sandy loam soils are found at places. The soils are generally neutral in reaction but highly acidic (pH 4.00) acid sulphate soils are found at places in the

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Sundarban region. The soils are low to medium in available N content, variable in available P content and high in available K content (Bandyopadhyay *et al.*, 1985; Bandyopadhyay, 1990; Maji and Bandyopadhyay, 1991; Bandyopadhyay *et al.*, 2008). Major portion of applied N fertilizer is lost through volatilization (Sen and Bandyopadhyay, 1987). Integrated nutrient management has been found to be very effective for increase in fertilizer use efficiency and sustainable yield of crops on coastal saline soils.

The acid sulphate soils are highly deficient available P. For improving crop yield on the acid sulphate soils the application of lime and higher dose of phosphorus and green manuring are highly beneficial (Bandyopadhyay and Maji, 1999, Burman *et al.*, 2007). Half dose of lime was as beneficial as full dose. High K status in soil is due to presence of K containing elliptic materials and K containing salts like KCl and K_2SO_4. Under highly acidic condition, Fe and Al are present in toxic level. These soils are generally rich in almost all micronutrients except Zn at places.

Most of the coastal areas of West Bengal are affected by salinity. The salinity development in the soils is primarily attributed to tidal flooding, frequent inundation of saline water from sea or river, drainage congestion and upward capillary movement of saline water from brackish ground water located at shallow depth (usually within 1m depth, throughout the year). The salts are dominated by Cl^- and $SO_4^=$ of Na, Mg, Ca and K. In general saline soils of West Bengal are low in fertility status. They are low in available N content, low to medium in available P content and high in available K content.

Except Zn and Cu, other micro-nutrients in the soils are generally high in status. The profile characteristics of soils from different coastal districts of West Bengal are given in Table 1.

Hydrology of Coastal areas of West Bengal

The coastal areas of the West Bengal is located in the Gangetic delta region and is a part of Bengal basin. Due to new-tectonic movement during 16th to 18th century the Bengal basin had tilted easterly along a hinge zone starting from Sagar (Sundarban) going north of Malda (North of West Bengal) and curving towards Dhaka (Bangladesh). As a result of this, the flow of Ganges river started coursing through the river Padma in Bangladesh leaving Hugli the erstwhile course as a more tidal channel. During 16th – 18th century innumerable distributaries were

Table 1. *Characteristics of some pedons of the coastal districts of of West Bengal West Bengal*

Horizon	Depth (cm)	Texture	Clay (%)	pH (1:2)	ECe (dSm^{-1})	SAR	ESP	CEC (c mol (p+) kg^{-1})	Base sat. (%)	Org. C (%)
Pedon: Bayarmari, P.S. Sandeshkhali, district North 24 Parganas :										
Ap	0-15	cl	38	4.6	7.2	8.5	13.4	12.0	65.0	1.09
Bwg1	15-50	cl	35	4.3	3.7	6.4	13.0	13.3	65.0	1.00
Bwg2	50-100	c	55	4.2	4.7	7.0	13.2	17.6	69.0	2.23
Bwg3	100-125	sic	55	4.1	9.9	9.2	12.9	16.2	68.0	2.26
Bwg4	125-150+	sic	52	5.4	18.9	12.1	15.0	15.6	69.0	1.68
Pedon: Bhagankhali, P.S. Basanti, district South 24 Parganas:										
Ap	0-19	sil	26	7.4	7.2	10.0	9.0	10.4	64.1	0.37
Ag	19-169	sil	26	7.9	5.5	8.7	7.6	9.7	65.1	1.08
Bwg1	169-209	sic	46	7.5	5.9	8.0	6.8	13.5	73.9	1.14
Bwg2	209-244	sic	50	7.5	6.0	9.4	6.0	14.5	62.0	0.64
Bwg3	244-281	sic	46	6.4	2.8	9.2	5.7	13.7	61.8	0.73
Pedon: Dariberia, P.S. Tamluk, district Medinipur										
Ap	0-12	c	45.2	6.5	6.0	8.8	13.3	0.90	13.5	76.0
BA	12-30	sic	48.8	6.5	4.3	10.2	10.7	0.62	15.3	78.1
Bwg1	30-54	sic	43.2	6.4	5.9	10.0	12.4	0.63	11.1	79.1
Bwg2	54-90	sic	53.2	6.3	8.1	9.8	14.6	0.41	16.0	82.9
Bwg3	90-110	cl	34.2	6.5	10.0	11.1	13.7	0.40	9.8	80.0
Bwg4	110-150	sicl	37.9	6.7	10.4	11.0	13.0	0.60	11.6	84.0

(Source: Bandyopadhyay *et al.*, 2003)

generated from Ganges which formed huge network of creeks and channels within Sundarban delta of India and most of them act as brackish water channels. The water salinity of rivers/estuaries/ creeks has been increased.

The Central Ground Water Board, Eastern Region has studied the hydrology of the coastal areas of West Bengal in details (www.cgwber.nic.in/ westbengal.htm). Ground water occurs in porous alluvial formation both under water table and confined conditions. The yield of the aquifer is about 150m3 hr-1. Fresh ground water bearing aquifer is occurring at varying depth ranges within 180 - 360 mbgl with the drilled depth of 600 mbgl. The fresh groups of aquifers are sandwiched between saline/ brackish aquifer. The top saline / brackish aquifer lies within the depth span of 20 m - 180 m with max depth of 320 mbgl in the extreme south. The shallow fresh water aquifers occur in dunes in Dihga- Ramnagar area of East Medimipur down to depth of 9 mbgl and in levee deposit within 50 mbgl in Baruipur - Sonarpur – Bhangar – Canning tract in Sough 24 Parganas district.

The important chemical types of ground water are Ca-Mg-HCO_3 type for low mineralized water in North 24 Parganas and East Medinipur districts and Na-HCO_3 type in South 24 Parganas and Ca-Mg-Cl in some isolated patches in delta region. Owing to the sub-marine and estuarine environment in which sediments are deposited and also owing to saline water intrusion as a result of proximity to the sea and tidal influence, in East Medinipur and South 24 Pargans, Cl content is in general high in upper aquifer in Subarnarekha Basin 8-100m, in Haldia area and Kasai basin 40-115 m, and in South 24 Pargans 20-15 m depth range very high with specific conductance. However, aquifers at deeper depth 115 - 300 m in Digha, 125-300 m in Haldia area and 170-350 m in South 24 Parganas district are relatively fresh and Cl content is within permissible limit. The salinity in ground water in East Medinipur and South 24 Pargans is high (> 3 dsm^{-1} at 25°c). The iron content in ground water in all the districts of coastal West Bengal is at high level (< 1.0 mg l^{-1}). The arsenic contamination problem in ground water has been reported in some coastal regions of West Bengal.

Current Status of Agriculture in Coastal areas of West Bengal

The economy of coastal areas of West Bengal is mainly dependent on agriculture (agriculture, fisheries, forestry, etc.) which influences the livelihoods of millions of rural households in the region. Nearly 20% of the Net State Domestic Product (NSDP) is accounted by this primary sector in these coastal districts. Out of which agriculture contributed 16% of NSDP in East Medinipur, 12% in North 24 Parganas and 15% in South 24 Parganas (Table 2). Agriculture's contribution to districts NSDP indicated a declining trend over the period 2002-03 and 2006-07. This indicated that the young generations are shifting towards other livelihood options than the agricultural sector alone as those are more effective to pull the income. The low producing agriculture sector of the coastal region alone can no longer fulfill the requirements of their livelihood needs. However, agriculture sector remain to be most important sector because this sector supports the livelihood of large number of active workers.

The employment pattern in the rural areas of the coastal region of West Bengal shows that the availability of labour force is less than demand during the pick planting (July-August) and harvesting (November- December) periods of *Kharif* rice which the major crop of the region. In the remaining periods there is huge surplus labour force who are to depended on non-agriculture based livelihood options available in nearby cities and towns. Thus there is huge migration of workers to nearby cities and towns during the lean periods of agricultural activities. If the agricultural activities are intensified through scientific soil, water and crop management the agriculture dependent livelihoods

Table 2. *Estimates of Net State Domestic Product (NSDP) of Coastal districts of West Bengal*

(at 1999-00 constant prices)

Particulars	East Medinipur		24 Parganas(N)		24 Parganas (S)	
	2002-03	2006-07	2002-03	2006-07	2002-03	2006-07
Agriculture	23.9	15.7	15.3	11.5	17.7	14.6
Forestry	0.9	0.8	0.5	0.5	1.2	1.3
Fisheries	10.6	8	3.3	4.5	7.6	6.8
Per Capita Income (Rs)	19166	28061	18034	23108	16621	18892

Note: NSDP in %

and employments in the coastal areas can be improved substantially thus curtailing the migration of labour forces to the cities and towns to a great extent.

The agriculture in the coastal region is, as a whole, complex, diverse and risk prone. The cropping pattern is predominantly mono-cropped with low yield, growing traditional rice in almost 98% of the area in monsoon season as no other crops is possible during the period due to submergence of agricultural fields. The crop production in monsoon season suffers from various adversities like heavy and intensive rain resulting deep-water logging, periodical inundation by high tides, poor surface and subsurface drainage, frequent cyclonic storms and floods. Land utilization pattern in coastal districts indicated that, at district level, in East Medinipur district nearly 73% of reported area is under cultivation (Net Sown Area) followed by 67% in North 24 Parganas and only 39% in South 24 Parganas. The cultivable land in all these districts are highly fragmented and more than 85% of operational holdings are categorized as marginal (<1 ha) and nearly 10% of the holdings are of small categories (1-2 ha). While implementing land and water management technologies the size of operational holdings should be kept into mind. Most of lands (about 80-90%) in the region remain follow in the other season because high soil and water salinity, and lack of good quality irrigation water.

Though the coastal areas are dominated by the mono-cropping with rice, However, the overall productivity of rice in the in the area is low, ranging between 2.2-2.6 t ha^{-1}. Among the rice productivity under different season, the productivity of boro rice (3 t ha^{-1}) is relatively higher than *Aman* (2 t ha^{-1}) and Aus rice (2.2-2.6 t ha^{-1}). Majority of the rice are grown as *Aman* paddy (80% in South 24 Parganas and 62% in East Medinipur & North 24 Parganas). The productivity of rice exclusively in coastal salt affected areas are over poor, sometime below 2 t ha^{-1} during *Kharif* (*Aman* paddy) season and the scope for paddy cultivation in *Rabi* season is severely restricted due to scarcity of good quality of irrigation water.

Though the coastal areas of West Bengal is mostly mono-cropped with rice, but there lies plenty of opportunities of crop diversification towards high value fruits & vegetable crops by adopting suitable soil, water and crop management practices.

(a) Water management

Expansion of irrigated area and availability of quality irrigation is the most challenging task in the coastal areas of West Bengal to increase the crop production and productivity. Among various sources of irrigations shallow tube well (STW) and rain water harvested in Govt. Canals, ponds, ditches and depression are the most important sources. The coastal districts receive plenty of rainfall during *Kharif* season in much excess of the evapo-transpiration demand during the season. The excess water goes waste into the sea as run off can be harvested in suitable structures in the farm to create potential irrigation resource. The cropping intensities in the area during dry seasons can be increased substantially with this irrigation resource provide the crops that requires less water (Ambast *et al.*, 1998) are selected. The water balance study at CSSRI, RRS, Canning Town has shown that about 450 mm of rainfall in the monsoon season would be excess after meeting the evapo-transpiration losses. The excess rainwater can be stored in dug out farm pond, which can be simultaneously used for dual purposes of fresh water pisci-culture and as irrigation resource.

b) Land management

Major coastal areas of the country face the problem of salinity, water logging, drainage congestion and presence of brackish ground water table very near to the surface. Many of these problems can be substantially reduced by adopting suitable Land shaping, some of them are described below. The basic purpose of these land shaping is to create different land types (high, medium and low) for multiple & diversified crops in different seasons, harvesting rain water, to reduce drainage congestion of some land area in the farm and providing scope for crop/paddy-fish simultaneous cultivation for higher farm income and employment generation. The selection of a technology will depend on situation of the land, the soil characteristics, land holding capacity and above all the choice of the farmer. Covering the soil surface with mulches (rice straw, farm waste, etc.) or canopy cover (field crops, green maturing corps etc.) or even ploughing up of soil will reduce the soil salinity build up in soil in dry months.

(i) Farm pond (FP)

Soil dug out for making farm pond on 1/5th of farm area) is used for rainwater harvesting and fish cultivation throughout the vear. The remaining field is made into high, medium and low (original land) land. The high land is used for vegetable cultivation throughout the year. The medium and low land are used for cultivation of paddy (or paddy-cum-fish) in *Kharif* and low water requiring field/vegetable crops (or paddy in small area) in *Rabi* with harvested rain water. This technology offers a scope for multiple crop cultivation on rain fed mono-cropped coastal region and generates higher employment and farm income (CSSRI, 2008).

(ii) *Deep furrow and high ridges*

Half of the farm area is shaped into alternate deep furrow and high ridges. The furrows are used for rainwater harvesting and fish cultivation in *Kharif*. Ridges are used for vegetable cultivation throughout the year. The remaining land is used for paddy-cum-fish cultivation in *Kharif* and low water requiring field/vegetable crops in *Rabi*/ summer. The furrows provide better drainage and protect the crops from damages due to occasional heavy rains following *Rabi*/summer due to climatic disturbances. The rain water stored in furrows keep the root zone soil relatively saturated with fresh water during the initial dry months after *Kharif*, thus reduces upward capillary flow of brackish water from shallow subsurface layer and thereby reducing the salinity build up in soil.

(iii) *Shallow furrow and medium ridges*

Half of the farm area is shaped into alternate shallow furrow and high ridges with excavated soil at an interval of 3.0m. The furrows are used for rain water harvesting and fish cultivation under paddy-cum fish in Kharif. Ridges are used for fruit crop/vegetable cultivation throughout the year. The remaining land is used for cultivation of paddy-cum-fish in *Kharif* and low water requiring field/vegetable crops in *Rabi*/summer.

(iv) *Paddy-cum-fish (PCF)*

Channels are dug around the field for Paddy-cum fish cultivation and rainwater harvesting in *Kharif*. Raised lands are (bunds of channels) used for vegetable cultivation throughout the year. In *Rabi* and summer seasons the land is used for cultivation of low water requiring field/vegetable crops and paddy (small area) with harvested rain water in channels.

(v) *PCF* (Kharif) *+ Brackishwater fish* (Rabi)

Same as Paddy-cum-fish (b) above. Except that brackishwater fish is cultivated in Rabi and summer instead of field/vegetable crops.

c) Crop management

The cropping system in the coastal areas is predominantly rice based mono-cropping. A change in cropping system for higher production and income from agriculture in the coastal region integrated farming activities covering agriculture, horticulture, fisheries, animal husbandry and forestry/agro-forestry is the need of the hour. Research focus needs to be re-oriented towards integrated rice based cropping system, which should be compatible with the available land and water resources. Special stress is to be given on simultaneous development of both agriculture and fishery. (Prain 1994) as was also opined by others (Natarajan and Ghosh, 1980, Sinha, 1981, Srivastava *et. al.*, 2004, Pandey *et al.*, 2005). Halwart and Gupta (2004) also pointed out that the most viable option for increasing agricultural production in the rain fed coastal areas of the country is the integrated agriculture-aquaculture farming system. Besides the fresh water fisheries brackish water fisheries have great potentiality on account of large resources of both surface and subsurface brackish water in the coastal region. Brackish water fisheries can produce prawns in addition to other brackish water fishes and can give much higher income. Composite fish culture instead of monoculture needed to be followed in inland fresh water fisheries for higher income.

There is a great scope not only for the field crops but also for a wide variety of other crops. Suitable salt tolerant varieties of *Rabi* field crops like, sunflower, cotton, groundnut, etc. and vegetable crops like cucurbits, tomato, brinjal, knolkhol, sweet potato, leafy vegetables, flowers, fruit/plantation crops like, coconut, areca nut, sputa, guava, cashew, and spices like, turmeric, black cumin, coriander, fennel & fenugreek are high value commercial crops etc. are to be developed and introduced in coastal salt affected areas for higher yield. The crop varieties to be developed should have the characteristics of salt tolerance, high yield, and short duration and low water requiring.

Development of agro-forestry, has significant productive as well as protective functions in the coastal areas. Salinity and water logging resistant trees are to be introduced for meeting the local requirement (Burman *et al.*, 2007b). A forestation not only supplies timber, fuel, fodder and variety of other products but also has a moderating influence against floods and erosion and help to maintain soil quality and ecology. Agro-forestry plants along the coast might also check the menace of felling of trees in the adjoining forest areas by the poor rural people of coastal areas to meet their requirement of timber and fuel. Some of the promising agro-forestry plants in the area are: *Casuarinas, Eucalyptus, Akashmoni, Sunddari, Pasur* (Burman *et al.*, 2007b). Besides the agro-forestry the tropical rain forests/mangrove forest occupying along the sea coast are to be conserved and their area needs to be augmented, for the protection of coastal area. Mangroves colonies stabilize the saline silted lands/wetlands adjoining the coastal line and are also valuable repositories of biodiversity. They play a vital role in protection of the shoreline against erosion caused by wave action and cyclones.

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J. Indian Soc. Coastal agric. Res., 28(1), 8-11, 2010

Management of Acid Sulphate Soil of Coastal Sunderbans Region: Observations under On-farm Trial

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The acid sulphate soils are found at some places in Sundarbans region of West Bengal. These soils are highly acidic, deficient in P and, high in Fe and Al content with very poor crop yield. In the present investigation the effect of P-fertilizer, lime and green manure on the productivity of rice and effect of P-fertilizer and residual effect of lime on sunflower was studied under farmer's field condition with an objective to develop strategies for the efficient management of these soils. Under the on-farm study 3 doses of P [0, 40 (recommended dose) & 80 (double of recommended dose) P_2O_5 kg ha^{-1}], 3 doses of lime (0, half & full of lime requirement determined by KCl extraction method) with or without green manure were evaluated under RBD laid out field experiment with 3 replications. Locally available oyster shells (milled) were applied as cheap source of lime during dry season. Significant increase in the plant growth parameters like plant height and root density was recorded at double the recommended dose of P followed by the recommended dose compared to no P-fertilizer treatment. The increase in grain and straw yield of rice and grain yield of sunflower was also followed the same trend. The improvement in growth and yield of rice due to application of lime and residual effect of lime on yield of sunflower at P-fertilizers treatments with full lime requirement dose was at par with half lime requirement dose. The effect of the application of green manure was found to be significant at all the treatments of P fertilizer and lime. Lime application resulted in increase in pH of soil and decease in KCL extractable Al and, DTPA extractable Fe and Mn of the soil. The available P content of the soil has been increased due to application of P-fertilizer as well as lime.

(***Key words:*** *Acid sulphate soil, P-fertilizer, Lime, Green manure, Rice, Sunflower, Yield and growth parameters, Coastal soil*)

Highly acidic (acid sulphate soil) soils are found in some places in the coastal region of Sundarbans (Bandyopadhyay 1988, 1989, Bandyopadhyay *et al.*, 2003, Bandyopadhyay and Maji, 1995). Acidity of these soils is due to oxidation of pyrites and other sulphidic materials which has, sometime in the past, accumulated in the soils. The acid sulphate soils of Sunderbans are saline with toxic content of Fe and Al, and very low level of available P (Bandyopadhyay and Maji, 1995). Soil acidity impairs root growth of crops, reduces water and nutrient uptake, and subsequently decreases the yield. Due to adverse effect of acid sulphate soil farmers fail to grow crops on these soil particularly during dry season and the lands usually remain fallow after *kharif* rice. Application of lime and higher doses of P could increase the yields of crops grown in the acid suphate soils in Sunderbans region (Bandyopadhyay and Maji, 1999). However, farmers hardly apply those primarily due to cost factor. The beneficial effect of green manuring on the improvement crop yield on salt affected soils especially saline and alkaline soils has been reported by many workers (Bandyopadhyay *et al.*, 2008, Bandyopadhyay and Rao, 2001, Singaravel and Balasundaram, 1999). In the present experiment under on-farm condition attempts were made to improve the productivity of the acid sulphate soils through the use of low cost technology.

MATERIALS AND METHODS

A field trial was conducted during 2005 and 2006 in farmer's field at village Kheria in the District of South 24 Parganas, West Bengal, India. The site typically represents area affected by both acidity (acid sulphate soils) and salinity in the coastal Sunderbans region of India (latitude: 22°05′ – 22°30′N, longitude: 88°30′N – 88°55′E). The climate is sub-humid with aquic soil moisture and hyperthermic soil temperature regimes. The average annual rainfall is 1759 mm, out of which about 80% occurs during monsoon (June-October) and only very limited rain during rest of the period of year.

The pH of the experimental soil was low (4.2) with high soil salinity (ECe 21.5 dS m^{-1}), high extractable Al (111.9 ppm), high available Fe (172.5 ppm), high available K (489.0 kg ha^{-1}), medium org. C (0.62%), medium available N (372.5 kg ha^{-1}) and very low available P (4.28 kg ha^{-1}). Three doses of P-fertilizer [0, 40 (recommended dose) & 80 (double of recommended dose) P_2O_5 kg ha^{-1}] and 3 doses of lime (0, half & full dose of lime requirement determined by KCl extraction method) with or without green manure were evaluated under RBD laid out field experiment with 3 replications. Rice (c.v. SR26B) and sunflower (c.v. PAC36) were taken as test crops during *kharif* (2005) and *rabi*/summer (2006) seasons, respectively. Green manuring crop *Sesbania* was grown *in situ* and it was incorporated in the soil during land preparation for transplanting of *kharif* rice. *Sesbania* and rice were grown as rainfed crops (in *kharif*) while sunflower (in *rabi*/ summer) was grown under irrigated condition. Recommended dose on N as urea was applied to rice and sunflower. Phosphorous was applied as single super phosphate to both the crops. Lime was applied during dry season (February, 2005) before seeding of *Sesbania*. Milled oyster shell, a locally available material was used as a cheap source of lime. No lime was applied to sunflower crop and the residual effect of lime which was applied in dry season of previous year was studied on sunflower. The CaO content in the oyster shells was 64.46 wt%, which is comparable to that of commercial lime. Lime requirement of the soil was determined by KCl extraction method (Lin and Coleman, 1960). About 1.33 t ha^{-1} and 1.66 t ha^{-1} of oyster shells were applied as half and full of the recommended doses respectively.

Soil samples collected from the surface of the soil up to 15 cm depth. EC, pH, organic carbon, KCl extractable Al, and available N, P, K, Fe (DTPA) and Mn (DTPA) were determined following standard methods given by Black (1965). Al, Fe and Mn were determined by Atomic Absorption Spectrophotometer (ECIL, model-4141).

RESULTS AND DISCUSSION

There was a high significant increase in the plant height, root density, grain and straw yield of rice at double recommended dose (80 kg P_2O_5 ha^{-1}) followed by recommended dose of P (40 kg P_2O_5 ha^{-1}) compared to no P-fertilizer treatment (Table 1). Compared to control highly significant increase in grain yield of sunflower was also recorded at double of the recommended dose of P followed by recommended dose of P. The average increase in grain yield of rice was 72.84% and 123.46% at 40 kg and 80 kg P_2O_5 ha^{-1}, respectively over no P-fertilizer treatment. The improvement in the yield of sunflower was 30.20 % and 78.68 % at recommended and double of the recommended doses of P, respectively over control

Table 1. *Growth parameters, grain and straw yield of rice, and grain yield of sunflower grown on acid sulphate soil*

Treatments		Rice				Sunflower
		Growth at 60 DAT		Yield at harvest		
P_2O_5 & GM	Lime	Plant height (cm)	Root density (kg m^{-3})	Grain (t ha^{-1})	Straw (t ha^{-1})	Grain (t ha^{-1})
40 kg P_2O_5 ha^{-1} +GM	L_0	103	10.93	3.21	5.67	1.35
	$L_{1/2}$	108	11.61	3.69	6.83	1.78
	L_1	109	12.04	3.80	7.31	1.84
40 kg P_2O_5 ha^{-1}	L_0	97	9.24	2.80	5.28	1.23
	$L_{1/2}$	103	9.87	3.14	6.04	1.70
	L_1	104	10.30	3.15	6.18	1.75
80 kg P_2O_5 ha^{-1} +GM	L_0	110	11.84	4.01	7.43	1.67
	$L_{1/2}$	115	12.80	4.33	7.87	2.13
	L_1	117	12.38	4.36	7.79	2.17
80 kg P_2O_5 ha^{-1}	L_0	105	10.83	3.62	6.96	1.59
	$L_{1/2}$	110	11.40	3.97	7.49	2.05
	L_1	109	11.79	3.93	7.42	2.08
Control (No P_2O_5, lime and GM)		61	7.95	1.62	3.18	0.89
CD at P = 0.05		4.91	0.46	0.29	0.16	0.05

GM: green manure, L_0 : No lime application, $L_{1/2}$: Half dose of lime requirement (1.33 t ha^{-1}), L_1 : Full of lime requirement (2.66 t ha^{-1})

where no P fertilizer was applied. Increase in the growth parameters and yield of rice and sunflower were primarily due to higher P availability as soil was extremely poor in available P with high P fixation capacity. Bandyopadhyay & Maji (1999) also reported significant improvement in the yield of rice due to application of higher doses of P to acid sulphate soil of Sunderbans. The effect of application of green manure was found significant at all the treatments for both rice and sunflower crops. The green manure in combination of recommended and double recommended doses of P-fertilizer enhanced grain yield of rice by 98.15% and 147.53%, respectively and that of sunflower by 51.69% and 87.64%, respectively compared to control treatment where no green manure and phosphate was applied.

The effect of lime on growth parameters and yield (both grain and straw) of rice and its residual effect on yield of sunflower which was grown during dry season after harvest of *kharif* rice was found significant. The significant improvement in grain yield of rice (*kharif*) due to application of lime to acid sulphate soil was also reported by Bandyopadhyay and Maji (1999). In the present experiment, the improvement in growth parameters and yield of rice and yield of sunflower at full lime requirement dose was at per with half of lime requirement dose with all phosphate treatments and, with or without green manure. Maximum plant height, root density, grain and straw yield of rice and grain yield of sunflower was recorded when lime was applied at half or full lime requirement dose along with double recommended doses of P (80 kg P_2O_5 ha^{-1}) and green manure. In these treatments the improvement in grain yield for rice and sunflower was 169.14% and 143.82% respectively, compared to control treatment.

The physico-chemical properties of the surface soil up to a depth of 15 cm after harvest of the sunflower crop are presented in Table 2. The lime application resulted in increase in pH of soil. The soil pH increased from 4.2 at control treatment to 5.2-5.4 at half dose of lime and 6.0-6.1 at full dose of lime in combination with P and with or without green manure. The available P content of the soil increased due to application of P-fertilizer as well as lime and green manure. The available P content increased to maximum of 15.,2 kg ha^{-1} at double recommended dose of P along with application of full lime dose and green manure compared to control (3.68 kg ha^{-1}). Available N content of soil also increased due to application of green manure along with lime and P fertilizer. The effect of application of lime was found to reduce the extractable Al, and available Fe and Mn content of soil. The effect was more with full lime dose compared to half lime dose.

Table 2. *Soil properties at the surface soil (0-15 cm soil depth) after harvest of sunflower crop*

Treatments P_2O_5 & GM	Lime	Soil properties							
		ECe (dS m^{-1})	pH	Av. P	Av. N (kg ha^{-1})	Av. K_2O (kg ha^{-1})	Extra c.SAl (ppm)	Av. Fe (ppm)	Av. Mn (ppm)
40 kg P_2O_5 ha^{-1} +GM	L_0	6.5	4.3	8.2	290.5	401.4	109.5	203.6	47.0
	$L_{1/2}$	6.2	5.4	8.4	300.7	424.5	80.7	185.8	33.6
	L1	6.6	6.1	9.4	315.5	432.2	55.2	160.3	31.0
40 kg P_2O_5 ha^{-1}	L_0	6.3	4.3	8.0	237.8	405.1	107.3	219.3	39.8
	$L_{1/2}$	6.5	5.2	8.3	256.7	417.6	79.9	181.2	31.9
	L_1	6.9	5.8	8.6	269.5	424.3	56.3	157.3	31.2
80 kg P_2O_5 ha^{-1} +GM	L_0	6.4	4.6	15.0	305.3	411.5	103.9	208.9	42.5
	$L_{1/2}$	6.1	5.2	15.2	325.1	438.8	77.4	181.0	31.3
	L_1	6.7	6.0	15.7	356.7	448.4	57.9	158.3	30.7
80 kg P_2O_5 ha^{-1}	L_0	6.0	4.1	14.7	255.9	405.7	107.3	204.2	45.3
	$L_{1/2}$	6.1	5.3	15.3	264.4	426.4	84.0	184.3	33.7
	L_1	6.7	6.1	15.7	292.9	430.6	63.6	165.8	30.6
Control (No P_2O_5, lime and GM)		6.23	6.2	4.2	3.7	202.9	387.8	113.4	203.6

GM: green manure, L_0 : No lime application, $L_{1/2}$: Half dose of lime requirement (1.33 t ha^{-1}), L_1 : Full of lime requirement (2.66 t ha^{-1})

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J. Indian Soc. Coastal agric. Res., 28(1). 12-15, 2010

Evaluation of Frontline Demonstration of Greengram (*Vigna radiata* L.) in Sundarbans, West Bengal

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Green gram (mungbean) is one of the important pulse crop in India, plays a major role in augmenting the income of small and marginal farmers of Sundarbans. The low production of traditional varieties of greengram was a cause of concern for the farmers at large. To overcome this problem of low yield, Krishi Vigyan Kendra of CIFRI has conducted frontline demonstration field of fourteen villages in Kakdwip, Namkhana, Patharpratima and Kulpi blocks of Sundarbans, West Bengal. Cultivation of high yielding varieties of greengram viz. K-851, PDM-54, B-105, Pusa Baishakhi and Sonali has given yield increases of 38.25, 50.82, 25.0, 33.33 and 60.0 percent, respectively over local check. The technology gap were 396 kg ha^{-1} for K-851, 300 kg ha^{-1} for PDM-54, 350 kg ha^{-1} for B-105, 300 kg ha^{-1} for Pusa Baishakhi and 400 kg ha^{-1} for Sonali varieties of greengrain. The highest extension gap of 223 kg ha^{-1} was recorded in variety K-851, followed by 337 kg ha^{-1} for PDM-54, 300 kg ha^{-1} for Pusa Baishakhi, 200 kg ha^{-1} for Sonali and the lowest 150 kg ha^{-1} for B-105. This high extension gap in all these varieties requires urgent attention from planners, scientists, extension personnel and development departments. The technology index were 33 percent for K-851, 23.07 percents for PDM-54, 31.81 percents for B-105, 27.27 percents for Pusa Baishakhi and 33.33 percents for Sonali. Except PDM-54 and Pusa Baishakhi all other varieties have given technology index of more than 30 percents indicating that the performance by these varieties in Sundarbans conditions was not more than the satisfactory level and these varieties requires more tolerance to salinity. The changes will accelerate the adoption of newer varieties to increase the productivity of greengram in this area. There is a need to adopt multi pronged strategy which involves enhancing greengram production through horizontal and vertical expansion and productivity improvements through better adoption of improved technology.

(***Key words:*** *Frontline Demonstration, Technology gap, Extension gap, Technology index*)

Agriculture in India has shown a gradual transformation from subsistence farming to the commercial farming. The green revolution has provided a great boost to the food grain production especially in two crops namely rice and wheat. One of the attractions of the green revolution technologies is that they are, in principle, scale neutral, and can raise yields and incomes for both small- and large-scale farmers. But it has also generated several ecological problems (soil degradation and depletion of ground water) and steep variation in yield of better-endowed region to the less endowed region. In spite of the higher domestic prices of the two cereals farmers are not finding them remunerative because of the diminishing return. Pulse crop play an important role in Indian agriculture. Their ability to use atmospheric nitrogen through biological nitrogen fixation is economically more sound and environment friendly. With 35 percents of world area and 27 percents of production, India is the largest pulse producing nation.

Greengram crop is one of the important pulse crops and is being cultivated in Sundarbans after the harvest of aman rice. Greengram contains 25 percent of high digestible proteins and consumed both as whole grain as well as dal. It is a soil-building crop, which fixes atmospheric nitrogen through symbiotic action and can also be used as green manure crop adding 34 kg N ha^{-1}. The improved technology packages were also found to be financially attractive. Yet, adoption levels for several components of the improved technology were low, emphasizing the need for better dissemination (Kiresur *et al.*, 2001). Several biotic, abiotic, and socio-economic constraints inhibit exploitation of the yield potential and these needs to be addressed.

Agriculture is the main occupation in Sundarbans and rice is the main staple crop of the region. Crop growth and yield are limited through poor plant nutrition and uncertain water availability during the growth cycle. Inappropriate management

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J. Indian Soc. Coastal agric. Res., 28(1), 12-15, 2010

Evaluation of Frontline Demonstration of Greengram (*Vigna radiata* L.) in Sundarbans, West Bengal

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Green gram (mungbean) is one of the important pulse crop in India, plays a major role in augmenting the income of small and marginal farmers of Sundarbans. The low production of traditional varieties of greengram was a cause of concern for the farmers at large. To overcome this problem of low yield, Krishi Vigyan Kendra of CIFRI has conducted frontline demonstration field of fourteen villages in Kakdwip, Namkhana, Patharpratima and Kulpi blocks of Sundarbans, West Bengal. Cultivation of high yielding varieties of greengram viz. K-851, PDM-54, B-105, Pusa Baishakhi and Sonali has given yield increases of 38.25, 50.82, 25.0, 33.33 and 60.0 percent, respectively over local check. The technology gap were 396 kg ha^{-1} for K-851, 300 kg ha^{-1} for PDM-54, 350 kg ha^{-1} for B-105, 300 kg ha^{-1} for Pusa Baishakhi and 400 kg ha^{-1} for Sonali varieties of greengrain. The highest extension gap of 223 kg ha^{-1} was recorded in variety K-851, followed by 337 kg ha^{-1} for PDM-54, 300 kg ha^{-1} for Pusa Baishakhi, 200 kg ha^{-1} for Sonali and the lowest 150 kg ha^{-1} for B-105. This high extension gap in all these varieties requires urgent attention from planners, scientists, extension personnel and development departments. The technology index were 33 percent for K-851, 23.07 percents for PDM-54, 31.81 percents for B-105, 27.27 percents for Pusa Baishakhi and 33.33 percents for Sonali. Except PDM-54 and Pusa Baishakhi all other varieties have given technology index of more than 30 percents indicating that the performance by these varieties in Sundarbans conditions was not more than the satisfactory level and these varieties requires more tolerance to salinity. The changes will accelerate the adoption of newer varieties to increase the productivity of greengram in this area. There is a need to adopt multi pronged strategy which involves enhancing greengram production through horizontal and vertical expansion and productivity improvements through better adoption of improved technology.

(***Key words:*** *Frontline Demonstration, Technology gap, Extension gap, Technology index*)

Agriculture in India has shown a gradual transformation from subsistence farming to the commercial farming. The green revolution has provided a great boost to the food grain production especially in two crops namely rice and wheat. One of the attractions of the green revolution technologies is that they are, in principle, scale neutral, and can raise yields and incomes for both small- and large-scale farmers. But it has also generated several ecological problems (soil degradation and depletion of ground water) and steep variation in yield of better-endowed region to the less endowed region. In spite of the higher domestic prices of the two cereals farmers are not finding them remunerative because of the diminishing return. Pulse crop play an important role in Indian agriculture. Their ability to use atmospheric nitrogen through biological nitrogen fixation is economically more sound and environment friendly. With 35 percents of world area and 27 percents of production, India is the largest pulse producing nation.

Greengram crop is one of the important pulse crops and is being cultivated in Sundarbans after the harvest of aman rice. Greengram contains 25 percent of high digestible proteins and consumed both as whole grain as well as dal. It is a soil-building crop, which fixes atmospheric nitrogen through symbiotic action and can also be used as green manure crop adding 34 kg N ha^{-1}. The improved technology packages were also found to be financially attractive. Yet, adoption levels for several components of the improved technology were low, emphasizing the need for better dissemination (Kiresur *et al.*, 2001). Several biotic, abiotic, and socio-economic constraints inhibit exploitation of the yield potential and these needs to be addressed.

Agriculture is the main occupation in Sundarbans and rice is the main staple crop of the region. Crop growth and yield are limited through poor plant nutrition and uncertain water availability during the growth cycle. Inappropriate management

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may further reduce the fertility of soil (Rabbinge, 1995). The green gram crop is mainly cultivated in summer season from February to May in midlands and lowland on residual soil moisture. Frontline demonstration on greengram using new crop production technology was initiated with the objectives of showing the productive potentials of the new production technologies under real farm situation over the locally cultivated varieties.

MATERIALS AND METHODS

Frontline Demonstration is the new concept of field demonstration evolved by ICAR with the inception of technology mission on oilseeds and pulses. The main objective of frontline demonstrations is to demonstrate newly released crop production technologies and its management practices in the farmers' field under coastal saline soil of South 24 Parganas district of West Bengal. The present investigation was carried out at Narayanpur, Nandabhaga, Debnibas, Budhakhali, Arunberia, Shibpur, Mundapara, Gangadharpur, Bhubhannagar, Kusumpukur, Belpukur, Akshaynagar, Kumarpur and Dhurbachoti under Kakdwip, Namkhana, Patharpratima and Kulpi blocks of Sundarbans in South 24 Parganas district of West Bengal.

The materials for the present study comprised high yielding strains of greengram viz. K-851, Sonali, B-105, Pusa Baishakhi and PDM-54. Locally cultivated varieties were used as local check. The soil type was gangetic alluvium (Entisols) and medium to low in fertility status. The objective of the performance evaluation was to study the gaps between the potential yield and demonstration yield, extension gaps and the technology index. In the present study the data on output of greengram crop were collected from FLD plots, besides the data on local practices commonly adopted by the farmers of this region were also collected.

To estimate the technology gap, extension gap and the technology index the following formulae have been used. (Samui *et al.*, 2000, Sagar and Chandra Ganesh, 2004).

- Technology gap = Potential yield – Demonstration yield
- Extension gap = Demonstration yield - Farmers yield
- Technology index = {(Potential yield - Demonstration yield) / Potential yield} X 100

The soil type was gangetic alluvium (Entisols) and medium to low in fertility status (Table 1)

RESULTS AND DISCUSSION

The prevalent farming situation in Sundarbans areas being characterised paddy cultivation during *kharif* season under rain-fed condition and water requirement for growing rabi and summer crops are met only through residual soil moisture and/or stored rain-water. One of the greatest lacunae faced by the farmers of this area is lack of soil moisture. The green gram crop requires one irrigation during its whole life span.

Frontline demonstration was conducted on 129 hectares of land on 1430 demonstration plots. The five high yielding strains of greengram namely K-851, PDM-54, B-105, Pusa Baishakhi and Sonali were used. On an average the highest yield 1000 kg ha^{-1} was achieved by PDM-54 followed by 806 kg ha^{-1} by K-851, 800 kg ha^{-1} by B-105 and Pusa Baishakhi and 750 kg ha^{-1} by Sonali (Table 2). The result indicates that the Frontline demonstration has given a good impact over the farming community of Sundarbans as they were motivated by the new agricultural technologies applied in the FLD plots. Yield of greengram was, however varied in different years, which might be due to the soil moisture availability & rainfall condition, climatic aberrations, disease and pest attacks as well as the change in the location of trials every year. The high yielding varieties had performed well when compared to local check.

The percentage increase in the yield over local check was 38.25, 50.82, 25.0, 33.33 and 60.0 for K-851, PDM-54, B-105, Pusa Baishakhi and Sonali,

Table 1. *Soil characteristics of adopted blocks*

Sl. No.	Name of the Block	C%	pH	EC d Sm^{-1}
1.	Kakdwip	0.11-0.86	6.0-7.99	0.09-26.50
2.	Namkhana	0.21-0.69	6.5-7.6	0.33-4.0
3.	Kulpi	0.06-0.88	5.4-8.5	0.21-7.8
4.	Pathar Pratima	0.01-1.44	4.3-8.5	0.09-26.50

Table 2. Productivity of greengram, yield gaps and technology index

Variety	No. of Demons-trations	Area (ha)	Yield (Kg ha^{-1})			% increase over local check	Technology gap	Extension gap	Technology index
			Potential	Demons-tration	Local Check				
K-851	849	69.0	1200	806	583	38.25	396	223	33.00
PDM-54	70	10.0	1300	1000	663	50.82	300	337	23.07
B-105	95	10.0	1100	750	600	25.00	350	150	31.81
Pusa Baishakhi	230	20.0	1200	800	500	60.00	400	300	33.33
Sonali B-1	186	20.0	1100	800	600	33.33	300	200	27.27

respectively. The technology gap, the gap in the demonstration yield over potential yield were 396 kg ha^{-1} for K-851, 300 kg ha^{-1} for PDM-54, 350 kg ha^{-1} for B-105, 300 kg ha^{-1} for Pusa Baishakhi and 400 kg ha^{-1} for Sonali. The technology gap observed may be attributed to dissimilarity in the soil fertility status and weather conditions as well as the soil moisture availability. Hence location specific recommendation appears to be necessary to bridge the gap between the yields of different varieties.

The highest extension gap of 223 kg ha^{-1} was recorded in variety K-851, followed by 337 kg ha^{-1} for PDM-54, 300 kg ha^{-1} for Pusa Baishakhi, 200 kg ha^{-1} for Sonali and the lowest 150 kg ha-1 for B-105. This emphasized the need to educate the farmers through various means for more adoption of improved high yielding varieties and newly improved agricultural technologies to bridge the wide extension gap. More and more use of new high yielding varieties by the farmers will subsequently change this alarming trend of galloping extension gap. The new technologies will eventually lead to the farmers to discontinuance of old varieties with the new technology. This high extension gap in all these varieties requires urgent attention from planners, scientists, extension personnel and development departments.

The technology index shows the feasibility of the evolved technology at the farmers' field. The lower the value of technology index more is the feasibility of the technology. The technology index were 33 percent for K-851, 23.07 percents for PDM-54, 31.81 percents for B-105, 27.27 percents for Pusa Baishakhi and 33.33 percents for Sonali. Except PDM-54 and Pusa Baishakhi all other varieties have given technology index of more than 30 percents indicating that the performance by these varieties in Sundarbans conditions was not more than the satisfactory level and these varieties requires more tolerance to salinity. In Sundarbans, only a small chunk of farmers have access to irrigation or affordable chemical inputs, and where growth and yield reducing losses, farmers' actual yields are less than its genetic potential. Sustainable intensification strategies for Sundarbans require improved soil, water and nutrient management innovations. Summer greengram cultivation has also ensured sustainable natural resource management objectives. Vulnerability to natural disasters can substantially be reduced through the adoption of greengram cultivation because of the improvement in productivity, increase cash income and acquired assets that families can fall back on when disasters occurs. Direct involvement of beneficiaries in adopting green gram cultivation technology suitable to their condition has given high payoffs in terms of enthusiasms and interest and also in ensuring that the technology addresses the priority needs that have been identified by the beneficiaries.

Despite the low soil moisture availability climatic and natural aberrations faced in Sundarbans areas, the high yielding varieties of Greengram K-851, PDM-54, B-105, Pusa Baishakhi and Sonali had given a very good result in coastal agro-ecosystem of Sundarbans in comparison to local check. These varieties may be popularized in this area by the state agriculture departments and extension agencies to mitigate the large extension gap. Mainly small and marginal farmers are associated with the cultivation of sesame in Sundarban and the use of new production technologies will substantially increase the income as well as the livelihood of the farming community. There is a need to adopt multi pronged strategy which involves enhancing greengram production through horizontal and vertical expansion and productivity improvements through better adoption of improved technology. In the fragile environments and poor farm resource base, greengram is the best choice for farmers. Cultivation of greengram also helps in protecting the environment from the risk of high input agriculture.

ACKNOWLEDGEMENT

This work was carried out at Krishi Vigyan Kendra of CIFRI (ICAR), Kakdwip, South 24 Parganas, West Bengal during 2000-2004. The author expresses his sense of gratitude to the Director, CIFRI, Barrackpore and Dr. R. L. Sagar for constant support and help in carrying out the research work.

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J. Indian Soc. Coastal agric. Res., 28(1), 16-19, 2010

Effect of Subsurface Irrigation along with Mulch and Irrigation Schedules on Yield of Bitter Gourd in Lateratic Soils of Konkan

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An experiment was conducted on coastal lateratic soil of Konkan with irrigation systems combined with mulches and irrigation schedules to study the effect on yield of Bitter gourd during Rabi seasons of 2003-2006 at Water Management Scheme, Central Experiment Station, Wakawali. The experiment was laid out in split plot design with three replications. The main plot treatment consisted of irrigation systems with mulches (M_1 - Surface (Check basin method) irrigation with grass mulch, M_2 - Subsurface (Diffuser) irrigation with grass mulch, M_3 - Subsurface (Diffuser) irrigation with black polythene mulch) and the sub plot treatments consisted of irrigation schedules (I_1 - Irrigation 100% of PE, I_2 - Irrigation 80% of PE, I_3 - Irrigation 60% of PE, I_4 - Irrigation 40% of PE). Under the treatment of irrigation systems with mulch, treatment M2 (Diffuser with grass mulch) was significantly superior in increasing fruit yield (85.16 q ha^{-1}) over M_1 and M_3. In case of irrigation schedules, the treatment I_1 (Irrigation 100% of PE) registered significantly higher fruit yield (107.44 q ha^{-1}) and at par with I_2 treatment. While the treatment combination M2I1 has produced the highest fruit yield (116.97 q ha^{-1}). Maximum water use efficiency (532.43 kg ha^{-1}cm) was observed in treatment M2I4 closely followed by the treatment M3I4 (Diffuser with black polythene mulch at irrigation 40% of PE). The treatment M2I1 (Diffuser with grass mulch at irrigation 100% of PE) gave the highest net returns of Rs. 30,757 ha^{-1} with benefit: cost ratio 1.38.

***(Key words:** Bitter gourd, Irrigation systems, Mulch, Irrigation schedules, Water use efficiency)*

Bitter gourd (*Momardica charantia* L.) is one of the most popular and commonly cultivated vegetable crop in India as it has good medicinal properties. In Konkan it can be grown in Rabi as well as Kharif season. In spite of a very high annual rainfall of about 3500 mm, water scarcity is a normal phenomenon after the month of November. It is because of the soils of Konkan are lateratic type with least moisture retention capacity and high percolation as well as infiltration losses of water.

The advanced irrigation methods like drip and sprinkler system have limited applicability in the hilly terrain due to undulated topography, uncertainty of electric supply and poor financial conditions of farmers. Among the different irrigation systems, the subsurface irrigation is reported for improvement in yield and quality (Cole, 1971) together with substantial saving in water (Davis and Nelson, 1970) and energy. In Agriculture, major loss of water takes place through evaporation from soil surface, which can be minimized by covering the soil surface with mulching. Mulches provide hydrothermal microclimate in the root zone of the crops for enhancing the fertilizer uptake through the roots (Mashingaidze *et al.*, 1996). Irrigation being a precious input its judicious use along with mulching would certainly be a great help in better utilization and saving of water.

Due to poor economics and electricity constraint the applicability of the surface and subsurface drip systems becomes limited and hence effort was made of testing new techniques of low cost subsurface irrigation along with mulches on the yield of bitter gourd on lateratic soils of coastal Konkan.

MATERIALS AND METHODS

A field experiment on Bitter gourd (cv. Konkan Tara) was conducted during Rabi seasons of 2003-06 at Water Management Scheme, Central Experiment Station, Wakawali. The soil was sandy clay loam in texture, acidic (pH 6.2) in reaction, medium in available nitrogen (325.25 kg ha^{-1}), very low in available phosphorus (6.5 kg ha^{-1}) and medium in available potash (170.0 kg ha^{-1}). The organic carbon content was 0.70 per cent while the field capacity and permanent wilting point values of the soil were estimated at 32 and 17.80 per cent, respectively. The experiment was laid out in split plot design with three replications. The main plot treatments consisted of irrigation systems along with mulch (M_1 - Surface (Check basin method) irrigation with grass mulch, M_2 - Subsurface (Diffuser) irrigation with grass mulch, M_3 - Subsurface (Diffuser) irrigation with black polythene mulch) and the sub plot treatments consisted of irrigation schedules (I_1 - Irrigation 100% of PE, I_2 - Irrigation 80% of PE, I_3 - Irrigation 60% of PE, I_4 - Irrigation 40% of PE). The plot size was 3.0 m x 1.0 m. The organic manures and fertilizers were applied @ 25 t FYM ha^{-1} and 120:60:60 N, P_2O_5, K_2O kg ha^{-1}, respectively. In order to ensure better germination and initial stand of the crop, two common irrigations were given to each treatment. The measured quantity of water as per the irrigation treatment was given twice a week both for surface and subsurface irrigation system. Pucca clay mud pot (Diffuser) having three-liter capacity with five holes at the bottom for water to diffuse into the root zone of the crop was installed 30 cm away from the vine. To restrict the percolation losses manuring of FYM was done at the bottom of each clay diffuser. Mulching was done after establishment of vines. The recommended package of practices and plant protection measures were adopted. The fruit yield was recorded at each harvest and data was analyzed statistically.

RESULTS AND DISCUSSION

Effect of irrigation system with mulches on yield of bitter gourd

It is evident from the data presented in Table 1 that the fruit yield was influenced significantly due to irrigation systems along with mulch. The pooled data (2003-2006) revealed that the treatment M_2 (Diffuser with grass mulch) produced significantly higher fruit yield (85.16 q ha^{-1}) over rest of the treatments. Increase in yield of bitter gourd due to treatment M_2 was to the tune of 13 percent and 6 percent higher than the treatments M_1 and M_3, respectively. The increase in yield by organic mulch and irrigation system might be due to the checking of evaporation losses and development of hydrothermal microclimate in the root zone, which enhances the nutrient availability for the roots. On the contrary, in treatment M_3 (Subsurface (Diffuser) irrigation with black polythene mulch) substantial reduction in yield might be due to the absorption of more radiation by the black polythene mulch resulting increase in soil temperature and less moisture conservation as compared to organic mulch. These findings are in agreement with the observations made by Digrase and Awari (2008).

Effect of irrigation schedules

It could be seen from Table 1 that the treatment I_1 registered significantly higher fruit yield (107.44 q ha^{-1}) which was at par with I_2 treatment but was significantly superior over I_3 and I4 treatments. Increase in fruit yield due to treatment I_1 was to the tune of 4%, 7% and 17% than the treatments I_2, I_3 and I_4, respectively. Low yield obtained under the treatments I_3 and I_4 might be due to the moisture stress and its subsequent adverse effect during the crop growth stages. Similar observations were reported by Jadhav *et al.*, (1996) in bottle gourd and Hegde (1987) in water melon.

Table 1. *Fruit yield of bitter gourd (q ha-1) as affected by different treatments*

Treatment	Yield (q ha^{-1})				
	2003	2004	2005	2006	Pooled mean
Irrigation systems with mulch					
M_1-Surface (check basin) irrigation with grass mulch	69.08	76.61	98.53	116.61	73.32
M_2-Subsurface (diffuser) irrigation with grass mulch	82.49	83.83	123.82	147.86	85.16
M_3-Subsurface (diffuser) irrigation with black polythene mulch	75.52	82.24	98.57	143.94	80.12
SE +	1.771	2.337	14.440	8.291	1.385
CD (P = 0.05)	6.950	NS	NS	NS	4.270
Irrigation schedules					
I_1-100% of PE	71.74	78.85	124.44	154.74	107.44
I_2- 80% of PE	79.84	84.11	111.15	138.67	103.45
I_3- 60% of PE	85.22	82.51	99.57	130.85	99.54
I_4- 40% of PE	66.25	78.10	92.72	120.30	88.54
SE ±	1.759	1.397	8.204	7.763	2.510
CD (P = 0.05)	5.220	4.150	NS	23.054	6.959

Table 2. *Interaction effect of irrigation systems with mulch and schedules on fruit yield (q ha^{-1}) of bitter gourd*

I x M		I_2	I_3	I_4	Mean
M_1	100.64	98.05	84.83	77.30	90.21
M_2	116.97	109.61	111.95	99.67	109.55
M_3	104.72	102.67	101.83	91.26	100.12
Mean	107.44	103.44	99.54	89.41	-
SE +			2.090		
CD (P = 0.05)			NS		

NS- Non-significant

Table 3. *Yield, water applied, water use efficiency and economics of bitter gourd under different treatments*

Treat-ment	Yield (q ha^{-1})	Total water applied (cm)	WUE (kg ha^{-1} cm)	Total cost (Rs. ha^{-1})	Gross income (Rs. ha^{-1})	Net income (Rs. ha^{-1})	B:C ratio
M_1I_1	100.64	46.79	215.09	68865	95608	26743	1.39
M_1I_2	98.05	37.43	261.96	68865	93148	24283	1.35
M_1I_3	84.83	28.07	302.21	68865	80589	11724	1.17
M_1I_4	77.30	18.72	412.93	68865	73435	4570	1.07
M_2I_1	116.97	46.79	249.99	80365	111122	30757	1.38
M_2I_2	109.61	37.43	292.84	80365	104130	23757	1.30
M_2I_3	111.15	28.07	398.82	80365	106353	25988	1.32
M_2I_4	99.67	18.72	532.43	80365	94687	14322	1.18
M_3I_1	104.72	46.79	223.81	81615	99484	17869	1.22
M_3I_2	102.67	37.43	434.60	81615	97537	15922	1.20
M_3I_3	101.83	28.07	362.77	81615	96739	15124	1.19
M_3I_4	91.26	18.72	487.50	81615	86697	5082	1.06

Interaction effect

The interaction effect between irrigation system along with mulch and irrigation schedules was found to be non-significant. It was observed that the treatment combination M_2I_1 has produced the highest fruit yield (116.97 q ha^{-1}) than any other treatment combination (Table 2).

Water use efficiency

The quantity of water applied and water use efficiency in different treatments are presented in Table 2, which revealed that the maximum water use efficiency (532.43 kg ha^{-1} cm^{-1}) was observed in treatment M2I4 i.e. Diffuser with grass mulch at 40% irrigation of PE closely followed by M_3I_4 (487.50 kg ha^{-1} cm^{-1}) treatment. This indicates that the appropriate irrigation system along with mulch and irrigation schedules provided optimum moisture conditions and higher moisture availability within the root zone of bitter gourd, which has reflected into maximum water use efficiency and significantly higher yield levels as compared to surface irrigation. These results are in confirmation with the findings obtained by Balyan and Malik (1981), Sawake *et al.*, (2005).

Comparative economics of the treatments

The data on comparative economics of the treatments are presented in Table 3 which indicated that the treatment M_2I_1 (Diffuser with grass mulch at irrigation 100% of PE) gave the highest net returns of Rs. 30,757 ha^{-1} with benefit: cost ratio 1.38. While the treatment M_1I_1 i.e. Surface (Check and basin) along with grass mulch have maximum B:C ratio of 1.39 with net returns of Rs. 26,743 ha^{-1}.

From the three years results, it can be concluded that Bitter gourd cv. Konkan Tara be irrigated at 100% of PE (at an interval of three days) by using diffuser and grass mulch for obtaining higher yield in lateratic soil of Konkan.

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J. Indian Soc. Coastal agric. Res., 28(1), 20-22, 2010

Effect of Sub-surface Drainage System on Soil Salinity and Grain Yield of Rice in Konanki and Uppugunduru Pilot Areas under Nagarjunasagar Canal Command of Andhra Pradesh

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A subsurface drainage system was installed with observation wells and piezometers in Konanki and Uppugunduru pilot areas under Nagarjunasagar right canal command and Krishna Western Delta, respectively in Prakasam district of Andhra Pradesh by the Indo-Dutch Network Project, Bapatla to evaluate the performance of drainage system on soil salinity and grain yield of rice. The soil and water samples were collected after the harvest of the rice crop during 1999 to 2006 and analyzed for pH and ECe. The results of the drainage pilot area indicated a considerable reduction in soil salinity from 1999 to 2006. At Konanki Pilot area only 25% of the soils have ECe less than 2 dSm^{-1} and the same was increased to 52% during 2006, seven years after installation of drainage system. The results of ground water analysis from the observation wells also indicates that about 89 per cent and 52 per cent of salts were leached in Konanki and Uppugunduru pilot areas, respectively from 1999 to 2006. The grain yield of rice was increased from 2.7 to 5.6 and 3.0 to 5.9 t ha^{-1} was recorded in Konanki and Uppugunduru pilot areas, respectively due to installation of subsurface drainage systems.

(***Key words:*** *Soil Salinity, Subsurface drainage, Piezometers*)

The introduction of irrigated agriculture in arid and semi arid regions of the country has resulted in the development of twin problems of water logging and soil salinization, due to which considerable areas of canal commands either have gone out of production or experienced reduced yields. In India, it is estimated that an area of 8.4 M ha is affected by soil salinity and alkalinity, out of which 2.5 M ha is considered as water logged saline area and is distributed in the irrigated canal commands. In Andhra Pradesh, the command areas affected by water logging and salinity are estimated to be 2.74 lakh ha and 1.15 lakh ha, respectively. In many canals commands, there has been a rise in the water table and consequent degradation of soils through water logging and salt build-up and the impact of irrigation over many years has caused the ground water table to rise into root zones in the command areas which lead to reduction in crop yields (Anonymous, 1986). The technology of the sub-surface drainage system is most appropriate under the salinity and water logging conditions to leach out the excess and harmful salts from the crop root zone, providing a better environment for the plants to grow.

Characteristics of the Pilot areas

Konanki Pilot area

In order to suggest suitable reclamation technology, a closed sub-surface drainage system with a gravity outlet has been installed in an area of 8 ha in May, 1999 in a pilot area of 20 ha. at Konanki village under Nagarjunasagar Project right canal command of Andhra Pradesh. The area has a serious problem of water logging and soil salinity with a ground water table reaching ground surface during monsoon season apart from salinity and sodicity. Out of 21.63 ha, 1.6 ha was under fallow. The total number of farmers is 35 having an average land holding of 1.34 acres.

The soil is moderately alkaline in reaction, high in soil salinity. About 95 per cent area recorded pH more than 8.5. The soil salinity in most parts of the area is higher than 2.25 dSm^{-1} at all the depths. The ESP is more than 15 in almost entire area. On the basis of ECe and ESP of the soils of project area, most of the area has been identified with saline sodic problem. The bulk density of soils ranged from 1.17 to 2.23 Mg m^{-3} and the particle density of soils ranged from 1.54 to 2.23 Mg m^{-3}. Exchangeable Sodium Percentage varied from 14 to 55. The main crop grown in the project area is rice, which is generally transplanted during the second fortnight of October and harvested during February. No second crop was raised in the project area because lack of irrigation as well as poor establishment due to the problem of salinity. The water table fluctuated between the soil surface in the monsoon season and 2.4 m from ground level in summer season. Rainfall is very high in the month of October (Anonymous, 2002).

Uppugunduru pilot area

The drainage pilot area is spread over 20.92 ha and has 46 farm holdings ranging in size from 0.12 to 0.83 ha. The average annual rainfall in the area is 844 mm. This pilot area is affected by water logging (depth to water table, 0 to 2.04 m) salinity (ECe 1.04 to 52.7 dSm^{-1}, pH 6.5 to 8.8) problems. Rice is grown during monsoon season with very low yields (1.9 to 3.0 t ha^{-1}) due to water logging and salinity leaving the land as fallow during remaining part of the year.

MATERIAL AND METHODS

In order to suggest suitable reclamation technology, closed sub-surface drainage system with a gravity outlet is installed in May 1999, in a pilot area of 8 ha at Konanki and Uppugunduru villages under Nagarjunasagar right canal command and Krishna Western Delta, respectively, where water logging, salinity and sodicity are the major problems. Observation wells have been installed at both the pilot areas for measuring ground water table depth. Permanent bench mark has been established for the pilot area and contour map has been prepared for drainage system design. Thirty three observation wells and six deep piezometers were installed for monitoring the water table fluctuations. Soil samples were collected from 60 grid points spread over the entire pilot area. Soils were analyzed for pH and EC by using Elico LI612 and Elico CM 183, respectively. Yield data was also recorded from both Konanki and Uppugunduru pilot areas under study. Data was tabulated and presented.

The drainage systems were handed over to the farmers during 2003. The performance of drainage systems has been monitored by APWAM Project, Bapatla from 2003 onwards at Konanki and Uppugunduru pilot areas. The water samples were collected from the observation wells month wise and analyzed for pH and EC till 2006.

RESULTS AND DISCUSSION

A considerable reduction in soil salinity was observed from 1999 to 2006 (Table 1 and 2). At Konanki, before installation of drainage systems, only 25% of the lands had ECe less than 2 dSm^{-1}. Seven years after the installation of drainage systems, this has increased to 66 per cent. Similarly 60% of lands had pH greater than 8.5 before installation of drainage systems which was reduced to 8.0 to 8.5, seven years after the installation of the system. Similar technology can also be effectively used in the sodic soils to remove the soluble salts in huge quantities at shortest possible time.

Groundwater quality parameters

The water samples were collected from observation wells installed in Konanki and Uppugunduru pilot areas and were analyzed for pH and EC. High pH and EC values were observed in open SSD when compared to closed SSD system. Electrical Conductivity of drain water is high in closed SSD system than open SSD system.

The data presented in Table 3 and 4 indicated that in Konanki and Uppugunduru, pilot areas there

Table 1. *Salinity reduction at Konanki after installation of drainage systems and monitoring upto 2006*

Year / ECe (dSm^{-1})	1999	2000	2001	2002	2003	2004	2005	2006
0-2	25	40	46	52	41	34	58	66
2-4	44	35	40	41	31	29	18	16
4-8	20	25	12	7	16	22	14	12
8-12	4	2	2	0	9	8	6	4
>12	7	0	0	0	3	7	4	0

Table 2. *Salinity reduction at Uppugunduru after installation of drainage systems and monitoring upto 2006*

Year / ECe (dSm^{-1})	1999	2000	2001	2002	2003	2004	2005	2006
0-2	28	67	78	82	47	39	58	74
2-4	30	21	12	14	29	20	15	8
4-8	5	10	8	4	16	25	14	10
8-12	3	2	2	0	5	10	9	6
>12	34	0	0	0	3	6	4	2

Table 3. *Monitoring of water quality in Konanki pilot area*

Sl. No.	Particulars	Konanki		
		Before installation (May, 1999)	After installation (May, 2001)	Maintenance by the farmers (from 2003-2006)
1.	EC (dSm^{-1})	5 - 28	2 - 17	1.78 - 2.50
2.	pH	7.5 - 10	7 - 9	7.3 - 7.8

Table 4. *Monitoring of water quality in Uppugunduru pilot area*

Sl. No.	Particulars	Uppugunduru		
		Before installation (May, 1999	After installation (May, 2001)	Maintenance by the farmers (from 2003-2006)
1.	EC (dSm^{-1})	10-88	3-61	37.3- 46.5
2.	pH	7.4 -8.8	7.3-8.5	7.13-7.34

Table 4. *Changes in rice crop yields (t/ha) after installation of subsurface drainage systems at Konanki and Uppugunduru pilot areas*

Pilot area	Before installation of drainage 1998-99	After installation of drainage			Maintenance of the systems by the farmers from 2003	
		1999-00	2001-02	2002-03	2005-06	2006-07
Konanki	2.7	3.1	4.7	5.0	5.2	5.6
Uppugunduru	3.0	4.3	5.5	6.5	5.4	5.9

was a reduction in EC from 1999 to 2006 which might be due to good receipt of rainfall during the periods leading to better removal of soluble salts from the root zone. About 89 per cent and 52 per cent of salts were leached from the observation wells of Konanaki and Uppugunduru pilot areas, respectively from 1999 to 2006.

Crop yields

At Konanki and Uppugunduru pilot areas, poor germination, stunted growth of crops and nutrient deficiencies were observed before installation of drainage systems because of the problems of salinity and water logging. As a result, poor yields of rice crop were recorded. After the installation of drainage systems, an increase in rice yields from 1998-99 to 2002-03 and also from 2005-06 to 2006-07 (Table 4).

During the periods of 2003-04 and 2004-05, no crop was raised by the farmers due to deficit rainfall and non availability of canal water for irrigation in both the pilot areas. Earlier one rice crop is being grown in the pilot area before the installation of drainage system. The farmers are able to grow successfully a second crop after the installation of sub surface drainage system indicating that this technology is effective in reclaiming the salt affected lands in the pilot area under study.

The authors are thankful to International Land Reclamation Institute, Wageningen, The Netherlands for providing funds to carry out research work through Indo-Dutch Network Project and Andhra Pradesh Water Management Project of Acharya N.G. Ranga Agricultural University.

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Evolution and Reforms in Irrigation Institutional Arrangements in Orissa

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To make the agriculture performance in Orissa better, institutional reforms in water sector are of paramount importance. In this context, present study reflects on the way the institutional set-ups have emerged and transformed over a period. In Orissa, irrigation institutional innovations have been taking place over the years since 1958. Three timelines comprising of organizational history, policy/act/rule and programmes/projects of State Government as well as Central Government organizations involving directly or indirectly with irrigation water management in Orissa were developed to understand the evolutions and changes of institutional arrangements over the time. Organizational reform in term of state management to farmers' management of irrigation system has showed a favorable effect on policy dimensions such as water pricing and cost recovery. The cost recovery from agriculture and industrial sectors has shown an increasing trend as total cost recovery has increased from Rs. 7.03 crore in the year 1996-97 to Rs. 35.64 crore in the year 2005-06.

(**Key words:** *Irrigation, Institutional innovations, Water right, Pricing and Cost recovery of irrigation water)*

Orissa is endowed with rich natural resources in the form of fertile land, plentiful surface and ground water resources. But such resources have not been exploited adequately for income generation activities. As a result Orissa ranks very low among the Indian states in terms of per capita income and it has the highest proportion of population (47%) living below the poverty line (Economic survey 2001-02). It is believed that the poverty alleviation is possible only by sustainable increase in crop production through increased cropping intensity and productivity. Water, as an input to agriculture, is critical for it. Thus, the strategy in planning and managing water resources assumes greater importance. Annual investment in irrigation sector in Orissa is remained consistently high as compared to many other states. Scaled against ten major Indian canal commands by output impact per ha of irrigated area, *Mahanadi* command of Orissa ranked last. Also in output per unit of water in the above canal commands, Orissa is bottom of the list with 14 kg per ha cm (Selvarajan *et al.*, 2001). Canals are the dominating source of irrigation. Low irrigation coverage and rice dominated cropping pattern are the unique features of Orissa agriculture. Agricultural growth in Orissa is averaged just over one percent per annum over the last two decades.

Institutional innovations clearly have a vital role to play in reforming public sectors of agricultural water management, developing linkage and partnership with the related water sector organizations (Hall *et al.*, 2000). The reforms related to the people's participation in irrigation water management and drainage measures have been major focus since last decade to address the problems related to operation and maintenance of irrigation systems and low irrigation efficiency (Tanwar, 1998). Despite some initiatives since mid nineties, impact of the reforms to date has been less than expected. There may have been some impact; however, extension, administrative and financial procedures have not witnessed any major change (Paroda and Mruthyunjaya, 2000). Institutional innovations have mostly been initiated by the private sector and the public sector's response so far has not been satisfactory. Donor driven institutional initiatives cannot sustain long. Institutional analysis can assist to be aware of institutional issues, which could hinder or help a research initiative. It also identifies key partners and networks for research and development (Matsaert, 2002). Hence, it is worth to understand the evolution of reforms in irrigation sector.

MATERIALS AND METHOD

Institutional innovations for irrigation water management refers to the understanding how governments, communities and entire farming communities change their habitual behavior and

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institutional roles in managing water resources for agriculture. To gain insights of this issue it requires a study on laws, rule making, policies, water allocation, water rights, etc. Analyses of the irrigation institutional reforms in Orissa agriculture carried out following the institutional analysis framework that has included both theoretical and analytical frameworks. Theoretical framework explains water institutional evolution and change. Analytical framework involves quantitative changes over a period (Saleth, 2004). The time lines were developed to explore the nature and evolution of institutional innovations for irrigation water management in Orissa. It was carried out through literature review (government institutions dealing with irrigation management and water user associations (WUAs) provided relevant information), secondary data collection and group discussions. Trends were set to understand the changes in fixation and collection of water rates over a period.

RESULTS AND DISCUSSION

Irrigation institutional evolution

Timeline of organizational history of State Government as well as Central Government organizations involving in irrigation management in Orissa is presented below to understand the irrigation institutions' evolutions and changes over a period of time.

State Department of Water Resources

1958: Department of Irrigation and Power was created out of the erstwhile Public Works Department.

1962: Orissa Construction Corporation (OCC) was established.

1971: Minor (Flow) irrigation was taken out from the control of Revenue Department to form a new Rural Development Department.

1973: Orissa Lift irrigation Corporation (OLIC) that was under irrigation department transferred to Rural Development Department.

1975: Command Area Development (CAD) Programme started.

1980: Rural Development Department was abolished and Minor Irrigation sector merged with the Irrigation and Power Department.

1984: Water and Land Management Institute (WALMI) Orissa came into being as a component of the Office of the Engineer-in-Chief, Irrigation, Orissa.

1986: WALMI was registered under the Society Registration Act 1860 as an autonomous Organization.

1990: Rural Development Department was again created and Minor Irrigation sector tagged with it once again.

Department of Power was separated.

Central planning unit was created.

1993: The Water Resources Board (WRB) formed as the highest coordinating body on water planning and allocation between sectors and provides guidance to the Department.

1994: The Department of Irrigation was renamed as Department of Water Resources (DWR).

1996: The Directorate of Ground Water Survey & Investigation (GWSI) started functioning as an independent entity under the administrative control of DWR.

Project Monitoring Unit (PMU) was established as a registered society for rehabilitation of minor irrigation projects in Orissa with the aid from European Commission.

Related activities of Pani panchayat/Water User Association started under four pilot projects - Ghodahada Project, Rushikulya Distributary's No. 11 of Ganjam district and Aunli and Derjang Projects in Angul district.

Central Government Water Organisations in the State

1969: Central Flood Forecasting Division of Central Water Commission (CWC) was established at Balasore and subsequently shifted to Bhubaneswar in 1971.

1970: CWC's Eastern Gauging Division was created at Bhubaneswar.

1972: Central Ground Water Board, Eastern Region established. Orissa was under its jurisdiction having a State Unit Office functional at Bhubaneswar.

1983: CWC's Mahanadi Division was established at Burla, Sambalpur.

National Water Development Agency (NWDA) established it's one of three Chief Offices (Chief Engineer, North) at Bhubaneswar.

1985: CWC's Central Flood Forecasting Division and Eastern Gauging Division were renamed as Bramhani-Subarnarekha Division and Eastern Rivers Division, respectively.

Orissa was separated from the aegis of Central Ground Water Board, Eastern Region.

1986: Central Ground Water Board (CWGB), South Eastern Region was established at Bhubaneswar headed by Regional Director.

1989: CWC established Eastern River Circle at Bhubaneswar and brought Bramhani-Subarnarekha Division, Eastern Rivers Division and Mahanadi Division under it.

1995: Mahanadi and Eastern Rivers Organisation was started functioning at Bhubaneswar as a regional organisation of CWC headed by Chief Engineer with three wings namely Monitoring and Appraisal Directorate, Hydrological Observation Circle and Coordination headed by Superintendent Engineers. Hydrological Observation Circle comprises of Eastern Rivers Division and Mahanadi Division. Bramhani-Subarnarekha Division was merged with Eastern Rivers Division.

1997: NWDA Chief Offices (Chief Engineer, North) shifted to Allahabad and presently it's Investigation Circle and Investigation Division is functional at Bhubaneswar.

To reform the irrigation sector in the state Central and State Government have been evolving Policies, Acts, Rules, etc over the years, timeline of which is given below:

1919: Under the Government of India 1919 Act, Irrigation become a provincial subject and Govt. of India's responsibility in the field was confined to advice, co-ordination and settlement of disputes over right on water of Inter-Provincial rivers.

1956: River Boards Act. This central act is related to establishment of River board and concerned regulation or development of an interstate river valley or any specified part thereof.

1956: Interstate Water Disputes Act. It is a central act.

1959: Orissa Irrigation Act for management of irrigation in the state.

1961: Orissa Irrigation Rules for management of irrigation in the state.

1987: National Water Policy.

1994: State Water Policy of Orissa.

Orissa Resettlement and Rehabilitation Policy. It aims at integrated development of displaced family and project affected persons.

2002: National Water Resources Council has adopted the revised National Water Policy as "National Water Policy - 2002".

State Water Policy/Orissa's Water Resource Policy.

The Orissa Pani panchayat Act - an act to provide for farmers' participation in the management of irrigation systems and for matters connected therewith or incidental thereto. This act has given Pani panchayat a statutory status.

2003: *Pani panchayat* Rule has been promulgated for effective implementation of *Pani panchayat* Scheme.

2007 State Water Policy of Orissa.

Different programmes have been implemented by the State and Central Government for water resources development and management in Orissa over the years. A timeline of few programmes is presented below.

1974-75: Command Area Development Programme started to reduce the gap between the irrigation potential created and utilized and to increase crop productivity in command areas.

1970s: River Valley Project (RVP) funded by Govt. of India implemented in the catchments of inter state river valley to combat land degradation problems and silt inflow into the reservoir.

1980s: Drought Prone Area Programme (DPAP), a centrally assisted scheme (cente : state = 75:25) implemented covering 47 blocks in Orissa.

1989: Ministry of Rural Areas and Employment launched Million Wells Schemes (MWS).

1996: Pani panchayat (Water User Association) Scheme for participatory irrigation management implemented.

Accelerated Irrigation Benefit Programme (AIBP) with loan assistance from Govt. of India (center : state = 3:1) with a view to early completion of irrigation projects.

Orissa Water Resources Consolidation Project (OWRCP) under World Bank assistance.

Irrigation Scheme under Rural Infrastructural Development Fund (RIDF) with the loan assistance from National Bank for Agriculture and Rural Development (NABARD).

1997-98: Agricultural Intensification Programme (AIP) is being implemented by Department of Agriculture (DoA) with the main aim is to ensure efficient utilization of irrigation water.

2002: Biju Krushak Vikas Yojana (BKVY) launched with an outlay of Rs. 1000.00 cores to be spent during 2002-2005. This scheme is a happy marriage of participatory irrigation management with the promotion of minor and lift irrigation project.

Evolution of institutional innovations for irrigation water management in Orissa started since 1958. All the organizations involved in development of water resources in Orissa were brought under Water Resources Department during 1994 onwards. It has been the lead agency for water resources development in the state, responsible for planning, developing and managing the states water resources for irrigation, bulk water supply, drainage and flood control, with direct responsibility for implementation of major, medium and minor irrigation projects, and their operation and maintenance as well as ground water exploitation. Most of the reforms in water sector in the state have been taking place since 1990s. Agricultural water management has been shifting from a culture of supply management to demand management and resources construction to people's participation.

Institutional Reforms

Water rights

It is a mechanism for allocation and accountability. India does not have any explicit legal framework specifying water right so does the State of Orissa. However, various acts have a basis for defining some form of rights as mentioned below:

- British legislation in India during 1859-1877: It recognizes customary water rights of individuals and groups.
- Easement act of 1882: All rivers and lakes are the absolute rights of the state. From the perspective of water use, de facto control over water by actual users at micro level.
- Individual rights to both surface and ground water are recognized only indirectly through land rights
- Land acquisition act 1894: A landowner can have a right to ground water as it is considered an easement connected to the dominant heritage i.e. land. Therefore, it legally excludes those without land to have any access to ground water.
- Orissa irrigation act 1959 and Orissa irrigation rule 1961: The Orissa Irrigation Act came into force in 1959 and the Orissa Irrigation Rules in 1961. The Act covers the legal aspects related to construction and maintenance of irrigation works. It also prescribes the basic water rates to be made applicable to various classes of irrigation systems for which water is to be supplied. The Orissa Irrigation Rules were amended in 2002 for revision of basic water rates for various class of irrigation system & as well as for crops other than the basic cereal crops. Rates for water supplied for purposes other than irrigation works were also amended in 1998 to cover the industrial and municipal water supply. In the case of canal water, the rights to access are limited only to those having access to land in canal command areas and these rights are only use rights and not ownership rights, because Irrigation Act in Orissa (also in the case of other states) does not allow the moving of canal water to non-canal areas.
- Orissa pani panchayat act and rule: The primary objective of this Act is to ensure optimum utilization of water by farmers for improving agricultural production, to involve farmers' organizations in the management and maintenance of the irrigation system to ensure and dependable supply and distribution of water. The Pani panchayat Rule provides guidelines for formation, membership, duties and responsibilities of Water Users' Associations.
- The model ground water (control and regulation) bill 1992: It postulates ground water permit system but it fails to set the withdrawal limits. It has not received serious consideration in most of the states including Orissa and thus the control over groundwater at the field level is governed by de facto system of rights as determined by farm size, the depth and number of wells, pumping capacity and economic power.

Under conditions of unequal land ownership and income pattern, the practice of linking water indirectly with land and the fact of de facto control by better-endowed persons only accentuates rural inequality and water use efficiency.

Water policy

Water policy relates to the declared statements as well as the intended approaches of the central and state governments for water resource planning, development, allocation and management

General and specific policies in water sector are also influenced by other sect oral policies related to agriculture, public finance and basic needs. Immediate factor that prompted National Water Policy (NWP) was unprecedented drought of 1987 with the following main goals:

- Promotion of conjunctive use of water from surface and sub-surface sources
- Supplemental irrigation
- Water conserving crop pattern and irrigation and production technologies
- Raising canal water rates and promoting user participation in canal management.

Although NWP has recognized to limit individual and collective water withdrawals, it has failed to define/identify the institutional mechanisms necessary for defining and enforcing such physical limits. National Water Policy 2002 is almost a repeat of earlier version with a paradigm shift from water development to performance improvement.

The Orissa state formulated its first State Water Policy in 1994 following the principle enunciated in the National Water Policy 1987. In the meantime, a number of developments have taken place; new information and knowledge have been generated and new issues and challenges have emerged in the field of development and management of water resources. The National Water Policy 1987 has been reviewed, updated and a new policy titled National Water Policy 2002 has been adopted by the Government of India. It was therefore felt necessary by the State Government to review the State Water Policy 1994. After due consideration, the State Government have prepared a new Water Policy called Orissa State Water Policy 2007 in keeping with the National Water Policy 2002. Orissa State Water Policy 2007 adopts following order of priority in water allocation:

- Drinking water and domestic use (human and animal consumption)
- Ecology
- Irrigation, agriculture and other related activities including fisheries
- Hydropower
- Industries including agro industries
- Navigation and other uses such as tourism

In view of the relatively low status of water resources development and majority of the population being poverty stricken, it has become necessary to address the issues relevant to the State within the framework of National Water Policy through a State Water Policy (SWP). The implementation of Orissa's Water Resources Policy is carried out by the Department of Water Resources (DWR). The Water Resources Board (WRB), formed in October 1993, is the highest coordinating body on water planning and allocation between sectors and provides guidance to the DWR. Representation on the Board covers the key Water using Departments of Government (inter ails secretaries of Water Resources, Urban Development, Industry, Rural Development, Agriculture, Energy, Environment, Fisheries, Panchayati Raj).

The diagnosis of the NWP as well as SWP is found as right but its prescriptions fail to address the serious economic and institutional vacuum within which the water sector is operating.

Pricing and cost recovery

Water rates for supplying irrigation are normally fixed considering the annual cost of providing irrigation that consists of three elements: operation and maintenance (O&M) expenses, depreciation and interest of the capital invested. But a wide diversity of opinion exists regarding fixation of the rates. National Water Policy 1987 envisaged the water rates should cover annual O & M charges and a part of the fixed cost. National Water Policy 2002 stipulates that water charges should cover at least O & M cost of providing the service initially and a part of capital cost subsequently. It also prescribes subsidy to the poorer sections of the society in very abstract terms. Vaidyanathan committee (1992) recommended full recovery of O & M cost plus 1% capital cost during the initial phases. Work group (1994) for further study on Vaidyanathan committee report states that the irrigation water rate should cover full O & M costs within 5 years. 2nd Irrigation Commission (1972) recommended that water rate should cover the working expenses and interest on capital. Other recommendations by different commissions are as follows:

- 5th Finance Commission: A return of 2.5% of capital investment over and above the O&M cost
- 6th & 7th Finance Commission: Lowered the return from 2.5% to 1% of capital investment
- 8th & 9th Finance Commission: Recovery of O & M cost
- 10th Finance Commission: Recovery of full O & M costs plus 1% capital costs
- Pricing irrigation water in 1992: Recovery of O & M cost + 1% capital cost + % of depreciation cost

- 11th Finance Commission: Rs 450/- per ha for utilized potential; Rs 150/- per ha for unutilized potential.
- 12th Finance Commission: Rs. 600/- per ha for major & medium and Rs. 400/- per ha for minor projects in case of utilized potential; Rs. 200/- per ha for major & medium and Rs. 100/- per ha for minor projects in case of unutilized potential is proposed by CWC for 12th Finance Commission.

The irrigation being a state subject, the pricing and cost recovery of irrigation water is referred to the states for enforcement. As per the Orissa State Water Policy, the cost of operation and management will be fully recovered from the beneficiaries. Water Rates & Cost Recovery Committee has been formed to fix and review water charges. The Committee recommends the water charges to Water Resource Board for approval. The water rates for irrigation use have been revised twice during 1998 and 2002. Water rates in Orissa are assessed on the basis of area irrigated and the types of crops grown and levied per unit area (ha) basis separately for *Kharif* and *Rabi* crops. *Kharif* crops are levied with a compulsory basic water rate on the basis of four classes of irrigation viz. Class I, II, III and IV with 28", 23", 18" and 9" depth of irrigation supply, respectively (Fig. 1). As per the latest estimate (2002-03), the water rate varies from Rs. 63.00 for class IV to Rs. 250.00 for class I category of irrigation, which is to be paid irrespective of its use. However, the water rate for *Rabi* crops is not compulsory and payable on use and specific to the crops grown (minimum of Rs. 28.00 for green gram and maximum of Rs. 930.00 for cannabis) as mentioned in Table 1. Water rate for flow irrigation in Orissa was very low till revised on 1998-99 irrespective of class of irrigation. Recent revision of irrigation water rate (2002-03) has made two-fold increase over the rate on 1998-99.

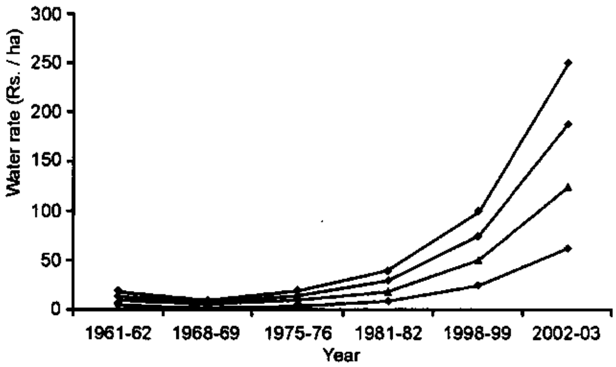

Fig. 1. Compulsory basic water rate for flow irrigation in *Kharif* season in Orissa

The water rates for non-irrigation use have been revised during 1994 and 1998. Unlike irrigation water rate, the revision of water rate for industrial and other purposes has increased the rate marginally (Table 2). It has led to collection of relatively lower amount of annual water tax from non-irrigation sector.

Current water rate demand from irrigation charges is much lesser than the potential demand. There is also gap between demand and actual collection; in fact, average collection is less than the demand raised (Fig. 2) leading to poor cost recovery of 25%. Both collection of agricultural and industrial water rate is depicted in Fig. 3. Due to implementation of *Pani panchayat* programme (1996 onwards) it became feasible to increase the water rate in the agriculture sector and collection of agriculture water rate has been increased from 3.40 crore in 1996-97 to 28.29 crore in 2005-06. Gap between agricultural water rate and industrial water rate collection widened since 2000 as it is increased up to 28 crore for the former while it remained about 8 crore in case of later. To increase the cost recovery from the industrial sector, adequate steps are to be taken. Installation of flow meters for metering the industrial water use is a potential option. DWR may also consider for execution of fresh agreements with the industries towards collection of water rates.

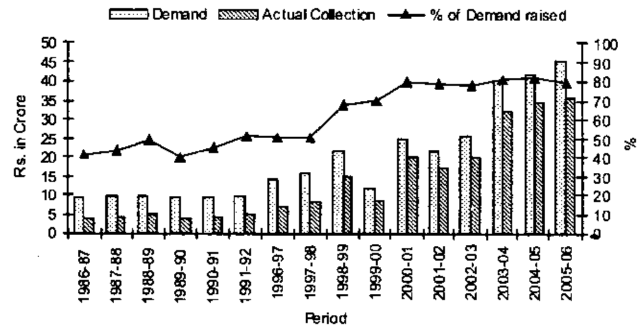

Fig. 2. Demand raised and actual collection of total water charges in Orissa

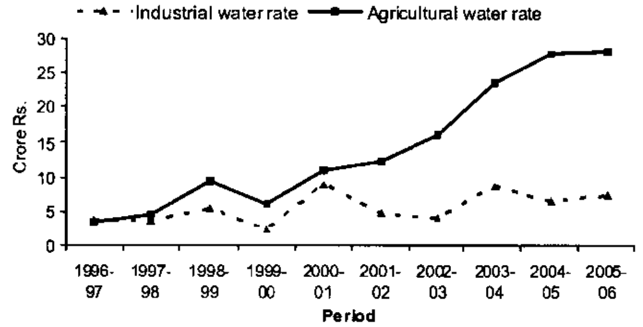

Fig. 3. Collection of agricultural and industrial water charges in Orissa

Table 1. *Water rates for crops grown during Rabi season*

	Name of the crop	Rate per ha per year (Rs.)		
		1981-82	1998-99	2002-03
1.	Paddy (rabi season)	88.96	225.00	450.00
2.	Tobacco	83.40	210.00	420.00
3.	Potato	55.60	140.00	280.00
4.	Vegetable including peas	44.48'	115.00	230.00
5.	Onion	55.60	140.00	280.00
6.	Wheat	33.36	85.00	170.00
7.	Maize	27.80	70.00	140.00
8.	Green gram	5.56	14.00	28.00
9.	Groundnut	27.80	85.00	170.00
10.	Orchards	66.72	167.00	334.00
11.	Sugarcane	100.08	250.00	500.00
12.	Jute	16.68	42.00	84.00
13.	Fodder	27.80	85.00	170.00
14.	Pulses	11.12	30.00	60.00
15.	Cotton	55.60	140.00	280.00
16.	Oil seeds	11.12	30.00	60.00
17.	Betel vine	166.79	420.00	840.00
18.	Pigeon pea	27.80	85.00	170.00
19.	Sunhemp	38.91	100.00	200.00
20.	Chilly	27.80	85.00	170.00
21.	Taro	166.79	420.00	840.00
22.	Millet	13.99	35.00	70.00
23.	Mustard	11.12	30.00	60.00
24.	Cannabis	185.33	465.00	930.00

Source: Department of Water Resources, Govt. of Orissa

Prior to 1999, the cost recoveries from Agricultural and Industry sectors were done by Revenue Department. In 1999, the cost recovery of Industrial sector was transferred to the control of Water Resources Department. The cost recovery from agriculture and industrial sectors has shown an increasing trend as total cost recovery has increased from Rs. 7.03 crore in the year 1996-97 to Rs.35.64 core in the year 2005-06.

Efforts are to be made to impose and collect more water rates from industrial sector for the use of water resources to have a proper operation and maintenance of canals. Organizational change (state management to farmers' management of irrigation system) showed a favorable effect on policy dimensions such as water pricing and cost recovery. Some of the related points mentioned in the Orissa State Water Plan (2007) are as follows:

- Water rate should be proportional to incremental benefits.
- It should also take into account the ability of farmers to pay.
- Present water rate collection is based on quantity of area and type of crop.
- In order to address the problem of excess use of water and wastage, volumetric pricing of water has to be introduced.
- The farmer has to pay depending upon his decision regarding the water usages, and the rate and the total revenue vary from farmer to farmer, land to land, and also crop to crop, even in the same abacus thereby creating a scope for financial incentive for his efficiency in water use.
- Orissa irrigation system is not equipped at present to switch over to volumet basis of water rate. A gradual chang over is recommended - the sooner, the better.
- Supply to Pani panchayats may be made on volumetric basis. Volumetric water

Table 2. *Water rates for non-irrigation uses*

Purpose for which water is supplied	Unit	Rate (Rs.)		
		1981-82	1994-95	1998-99
1. Bricks or tile making	1000 nos.	0.25	5.00	6.00
2. Water used and consumed for industrial purpose	100000 gallons	20.00	200.00	250.00
3. Water temporarily used for industrial purpose and discharged back unpolluted or after purification into irrigation project from which the same has been drawn	100000 gallons	4.00	50.00	60.00
4. Bulk water supply to municipalities and other local authorities for drinking, washing, etc.	10000 cft.	5.00	25.00	30.00
5. Construction of buildings	100 cft.	0.15	3.00	4.00
6. For filling tanks	10000 cft.	5.00	-	30.00
7. For filling tanks mainly for drinking purpose	10000 cft.	2.50	-	15.00

Source: Department of Water Resources, Govt. of Orissa

Table 3. *Status of Pani panchayats under PIM programme in Orissa*

Projects	Total target		Formed		Handed over	
	Number	Area covered (Lakh ha)	Number	Area covered (Lakh ha)	Number	Area covered (Lakh ha)
Major and medium	2559	11.17	1455	6.35	1125	4.96
Minor (flow)	1883	3.28	1005	1.92	775	1.50
Minor (lift)	11211	2.47	11211	2.47	10600	2.35
Total	15633	16.93	13671	10.76	12500	8.81

Source: Annual Report (2006-07), Department of Water Resources, Govt. of Orissa

measurement is introduced on trial in some Pani panchayats (Derjang medium irrigation project and Darpanarayanpur minor irrigation project) in Orissa.

User and private sector participation

Conforming to the policy guidelines of National water Policy (1987) and state Water Policy of Orissa (1994), the government of Orissa with a view to providing equitable, timely and assured irrigation has introduced the concept of Pani panchayat for PIM. The concepts finally lead to transfer of tertiary irrigation networks (Minor/Sub-minors) to registered 'Pani panchayats'. The responsibility of O & M of the reservoir/diversion weir (as the case may be) Dam, Spillways, Sluices, Primary and secondary distribution networks etc. rests with the Department of Water Resources, where as the responsibility of O & M of the tertiary systems i.e. (Below minor/sub-minor) is with Pani panchayat. This programme envisages making farmers to participate in the water resources planning and management and to hand over the system to the farmers for which suitable legislation has already been done. The Orissa Pani panchayat Act-2002 and Orissa Pani panchayat Rules-2003 are concrete steps in this direction (DWR, Govt. of Orissa, 2004). The geographical extent of the participatory irrigation management programme covers the entire State comprising of about 17.00 lakh hectares of irrigation command under different irrigation systems (Table 3).

Water institutional reforms in Orissa mostly initiated in the year 1990s. Organizational change (state management to farmers management of irrigation system) showed a favorable effect on policy dimensions such as water pricing and cost recovery (collection of water rate has been increased from 3.40 crore in 1996-97 to 28.29 core in 2005-06). Water entitlements in canal irrigation are singular, that is only refer to agricultural production and they are exclusive, that is only landholders in the command area can enjoy them. However, water as a common resource has other functions like domestic and industrial use. Existing legal and regulatory policies reinforce rather than regulate de facto control of ground water by resource rich farmers and access of canal water by the farmers having land in command areas, ignoring the landless altogether that may accentuate inequity. Policies to reform the water sector in the state have been already evolving and how quickly and genuinely these institutional reforms are pursued to cover all sources and uses of water will determine future water and food security as well as poverty alleviation in the state.

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J. Indian Soc. Coastal agric. Res., 28(1), 32-39, 2010

Investigation on Extreme Hydrologic Events – A Study in a Hilly Watershed of Southern Orissa

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Present paper is attempted to determine the total annual and event based runoff/sediment yield (for rainfall intensity ? 20 mm/hr) in a 169.5 ha hilly watershed area prone to intense rainfall conditions in District Koraput, Orissa for assessing the erosive capacity of the runoff carrying sediment along it. Unusual extreme rainfall events were also analyzed and hourly runoff and sediment yield was computed. USDA SCS Curve Number method (based on antecedent runoff condition) and Modified Universal Soil Loss Equation (MUSLE) were used for estimation of the runoff and sediment yield, respectively. Results of both the methods were compared with Rational method and Duggal *et al.*, (2000) approach, respectively. No significant difference was found between computed and observed total seasonal runoff for the period (2001-2005) at 0.01 % probability level. However, while no significant difference was found between event-based runoff computed by USDA SCS CN method and Rational method, there was difference at 0.01% probability level while comparing event based sediment yield between MUSLE and Duggal *et al.*, (2000) approach. In one – hour peak rainfall event of 61 mm (peak runoff = 33 mm), 116.2 t ha^{-1} of sediment yield (244.0 kg of N, 6.7 kg of P, and 128.0 kg of K) was estimated. It is found that in an unusual extreme rainfall event of 244.4 mm (with tri – modal peaks in time interval of 3-hours), a record no. of five runoff and sediment events (for rainfall intensity > 20 mm/hr) with maximum of 15.4 mm/hr and 50.9 t ha^{-1}, respectively was estimated. Functional relationships developed for prediction of peak runoff and sediment yield can help in providing first hand planning information in similar nearby watersheds having identical hydrologic features in the region.

*(**Key words:** USDA SCS CN method, MUSLE, Peak runoff and sediment yield, Watershed)*

Soil movement by rainfall is usually greatest and most noticeable during short-duration, high-intensity storms. Runoff can occur whenever there is excess water on a slope that cannot be absorbed into the soil or trapped on the surface. Naturally, the steeper the slope of a field, the greater the amount of soil loss from erosion by water. If the peak flow increases, the soil surface will be cut and soil erosion will start and if the ground is saturated, precipitation results in runoff. It can cause flooding and erosion problems. Thus, it requires to be managed judiciously so that, it does not harm the watershed.

Intensity of rainfall, antecedent runoff condition, the gradient of the slope and the catchments area are the most influencing factors, which cause runoff from a watershed (Stocking, 1978).

Cumulative rainfall in cases where runoff sets in after saturation of the soil or the intensity of rainfall over 30 minutes results in ample onset of runoff (Wischmeier and Smith, 1978).

It is found that much of the reduced yield observed on eroded soils was due to decrease in the amount of water available to the plant on eroded soils (Schertz, 1989). On shallow soils on sloping terrain, erosion may completely destroy productivity if appropriate conservation practices are not initiated (USDA, 1989).

The empirical models of USLE, MUSLE and their revised versions are widely used in hydrology and environmental engineering for computing the amount of potential soil erosion and sediment yield (Mishra *et. al.*, 2006). Since USLE (Wischemeier and Smith, 1965) was developed for estimation of annual soil loss from plots of an average length of 22 m, its application to individual storm events and large areas in watershed basis leads to large errors (Hann *et al.*, 1996 and Kinnell, 2005). In order to overcome this difficulty, Williams (1975) and Williams and Berndt (1977) developed a modified version of the USLE (MUSLE) to derive a sediment yield estimation model based on runoff characteristics, as the best single indicator for sediment yield prediction (Hrissanthou, 2005).

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Prediction of runoff peak discharges in watersheds is an important task for hydrologists. Past record of runoff data is also required, which can help in designing various hydraulic structures. Considerable uncertainty exists in predicting storm runoff from small watersheds. A poor estimate of storm runoff can lead to under designed structures with a high risk of system failure or over design with tremendous unnecessary additional expenditure. For efficient management of runoff, prediction of intensity and total, as well as peak runoff is essential, to predict soil loss from watersheds. Thus, in the present study, attempt was made to estimate the total, event based peak and unusual extreme runoff and sediment yield status from a hilly watershed namely; Kokriguda located in Koraput district (Eastern Ghat High Land zone) of Orissa. This information can address as an important check for taking the precautionary measures while designing erosion control structures.

MATERIALS AND METHODS

Computation of event based runoff and sediment yield was made using USDA SCS Curve Number (SCS, 1986) method and Modified Universal Soil Loss Equation (MUSLE) (William & Berndt, 1977; Smith *et al.*, 1984), respectively. In absence of availability of hourly-observed runoff and sediment data, both the methods have been compared with Rational method and Duggal *et al.*, (2000) approach, respectively.

USDA SCS Curve Number method

The basic hypothesis of SCS CN technique for a simple storm, the relation between rainfall, runoff and retention in which rainfall and runoff begin simultaneously over a watershed is presented as follows (SCS, 1986).

$$\frac{E}{S} = \frac{Q}{P} \qquad \text{...(1)}$$

where, E= actual retention of precipitation, mm; S= potential maximum retention, mm; Q= direct runoff, mm; and P= total precipitation, mm.

and subsequently, the SCS rainfall-runoff relation is expressed as

$$Q = \frac{(P - I_a)^2}{(P - I_a + S)} \qquad \text{...(2)}$$

and

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)}, \text{ when } P > 0.2S \qquad \text{...(3)}$$

$$Q = 0, \text{ when } P \leq 0.2S \qquad \text{...(4)}$$

Through studies of many small agricultural watersheds, I_a was found to be approximated by the empirical formula $I_a = 0.2S$ (SCS, 1986). The initial abstraction Ia, encompasses all losses that occur before runoff begins. It includes water retained in surface depressions, water intercepted by vegetation, ET, and infiltration. S is expressed in terms of CN and it is determined for watershed characteristics such as soil types, land use, hydrologic condition and antecedent runoff condition and expressed as follows:

$$CN = \frac{25400}{(254 + S)} \qquad \text{...(5)}$$

The index of runoff potential before a storm event is the antecedent runoff condition (ARC). ARC is an attempt to account for the variation in Curve Number at a site from storm to storm. The Curve Number for the average ARC at a site is the median value as taken from sample rainfall and runoff data and is used primarily for design application.

Rational method

The rational method (which is traced back to the mid-nineteenth century) is still the most widely used method for hydrologic design purpose (Pilgrim, 1986; Linsley, 1986). Thus, in absence of observed event based hourly runoff data, presently this method is used for comparing the peak runoff rate computed by USDA SCS CN method. The formulation of Rational method is expressed as follows:

$$Q = 0.0028\ CIA \qquad \text{...(6)}$$

where, Q = peak runoff rate, m^3/s; C = the runoff coefficient; i = rainfall intensity, mm/hr for the design return period and for a duration equal to the time of concentration of the watershed; and A = the watershed area, ha.

Modified Universal Soil Loss Equation (MUSLE)

Sediment yield for an individual storm event can be estimated by MUSLE (William & Berndt, 1977; Smith *et al.*, 1984) as follows:

$$Y = 11.8\,(Qq_p)^{0.56}\ KLSCP \qquad \text{...(8)}$$

where, Y = sediment yield, t; Q= runoff volume, m^3; qp = peak runoff rate, m^3s^{-1}; K = soil erodibility factor; C = crop management factor; P = erosion control practice factor; and LS = slope length & gradient factor.

The terms K, L, S, C and P are same as used in USLE (Wischemeier and Smith, 1965). The peak rate of runoff, qp is computed as mentioned below (Singh *et al.*, 1981) :

$$q_p = \frac{0.0208AQ_d}{T_p} \quad ...(9)$$

where, q_p = peak rate of runoff, m^3s^{-1}; A= watershed area , ha; Q_d = runoff depth, cm.

Time to peak, T_p is computed as follows:

$$T_p = 0.6T_c + \sqrt{T_c} \quad ...(10)$$

where, T_p = time to peak, hr; T_c = time of concentration, hr

Time of concentration, T_c is computed as follows:

$$T_c = 0.0195\ F^{0.77} \quad ...(11)$$

and $$F = \frac{\sqrt{L^3}}{H} \quad ...(12)$$

In the above equation, T is expressed in min, L = maximum length of flow, m and H = difference in elevation between the most remote point and the outlet, m. As T_c in hr is required for computation of q_p, Equation 10 is divided by a numeral 60.

Soil erodibility factor, K has been estimated considering percent silt plus very fine sand, percent sand, organic matter percent, soil structure and permeability of the soil of the study area.

Slope length factor, L and Slope factor, S were computed based on Mc Cool *et al.*, (1987) and Mc Cool et al., (1989) and are expressed as follows:

$$L = (l/22)^m \quad ...(13)$$

where, L = slope length factor; l = slope length, m; and m = dimensionless exponent and it is 0.5 when the percent slope is 5 of more.

For slope shorter than 4%,

$$S = 3.0\ (\mathrm{Sin}\theta)^{0.8} + 0.5 \quad ...(14)$$

For slope longer than 4% and less than 9 %, $S = 10.8\ \mathrm{Sin}\theta + 0.03$ ...(15)

where, θ = field slope steepness in degrees = $\tan^{-1}(s/100)$; and s = field slope, %.

Cover and management factor, C and support practice factor, P have been considered based on the land cover of the study area (www.ejge.com/2003/Ppr0339).

Duggal et al., *(2000) empirical method*

While working for the Kandi area of Punjab (the foot hills of Shiwalik), India, Duggal *et al.*, (2000) used a different constant 8.0 instead of 11.8 (which is used in MUSLE) for simulation of event wise sediment yield. While keeping the values of the parameters K, LS, C and P same as MUSLE, they attempted for calibrating various values of the constant varying from 6 to 12. It was found that instead of 11.8, the value of constant as 8.0 simulated the sediment yield in close agreement with the historic values with simulation error within 30 percent for 36 storm events (while considered during 1983 – 1991). As the present study watershed is located in the Eastern Ghat High Land zone of Orissa and the land situation is almost similar to the foot hills of Shiwalik, this approach was considered for comparison of sediment yield data computed by MUSLE.

Data Used

The daily rainfall, event based rainfall intensity data of 2001-2005 (> 20 mm hr^{-1}) and an unusual extreme storm event of August 3-4, 2006 collected from the meteorological observatory of CSWCRTI, Research Center, Koraput (Orissa) were used for ascertaining the total, peak and unusual extreme hourly runoff rate and sediment yield. Daily runoff data during 2001 – 2005 was collected at the outlet of the Kokriguda watershed. Computation of runoff and sediment yield was made by USDA SCS CN method and MUSLE, respectively. In absence of hourly runoff and sediment yield data, results of both the methods were compared with Rational method and Duggal *et al.*, (2000) approach, respectively.

Study Area

The study has been carried out in the Kokriguda hilly watershed in Koraput district of Orissa (Fig. 1) which is located between 82° 52′ 59″ E - 82° 54′ 03″ E longitude and 18° 40′ 15″ N - 18° 40′ 44″ N latitude (950 m average msl). The watershed is representative of the Eastern Ghat high region, which is affected by intense and short duration rainfall events. Topography, socio-cultural setup and agro-ecology of the study area are also representative to the region. The district falls within the region of cyclonic disturbances of Bay of Bengal. Storms accompanied by heavy rains frequently occur during monsoon period. Climate of the area is characterized to be moist subtropical with occurrence of medium to high intense rainfall. Predominantly, red loam to red sandy loam soils are found in the study area which can be categorized to be under the sub order Ustalfs having well drained and moderately acidic characteristics. There is a clear cut catenary's association corresponding to the drainage scale of the region, with well drained coarse textured soils on the hill slope to ill drained clay to silty clay soils at the base of the slope, locally called as Jhola lands. Mostly marginal crops like ragi, upland paddy niger and minor millets like Suan are grown by the tribal farmers in these lands with low level of management and input use.

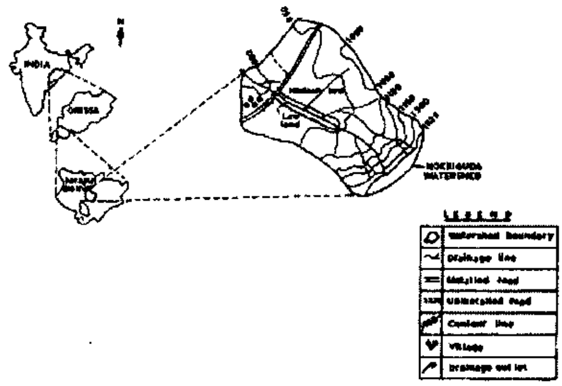

Fig. 1. Study area

RESULTS AND DISCUSSION

Extreme rainfall events occurring in the study area were analyzing for the 2001- 2007 for ascertaining the extent of gravity of occurrence of these events. It is evidenced that during the monsoon period (June – September), a greater proportion of the extreme rainfall events are experienced (Table 1). For example, on a single day during 2006 and 2007, maximum an amount of 142.2 mm and 175.2 mm are recorded. Similarly, during 2003, maximum 14 nos. of events occurred more than 30 mm with maximum one day rainfall of 86.2 mm. Thus, being very erosive in nature, there is need of systematic investigation of extreme hydrologic events in such intense rainfall areas, so that proper integrated sustainable planning can be made while working in a watershed mode in hilly watersheds.

Annual rainfall versus runoff

Based on the available rainfall data, seasonal (monsoon and non monsoon period) total runoff was computed for the period 2001 – 2005 using USDA SCS CN method (Table 2). Monsoon season average rainfall was found as 1265 mm (87 percent of total annual rainfall). Average 730 mm (57.7 percent of total rainfall) runoff was observed in comparison to computed runoff of 1089.1 mm (86.1 percent of total rainfall) by USDA SCS CN method during the monsoon season (June – October). However, 39.9 mm (20.7 percent of total rainfall) runoff was observed as against of 41.8 mm (21.7 percent of total rainfall) computed runoff during post monsoon season (November – May) in the study area. Statistically, no significant difference was found between computed and observed annual runoff for the period at 0.01 % probability level.

Estimated event based runoff, sediment yield and unusual extreme storm event

Experimental evidence confirms that rainfall intensities less than 25 mm hr^{-1} does not contribute significant erosion in the watershed (Murty, 1985). Thus, in order to quantify the erosive event based runoff and sediment yield, rainfall intensity? 20 mm hr^{-1} was considered in the present study for computation of peak runoff and sediment yield. During the study period, more than 20 mm hr^{-1} rainfall events were considered for getting a good number of rainfall events for analysis. Total thirty five (35) no. of rain events of more than 20 mm hr^{-1} found during the period 2001 – 2005 were used for computation of peak runoff and sediment yield. Based on watershed characteristics such as soil types, land use, hydrologic condition and antecedent runoff condition, weighted average of CN value for the study area was considered as 88. Accordingly, peak hourly runoff was computed (Table 4). These results were compared with Rational method. The weighted average of runoff coefficient and rainfall intensity (based on the design return period of 25 years of one-hour duration and time of concentration of 14 minutes) was computed as 0.35

Table 1. *Maximum erosive rainfall events occurring during monsoon season.*

Year	Wet spell period	Total rainfall during wet spell (mm)	No. of days > 30 mm	Maximum in one day (mm)
2001	Aug. 1 - Aug. 29	304.3	4	54.0
2002	Jul 29 – Aug. 24	438.9	3	88.4
2003	Jul 9 – Sept 14	1055.3	14	86.2
2004	Jul 21 – Aug. 23	524.0	5	100.2
2005	Jul 23 – Aug. 21	359.5	4	63.0
2006	Jun 21 - Jul 5	341.2	3	142.2
2007	Jun 16 – Jun 30	598.0	6	175.2

Table 2. *Computed and observed runoff (mm) during monsoon and post monsoon period. (Data in parentheses indicate the no. of rainy days)*

Year	Monsoon Season (Jun - Oct)			Post monsoon Season (Nov - May)		
	Rainfall	Computed Runoff	Observed Runoff	Rainfall	Computed Runoff	Observed Runoff
2001	1199.4 (61)	1024.4	660.0	203 (15)	42.7	0.0
2002	1022.2 (60)	850.2	672.2	144.5 (10)	16.5	0.0
2003	1493.9(72)	1315.3	866.5	286.9 (17)	92.5	43.3
2004	1441 (62)	1262.9	714.0	220.7(19)	52.2	71.2
2005	1167.4(61)	992.8	744.5	107 (17)	5.3	35.2
Avg	1264.8	1089.1	730.0	192.4	41.8	39.9
$t_{calculated}$		4.4			0.7	
$t_{tabular\ at\ 0.01\%}$		4.6			4.6	
Remarks		No significant difference			No significant difference	

Table 3. *Parameters for computation of Sediment yield by MUSLE*

Particulars	Computed parameters
Maximum length of flow, L	1125 m
Difference in elevation between the most remote point and the outlet, H	55 m
Area of the watershed, A	169.5 ha (Forest area = 111.5 ha, Jhola area = 7.5 ha and sloping medium land = 50.5 ha)
Topographic factor, LS	3.998
Soil erodibility factor, K	0.26
Cover and management factor, Weighted C	0.828* (Rice = 0.1, Open Forest = 0.8 and sloping medium land = 1.0)
Support practice factor, Weighted P	0.825* (Rice 0.03, Open Forest = 0.8 and Fallow = 1.0)

* www.ejge.com/2003/Ppr0339

and 40 mm hr^{-1}, respectively. Accordingly, the peak rate of runoff was estimated as 14.1 mm hr^{-1} as against of average runoff of 10 mm hr^{-1} by USDA SCS CN method. While comparing both the methods, statistically no significant difference was found between event-based runoff computed by USDA SCS CN method and Rational method at 0.01 % probability level.

The parameters required for computation of event based peak sediment yield (on hourly basis) by MUSLE were computed based on the Kokriguda watershed condition and presented in Table 3. Maximum one - hour peak erosive rainfall of 61 mm with 33 mm runoff and 116.2 t ha^{-1} sediment yield equivalent to 244.0 kg of N, 6.7 kg of P and 128.0 kg of K as reported by Paikaraya (2005) was estimated during 2003. Whereas, with average one - hour peak erosive rainfall of 30.2 mm, 10 mm runoff and 31.6 t ha^{-1} sediment yield was estimated during 2003 while calculated based on USDA SCS CN method and MUSLE, respectively. While comparing the results of event based sediment yield by MUSLE and Duggal *et al.*, (2000) approach, significant difference was observed at 0.01% probability level. However, MUSLE was accepted for the present study for computation of sediment yield as its application in watershed-sized areas is suggested owning to its simplicity and the accessibility of required inputs (Sadeghi *et al.*, 2007) in comparison to sediment yield estimation for plot-sized areas. This was also emphasized by Hrissanthou (2005) who developed sediment estimation models for watersheds without sediment data.

Over the last six years period (2001-2006), an unusual storm event was experienced during August 3-4, 2006. Amazingly, during the 24-hours period, an amount of 244.4 mm was recorded in the watershed and the total runoff depth of 115.2 mm was observed. This massive amount of runoff occurred in three peak events in time interval of

Table 4. *Estimated runoff (mm hr⁻¹) and sediment yield (t ha⁻¹) from storm events ≥ 20 mm hr⁻¹ during 2001-2006*

Date of event	Rainfall	Runoff, mm hr^{-1}		Sediment loss, t hr^{-1}	
		USDA SCS CN method	Rational method	MUSLE method	Duggal *et al.* approach
16.04.2001	52	25.5	14.1	87.1	59.1
8.6.2001	23	5.1	14.1	14.4	9.7
9.6.2001	20	3.6	14.1	9.7	6.6
13.6.2001	20	3.6	14.1	9.7	6.6
5.7.2001	31	9.9	14.1	30.1	20.4
6.7.2001	20	3.6	14.1	9.7	6.6
7.7.2001	26	6.8	14.1	19.7	13.4
8.7.2001	20	3.6	14.1	9.7	6.6
5.8.2001	33	11.2	14.1	34.7	23.5
6.8.2001	21.7	4.4	14.1	12.2	8.3
14.9.2001	36	13.3	14.1	41.9	28.4
8.1.2002	20.8	4.0	14.1	10.8	7.4
23.6.2002	20	3.6	14.1	9.7	6.6
16.7.2002	40.5	16.5	14.1	53.6	36.4
30.7.2002	34.5	12.2	14.1	38.2	25.9
31.7.2002	56	28.8	14.1	99.8	67.6
2.8.2002	27	7.4	14.1	21.7	14.7
18.7.2003	20	3.6	14.1	9.7	6.6
19.7.2003	30.5	9.5	14.1	29.0	19.7
5.8.2003	33.2	11.3	14.1	35.1	23.8
18.8.2003	22.1	4.6	14.1	12.9	8.7
13.9.2003	21	4.1	14.1	11.1	7.6
1.10.2003	61	33.0	14.1	116.2	78.8
2.10.2003	26	6.8	14.1	19.7	13.4
12.7.2004	36	13.3	14.1	41.9	28.4
28.7.2004	46	20.7	14.1	69.1	46.8
4.8.2004	23.3	5.3	14.1	14.9	10.1
3.9.2004	38	14.7	14.1	47.0	31.9
5.9.2004	34	11.9	14.1	37.0	25.1
25.7.2005	21.5	4.5	14.1	12.5	8.5
3.8.2006 (Unusual event)					
2 PM	26	7.1	14.1	21.4	14.1
3 PM	38	15.4	14.1	50.9	33.6
7 PM	26	7.1	14.1	21.4	14.1
8 PM	25	6.5	14.1	18.9	12.8
11 PM	27.25	8	14.1	24.5	16.1
Average	30.2	10.0	14.1	31.6	21.4
$t_{calculated}$		1.91		7.02	
$t_{tabular\ at\ 0.01\%}$		2.76		2.76	
Remarks		No significant difference		There is significant difference	

3 hours. Occurrence of these types of rainfall events is very common in the locality. Due to frequent occurrence of bi/tri modal rainfall events within a time span of 3 to 4 hours in the region, there remains no scope for the storm water to get absorbed in the watershed due to infiltration, percolation and building of groundwater table. As rainfall intensity exceeded the soil absorption capacity, suddenly a major proportion of the rainfall passed down the slope in the watershed as runoff carrying enormous sediments along with it. This causes an extensive damage to standing Kharif crops (especially the standing paddy crops in the Jhola lands (low lands); ragi and niger crops in the medium sloping lands. Thus, the threat posed by these erosive monsoon rain events, which occur frequently during the monsoon season in these intense rainfall areas ask for a comprehensive wholesome erosion control packages in the watershed.

Further, simple functional relationships were developed (shown in Eq.16 and 17) between one - hour peak rainfall versus peak runoff and peak runoff versus peak sediment yield, which can act as handy tools for the meteorologists to assess the runoff and sediment yield status in absence of suitable gauging provision in the un-gauged watersheds. Procedure of USDA SCS CN method and MUSLE were considered for development of these functional relationships.

$$YRO = 0.69\ X_{RF} - 10.8,\ R^2 = 0.99 \quad \text{...(14)}$$

$$YSY = 3.57Y_{RO} - 4.1,\ R^2 = 0.99 \quad \text{...(15)}$$

where, Y_{RO} = runoff yield, mm hr^{-1}; Y_{SY} = sediment yield, t ha^{-1}; and X_{RF} = rainfall, mm hr^{-1}.

As most of the district and block head quarters in the region are equipped with automatic rain gauges in the meteorological stations, with availability of one hour peak rainfall data, these equations can help to gather first hand information on runoff and sediment yield status before attempting for design of erosion control measures for the un-gauged watersheds of similar land situations.

Erosion control measures require careful design procedures in intense rainfall areas for providing full proof protection and thus, help in preventing the erosive runoff and sediment loss in a watershed. In order to achieve this objective, study of the spatial and temporal hydrological behavior in the watershed is pre requisite. However, barring few watersheds, there are many watersheds in the region, which are un-gauged. In absence of gauging information on peak runoff and sediment yield, the developed simple empirical relations can be handy tool for getting first hand information before attempting for design of erosion control measures. Exhaustive explorative study of the site blended with systematic design of the erosion control structures through extreme hydrologic event analysis can certainly be acted as full proof measures for retarding erosive runoff and sediment loss in a hilly watershed, where intense rainfall in a short spell is a phenomenal occurrence.

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J. Indian Soc. Coastal agric. Res., 28(1), 40-43, 2010

Effect of Foliar Application of Nutrients to Alphonso Mango in Lateritic Soils of Konkan

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Alphonso grown commonly in Konkan region records yield of about 2-3 t ha^{-1}. With good package of practices and along with recommended dose of fertilizer, if nutrients are supplied through foliar can increase the yield as demand of nutrients are more during productive phase. If nutrients are applied through soil, user efficiency is 20-30% in case of N, P, and K and 3-5% incase of micronutrients, however through foliar, the use efficiency expected around 40-75%. Literitic soils of Konkan are generally deficient in NPK and Zn, Bo, Mo and Cu as per previous reports. Nutrients requirement in the critical phase can be supplemented through foliar application which boosts up the fruit yield, hence present investigation was proposed.

*(**Key words:** Foliar application, Major and Micro nutrients, Critical phase, Literitic soil, Konkan)*

A field trial was conducted to study the effect of nutrient supplementation through foliar application to Alphonso mango in lateritic soil of Konkan during 2007-2008. The experiment included various nutrients with different concentration in the spray solution which are deficient in the lateritic soil of Konkan region. Foliar application was also carried out on inflorescence to test scorching effect. The experiment was conducted with six treatments and three replications with application of three sprays at critical stage of nutrients requirement. Recommended dose of fertilizer was applied to all treatments. Result indicated that there is significant increased in yield of mango fruits due to foliar spray. Treatment (T_1) three spray of 0.5% (Urea, SOP, SSP each) + 0.25 % ($ZnSO_4$+ Borax + $CuSO_4$ each) + 0.01% Ammonium molybdate produced yield of 45.93 Kg/plant which was significantly superior over control (29.38 kg plant^{-1}) and was at par with T_2 and T_3 (Higher concentration of nutrients) Out of three, second sprays on the inflorescence improved the yield than second sprays before initiation of flowering. Soil properties were not influenced significantly due to various treatments. Nutrients in leaf after harvest were reduced over sampling before flowering where spray was not carried out (T_1). However, there is reduction in major nutrients content in leaf after harvest of crop in most of the treatments. The nutrients in fruit pulp were not influence significantly due to treatment effects.

MATERIALS AND METHODS

Trial was conducted at Regional Fruit Research Station, Vengurle, Dist. Sindhudurg during 2008-09 on Alphonso mango to test effect of foliar application of major and micronutrients in later tic soil of Konkan. Recommended dose of NPK and FYM was applied during the month of June and PBZ during month of August. Total three foliar sprays were applied in which first and third spray was common. However, second spray was given before flowering of influences and after flowering of influences as per treatment. Spraying was carried out as first spray in the month of November, second spray December and January and third spray at egg stage of the fruits. RBD design was used with three replications with one plant per unit. The treatment details are given below.

T0 : Control.

T1 : 0.5% (Urea, SOP, SSP each) + 0.25% ($ZnSO_4$, Borax , $CuSO_4$ each) + 0.01% (Ammo molybdate) Second spray before flowering.

T2 : 1% .(Urea, SOP, SSP each) + 0.25% ($ZnSO_4$, Borax , $CuSO_4$ each) + 0.01% (Ammo molybdate) Second spray before flowering.

T3 : 2% (Urea, SOP, SSP each) + 0.25% ($ZnSO_4$, Borax, $CuSO_4$ each) + 0.01% (Ammo molybdate) Second spray before flowering.

T4 : 0.5% (Urea, SOP, SSP each) + 0.25% ($ZnSO_4$, Borax, $CuSO_4$ each) + 0.01% (Ammo molybdate) Second spray on inflorescence

T5 : 1% .(Urea, SOP, SSP each) + 0.25% ($ZnSO_4$, Borax, $CuSO_4$ each) + 0.01% (Ammo molybdate) Second spray on inflorescence.

T6 : 2% (Urea, SOP, SSP each) + 0.25% ($ZnSO_4$, Borax, $CuSO_4$ each) + 0.01% (Ammo molybdate) Second spray on inflorescence.

Table 1. *Effect of foliar nutrient spray on yield of Alphonso Mango.*

Sr. No.	Treatment	Yield kg plant^{-1}
1	T_0: Control (No spray)	29.38
2	T_1: 0.5% (Urea, SOP, SSP each) + 0.25% ($ZnSO_4$,Borax,$CuSO_4$ each) + 0.01% (Ammo molybdate) Second spray before flowering.	45.93
3	T_2: 1% .(Urea, SOP, SSP each) + 0.25% ($ZnSO_4$, Borax,$CuSO_4$ each) + 0.01% (Ammo molybdate) Second spray before flowering.	49.93
4	T_3: 2% (Urea, SOP, SSP each) + 0.25% ($ZnSO_4$, Borax, $CuSO_4$ each) + 0.01% (Ammo molybdate) Second spray before flowering.	64.40
5	T_4: 0.5% (Urea, SOP, SSP each) + 0.25% ($ZnSO_4$, Borax, $CuSO_4$ each) + 0.01% (Ammo molybdate) Second spray on nflorescence.	58.33
6	T_5: 1% (Urea, SOP, SSP each) + 0.25% ($ZnSO_4$, Borax, $CuSO_4$ each) + 0.01% (Ammo molybdate) Second spray on inflorescence.	59.00
7	T_6: 2% (Urea, SOP, SSP each) + 0.25% ($ZnSO_4$, Borax, $CuSO_4$ each) + 0.01% (Ammo molybdate) Second spray on inflorescence.	52.67
	SE ±	4.20
	C.D. @ 5%	12.96

Table 2. *Soil properties after harvest of crop*

Sr. No	Treatment	pH	EC dSm^{-1}	O.C %	kg ha^{-1}		ppm	
					P	K	Zn	Cu
1	T_0	5.903	0.100	2.763	63.840	436.800	8.977	7.420
2	T_1	5.630	0.133	2.780	26.133	526.400	10.523	6.960
3	T_2	6.050	0.080	2.737	75.480	480.933	10.850	7.200
4	T_3	5.680	0.070	2.843	79.533	440.533	6.197	8.300
5	T_4	5.790	0.063	2.363	39.573	336.800	6.940	3.580
6	T_5	6.043	0.073	2.597	52.640	436.800	10.147	5.773
7	T_6	5.553	0.100	2.450	46.640	395.733	9.280	3.913
	SE ±	0.074	0.012	0.180	14.292	46.029	3.283	1.075
	CD@ 5%	0.227	0.038	N.S.	N.S.	N.S.	N.S.	N.S.

Table 3. *Nutrients content in Alphonso Mango leaf before flowering*

Sr. No.	Treatment	N (%)	P (%)	K (%)	(ppm)			
					Zn	Cu	Fe	Mn
1	T_0	2.087	0.113	0.513	37.77	176.000	7.933	772.567
2	T_1	1.787	0.113	0.540	30.71	150.367	49.400	715.200
3	T_2	1.773	0.117	0.533	44.81	174.233	50.607	790.533
4	T_3	2.047	0.123	0.533	57.26	194.567	112.700	831.700
5	T_4	2.077	0.117	0.560	26.41	174.500	12.733	672.667
6	T_5	2.170	0.113	0.550	33.39	164.533	98.767	769.200
7	T_6	2.240	0.123	0.580	58.85	216.167	48.633	713.733
	SE ±	0.139	0.005	0.042	9.23	17.337	45.629	73.840
	CD@ 5%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

***Table 4.** Nutrients content in leaf of Alphonso Mango after harvest of crop*

Sr. No.	Treatment	N (%)	P (%)	K (%)	ppm			
					Zn	Cu	Fe	Mn
1	Control	2.240	0.029	0.453	29.09	75.433	11.467	713.900
2	T_1	1.680	0.038	0.467	53.567	166.923	12.467	719.167
3	T_2	1.867	0.039	0.453	56.967	150.067	9.433	586.867
4	T_3	12.693	0.040	0.410	56.233	124.567	8.133	748.167
5	T_4	1.493	0.041	0.510	94.333	279.300	19.600	691.233
6	T_5	2.427	040	0.427	62.300	152.400	4.267	605.933
7	T_6	2.427	0.036	0.477	61.433	80.233	12.200	737.233
	SE ±	3.972	0.002	0.019	6.43	37.158	4.294	85.845
	CD.5%	N.S.	0.006	0.057	N.S.	114.529	N.S.	N.S.

***Table 5.** Nutrients content and quality of Mango fruit pulp*

Sr. No.	Treatment (%)	Acidity (%)	TSS (%)	N (%)	P (%)	K (%)	ppm			
							Zn	Fe	Cu	Mn
1	T_0	0.38	17.83	0.92	0.023	0.487	58.533	95.467	6.300	6.633
2	T_1	0.47	20.06	0.93	0.030	0.550	79.967	161.333	10.467	9.933
3	T_2	0.51	17.60	1.06	0.015	0.397	52.533	124.933	12.733	5.967
4	T_3	0.40	21.13	0.98	0.031	0.447	36.767	104.867	4.233	2.900
5	T_4	0.29	17.73	0.98	0.023	0.470	31.667	122.333	4.133	3.200
6	T_5	0.30	19.13	1.10	0.018	0.413	73.167	151.400	4.467	7.733
7	T_6	0.52	19.13	1.07	0.020	0.373	42.600	88.133	4.600	5.667
	SE ±	0.12	0.86	0.130	0.004	0.052	16.365	28.713	2.534	1.919
	CD @ 5%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

RESULTS AND DISCUSSION

It could be seen from the Table 1 that significant increase in yield per plant due to foliar sprays was observed. Foliar nutrient spraying three times as per treatment, showed significant results over control (T_0). Treatment T_1 and T_2 were at par and significantly superior over control. Treatment T_4 and T_5 were at par and significantly superior over control and T_1.

II) Soil analysis

Soil samples were collected immediately after harvest of crop and analyzed for fertility parameters. pH of soil varied from 5.55 to 6.05, salinity range from 0.07 to 0.133 dSm^{-1}. No significant differences were observed due to treatment in case of organic Carbon, Phosphorus, Potassium, Zn and Cu content. Organic Carbon, phosphorus and Potassium ranged from 2.36 to 2.84 %, 26.13 to 75.48 and 336.80 to 526.40 Kg ha^{-1} respectively.

III) Leaf analysis

Nutrient content in leaf before flowering and after harvest of crop. Nitrogen, phosphorous, Potassium, Zn, Fe, Cu and Mn have been analyzed from leaf tissue and data is presented in Table 3 and 4. Significant difference was not observed due to treatments for content of nutrients. By and large depletion in nutrients was observed after harvest of crop in leaf tissue samples.

IV) Nutrients content in Mango fruit pulp

Nutrients content in Mango pulp have been estimated and data presented in Table 5. There was no significant difference due to treatments. Nitrogen, Phosphorus and Potassium in percent wise ranged from 0.992-1.10, 0.01-0.03 and 0.37-0.55, respectively. However, micronutrients Zn, Fe, Cu & Mn varied from 36.76 -79.96, 88.13-161.33, 4.13 - 12.73 and 2.90-9.93, (ppm) respectively.

Based on these results this centre has prepared the formulation as special nutrient spray with major and micro nutrients with 3 sprays to be supplied which gives almost double the yield compared to untreated control. These findings are in line with the reports of Edward Raja (2009) and Edward Raja *et al.*, (2005). Similar reports were reported by Rossetto *et al.*, (2000) and Kannan and Ramani, (1988).

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J. Indian Soc. Coastal agric. Res., 28(1), 44-47, 2010

Influence of Sub-surface Drainage on Rice Crop Yield in Saline and Waterlogged Soils of Konanki and Uppugunduru Pilot Areas of Andhra Pradesh

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The effect of sub-surface drainage systems on paddy crop yields in saline and water logged soils of Konanki and Uppugundur pilot areas of Nagarjuna Sagar Right Canal Command and Krishna Western Delta, respectively in Andhra Pradesh was studied during the period from 1999-2002. The pre and post drainage agronomic practices were compared by conducting the surveys and crop cut experiments. The pre drainage investigations revealed the problems of the stunted growth, poor crop stand, nutrient deficiencies and meager crop yields in these areas. The crop cut experiments were conducted at 58 grid locations at each pilot area during the three years 1999-2000, 2000-01& 2001-02). Post drainage agronomic studies revealed that the rice crop yields after the installation of sub-surface drainage systems were increased at both pilot areas. At Konanki pilot area, the percent increase in rice yield in the area drained by open sub-surface drainage (OSSD) system was 23, 34.5 and 33.6 in the years 1999-2000, 2000-01 and 2001-02, respectively. Similarly, in the area drained by the closed sub-surface drainage system (CSSD), the corresponding percent increases in rice yield were 59, 73 and 75.6 respectively. At Uppugunduru, the percent increase in rice yield were 59, 67 and 86 in the years 1999-2000, 2000-01 and 2001-02, respectively in the area drained by OSSD system. Similarly, in the area drained by the CSSD system, the corresponding percent increase in yields was 23, 17 and 55, respectively. Farmers are very much encouraged by the improvement in soil health in the pilot areas due to the installation of sub-surface drainage systems and these pilot areas farmers are now going for multiple crops.

*(**Key words** : Sub-surface drainag, Saline and waterlogged soil, Uppugunduru pilot, Konanki & Andhra Pradesh)*

The combination of irrigation and drainage is one of the important factor to maintain and improve the rice crop yield in the canal command areas. Drainage is a tool to manage the ground water levels and plays an important role in maintaining the rice crop yields in canal commands. A large portion of land in India is currently not being cultivated because of problem of water logging and salinity. The command areas affected by water logging and salinity in Andhra Pradesh are estimated to be 0.274 and 0.115 m ha, respectively. In order to suggest practical solutions for combating these twin problems of water logging and soil salinity, two drainage pilot areas near Konanki and Uppugunduru villages in Prakasham district of Andhra Pradesh under Nagarjunasagar Project Right Canal Command and Krishna Western Delta, respectively are selected for conducting operational research. The areas selected for conducting operational research at both the pilot areas are 21.63 and 20.92 ha, respectively. The cropping pattern in these pilot areas was single crop of rice with long and medium duration varieties.

MATERIALS AND METHODS

To study the influence of drainage systems on the rice crop yield at Konanki pilot area, the pilot area has been divided in to six sections based on the predominant soil characters namely southern section, centre section, northern section, lowest section, heavy clay section and uncultivated section. Closed horizontal and open sub-surface drainage systems were constructed in an area of 8 and 5 ha in central (sandy loam/sandy clay loam) and northern sections (sandy clay loam) of the pilot area respectively. Uppugundur pilot area has been divided in to three blocks namely Bloch-I, Block-II, and Block-III. The Block-I is again subdivided in to three sub-blocks. Closed and open sub-surface drainage systems were installed in an area of 7 and 5 ha in Block-III (sandy clay loam) and sub-block-ii (sandy clay loam) of the pilot area. Konanki and Uppugunduru pilot areas are located at the ends of NSP Right Canal Command and Krishna western Delta of Prakasham district of Andhra

Table 1. *Percent increase in rice yields after installation of drainage system*

Years	Konanki pilot area		Uppugunduru pilot area	
	OSSD	CSSD	OSSD	CSSD
1999-2000	22.6	59.4	59.0	22.0
2000-2001	34.5	72.9	66.7	17.4
2001-2002	33.6	75.6	86.4	54.7

Table 2. *Rice Yield During Pre & Post Drainage Conditions at Konanki Pilot Area*

Sections	Area (ha)	Predominant soil type	Improved drainage system	Improved irrigation system	Rice yield (t ha^{-1})			
					Pre drainag	Post drainag		
					1998-1999	1999-2000	2000-2001	2001-2002
Southern section	3	Loamy sand	No improvement fore seen (internal drainage/surface drainage)	No improvement fore seen (basin irrigation)	2.83	3.15	3.99	4.41
Centre section	8	Sandy loam/ sandy clay loam	Closed horizontal surface drainage	Improve surface drainage during pre-irrigation improved leaching	3.40	5.42	5.88	5.97
Northern section	5	Sandy clay loam	Open surface drainage	Improve surface drainage during pre-irrigation improved leaching	3.54	4.34	4.76	4.73
Lowest section	3	Loamy sand/ sandy loam	No improvement fore seen (surface drainage)	No improvement fore seen (controlled flooding)	3.51	3.68	3.99	4.43
Heavy clay section	2	Loamy sand	No improvement fore seen (surface drainage)	Improve surface drainage during pre-iirrigation	3.88	4.10	4.56	4.25
Uncultivated section	2	Sandy loam	—	—	0.00	2.52	2.2	4.33
Weighted average					3.11	4.29	4.7	5.01

Table 3. *Rice Yield During Pre & Post Drainage Conditions at Uppugunduru Pilot Area*

Sections	Area (ha)	Predominant soil type	Improved drainage system	Improved irrigation system	Rice yield (t ha^{-1})			
					Pre drainag	Post drainag		
					1998-1999	1999-2000	2000-2001	2001-2002
Block-I								
i)	0.65	Sandy clay loam	No improvements fore seen (internal drainage/ surface drainage)	No improvements fore seen (controlled flooding)	4.06	4.20	5.33	6.75
ii)	5.0	Sandy clay loam	Open surface drainage	No improvements fore seen (controlled flooding)	3.24	5.54	5.40	6.04
iii)	3.68	Sandy clay loam	Natural drainage/ normal soil	No improvements fore seen (controlled flooding)	5.89	6.49	6.28	6.44
Block-II	4.59	Sandy clay loam/sandy loam	Partial sub-surface drainage natural drainage	No improvements fore seen (controlled flooding)	4.59	5.16	5.36	6.27
Block-III	7.00	Sandy clay loam	Closed sub-surface drainage	No improvements fore seen (controlled flooding)	4.59	5.93	5.39	7.10
Weighted average					4.3	5.5	5.55	6.57

Pradesh, India. At Konanki, depth to water table, is ranged from 0 to 3.74 m, electric conductivity (ECe) of soil saturated extract ranged from 1.3 to 18.6 dSm^{-1}, pH is ranged from 7.2 to 10.00 and ESP ranged from 14.1 to 54.6. At Uppugunduru, the depth to water table, ranged from 0 to 2.04 m and salinity (ECe) ranged from 1.0 to 52.7 dSm^{-1} and pH was ranged from 6.5 to 8.8. The soils of Konanki and Uppugunduru pilot area are clay loam and sandy clay loam, respectively.

RESULTS AND DISCUSSION

Crop cut experiments were conducted based on grid locations where the initial soil samples were collected to evaluate the performance of constructed drainage systems at Konanki and Uppugunduru pilot areas. The rice crop yields increased from pre-drainage to post drainage situations in all the sections/blocks. The weighted average of crop yields from all the sections at Konaki pilot area has risen from 3.11 t ha^{-1} (1998-99) to 5.01 t ha^{-1} (2001-2002) showing an increase of 1.98 t ha^{-1} (61.2 %) from pre drainage to post drainage situation (Table 1). At this pilot area the sections where sub-surface drainage system was installed have also shown marginal improvement in rice crop yields under post drainage conditions when compared to pre drainage conditions. This marginal improvement in crop yield may be due to improved agronomic management practices such as maintaining optimum crop stand, timely weed control, plant protection and fertilizer management. However, interestingly, part of uncultivated section brought under cultivation during this season and recorded yields up to 2.52 t ha^{-1} (Table 1). The percent increase in yield was 23, 34.5 and 33.6 in years 1999-2000, 2000-01 and 2001-02, respectively in the drained area by open sub-surface drainage system. Similarly, in the area drained by closed sub-surface drainage system, the corresponding percent increase in yields during the above three years were 59, 73 and 75.6 respectively (Table 3). Where as in Uppugunduru pilot area the rice yield also risen from all blocks from 4.3 t ha^{-1} (1998-99) to 6.53 t ha^{-1} (2001-2002) showing an increase of 2.27 (52.8%) from all the blocks from pre-drainage to post drainage periods (Table 2). At Uppugunduru pilot area percent increase in rice yields were 59, 67 and 86 in the years 1999-2000, 2000-01 and 2001-02, respectively in the drained area by open sub-surface drainage system. Similarly, in the area drained by closed sub-surface drainage system, the corresponding increase in in yields is due to lowering down the water table to prevent the water logging situation and gone down the salinity to optimum level by leaching of salts through the pipe drains as well as open drains. In addition to this introduction of green manuring and adoption of salt tolerant rice varieties also contributed to improving the soil health and thereby increase in the rice yields.

The sub-surface drainage technology has found to be successful in improving the rice crop yields under saline and water logged conditions in canal commands.

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J. Indian Soc. Coastal agric. Res., 28(1), 48-50, 2010

Impact of Sub-surface Drainage on Paddy Yield and Cropping Pattern in Waterlogged Saline Soils

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At Konanki pilot area, pipe drains were installed in area of 8 ha at a depth of 0.9 to 1.1 m by adopting two spacing of 30 and 60 m where depth to water table, 0 to 3.74 m, salinity and sodicity (ECe, 1.3 to 18.6 dSm^{-1}, pH, 7.2 to 10.0., ESP, 14.1 to 54.6) problems were noticed, at Uppugunduru pilot area, pipe drains were installed in area of 7 ha at a depth of 1.2 to 1.35 m by adopting three spacings of 30, 45 and 60 m where waterlogging (depth to water table, 0 to 2.04 m) and salinity (ECe, 1.0 to 52.7 dSm^{-1}; pH, 6.5 to 8.8) were noticed. Three open drains were constructed in northern part of Konanki pilot area in area of 5 ha with 1:1 slope at 100 m spacing. Six open drains were constructed at Uppugunduru pilot area in area of 5 ha at spacing of 50 m. At both pilot areas, composite type of pipe drainage system were laid. After the installation of drainage system, the paddy yield at Konanki and Uppugunduru pilot areas was increased from 3.4 to 5.99 t ha^{-1} and from 4.55 to 7.1 t ha^{-1}, respectively in area drained by pipe drainage system. In the open drained area, the corresponding increase in paddy was from 3.54 to 4.73 t ha^{-1} and 3.24 to 6.04 t ha^{-1} at Konanki and Uppungunduru, respectively. After the reclamation of water logged saline soils with installed drains, farmers could grow the second crop in Uppugunduru pilot area and also introduce pulses like blackgram and greengram.

(**Key words:** *Sub-surface drainage, Paddy, Cropping pattern, Saline soils*)

Irrigation and drainage together are more important in sustainable agricultural production. Whereas irrigation management aims at supplying optimum quantity of good quality water through out the crop growth drainage aims at removal of excess water in short period. Excess moisture or water logging occurs due to heavy and continuous rains or due to faulty irrigation practices. Water logging and salinity causes several changes in soil and plant, resulting stunted crop growth and in some cases death of the plants. Water logging causes accumulation of toxic substances in the soil and plant and therefore (reduce the availability of oxygen) to crop. In most of the irrigation projects in India, adequate importance for drainage is not given and as a result, the water table built up steadily due to seepage, percolation losses, over irrigation, spillage from canals, etc. stalinization and water logging in canal commands have resulted in loss of land from cultivation.

MATERIALS AND METHODS

For suggesting suitable reclamation measures to combat the twin problems of salinity and water logging, two drainage pilot areas have been selected: one at Konanki village of Prakasham district, Andhra Pradesh under Nagarjuna Sagar Right Canal Command (NSPRCC) and second at Uppugunduru village of Prakasham district, Andhra Pradesh under Krishna Western Delta. The Konanki pilot area is situated by the side of Kolkata-Chennai National highway No. 5 and spread over 21.6 ha with 37 farm holdings and Uppugunduru pilot area is situated by the side of Chirala-Ongole state highway with 46 farm holdings and over an area of 20.92 ha. Konanki pilot area is in the tail end of NSPRCC and had serious problems of salinity, sodicity and water logging (ECe 1.3 to 18.6 dSm^{-1}; pH 7.2 to 10.0; ESP 14.1 to 54.6). At Uppugunduru, the problems of salinity (ECe 1.0 to 52.7 dSm^{-1} pH 6.5 to 8.8) and water logging (depth to water table, 0 to 2.04 m) were noticed. The average annual rain fall at both the pilot areas is less than 800 mm. the cropping pattern followed at both the pilot areas consists of single crop of rice with meager yields. At Konanki, pipe drains were installed in an area of 8 ha at a depth of 0.98 to 1.1 m adopting two spacings of 30 and 60 m. At Uppugunduru pilot area, drains were installed in 7 ha area at a depth of 1.2 to 1.35 m under three spacings i.e., 30, 45 and 60 m. three open drains were constructed in northern part of Konanki pilot area in an area of 5 ha with 1:1 slope and 100 m spacing. Six open drains were constructed at Uppugunduru pilot area in an area of 5 ha with a slide slope of 1:1 and spacing of 50 m. At both the pilot areas composite type of pipe drainage system were laid.

Table 1. *Change in Paddy Crop Yields after Installation of Sub-surface Drainage Systems at Konanki and Uppudundu Drainage Pilot Areas*

Type of Drainage system	Konanki Drainage Pilot Area				Uppugunduru Drainage Pilot Area			
	Pre-drainage	Post drainage			Predrainage	Post drainage		
	1998-99	1999-00	2000-01	2001-02	1998-99	1999-00	2000-01	2001-02
PSSD	3.4	5.42 (59.4%)	5.88 (72.9%)	5.97 (75.6%)	4.59	5.93 (22.0%)	5.39 (17.4%)	7.1 (54.7%)
OSSD	3.54	4.34 (22.6%)	4.76 (34.6%)	4.71 (33.6%)	3.24	5.54 (59.0%)	5.2 (66.7%)	6.04 (66.4%)

RESULTS AND DISCUSSION

At Konanki and Uppugunduru pilot areas, poor germination, stunted growth of crop and nutrient deficiencies were observed, before installation of drainage systems because of soil salinity and water logging problems. As a result, poor yields of paddy crop were recorded. After first, second and third years after installation of the drainage systems, paddy yield increased by 59.4, 72.9 and 75.6 %, respectively in the pipe drained area at Konanki (Table 1). The corresponding increase in the open drained area ware 22.6, 34.5 and 33.6 %, respectively. The increase in yield was found to be higher in the area drained by pipe drainage system than in the area drained by open drainage system because of closer spacing and intensive removal of excess water and salts by the pipe drainage system.

At Uppugunduru, the yield of paddy in pipe drained area increased from 4.59 to 7.1 t ha^{-1} with in two years after installation of pipe drainage system (Table 1). In the open drained area, paddy yield increased from 3.24 to 6.04 t ha^{-1}. The corresponding percent increase in the yield of paddy in the pipe and open drained areas ranged between 17.4 to 54.7 and 59 to 86.4 respectively. Although the highest average paddy yield of 7.1 t ha^{-1} was recorded in the pipe drained area as compared to 6.04 t ha^{-1} recorded in the open drained area, the percent increase in the open drained area, was much higher because of poor pre-drainage in that area., which was relatively more salinity and water logging due to seepage from adjoining irrigated tank. The increase in yield of paddy was mainly due to the control of water table and reduction of soil salinity at the pilot area because of installation of drainage systems.

At Konanki and Uppugunduru pilot areas, only mono crop of paddy used to grow during monsoon season and land used to kept fallow during remaining part of the year due to salinity and water logging problems. One year after the installation of drains, green manure crop Dhaincha could established successfully at Konanki and crops of sunhem, pillipesara and fodder Jowar as second crops after paddy at Uppugunduru. Three years after installation of drainage systems, income generating and short duration pulses are also introduced as second crop at Uppugunduru pilot area (Table1). The farmers of pilot areas grow second crop after evidencing incremental yield of paddy due to leaching of salts through the pipe drains as well as open drains.

Table 2. *Change of Cropping Pattern after Installation of Drainage Systems at Uppugunduru Pilot Area.*

Crop	Area in ha		
	1999-00	2000-01	2001-02
First crop			
Paddy	20.92	20.92	20.92
Second crop			
Sunhemp	6.8	8.8	8.9
Pillipesara	7.6	5.3	3.0
Fodder jowar	1.0	1.0	1.0
Greengram	-	-	1.2
Blackgram	-	-	1.2

The pipe and open surface drainage systems installed at Konankiand and Uppugunduru pilot areas under Nagarjunasagar project right canal command and Kishna western delta, respectively have reclaimed the water logged saline lands. The influence of these systems on increase in crop yields is as detailed below.

i. The yield of paddy crop increased by 59.4 to 75.6 % and 17.4 to 54.7% in the pipe drainaged area at Konanki and Uppugunduru, respectively. The corresponding increase in yield in open drained area at Konaki and Uppugunduru was 22.6 to 34.5% and 59 to 86.4%, respectively.

ii. Growing of sunhemp, pillipesara, fodder jowar, blackgram and greengram as second crop after paddy at Uppugunduru pilot area.

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J. Indian Soc. Coastal agric. Res., 28(1), 51-54, 2010

Relationship between Lamina Chloride and Leaf Burn in Flue-cured Tobacco (*Nicotiana tabacum* L.)

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Response of flue-cured tobacco (*Nicotiana tabacum* L.) to applied chloride varies depending on the tobacco type, variety, method of fertilization, cultivation and harvesting. Chloride is having significant effect on tobacco leaf burn. Therefore, an attempt was made to study the effect of applied chloride on lamina chloride concentration and the relation between lamina chloride, leaf moisture, leaf thickness and leaf burn and to find out the chloride limit for optimum leaf burn. Results revealed that leaf chloride content increased with increased level of applied chloride and leaf burn decreased with increased leaf chloride concentration. Leaf moisture content and leaf thickness increased with increased concentration of applied chloride. Leaf thickness was more in top position leaves followed by middle and bottom position leaves. Leaf burn showed negative correlation with leaf chloride, leaf moisture and leaf thickness. Lamina chloride showed positive correlation with leaf thickness. The relationship between leaf burn and lamina chloride could be expressed as Y = 5.92 – 1.71 X. (R^2 = 0.658). Where Y is leaf burn in seconds and X is lamina chloride (%). Based on the regression analysis it is concluded that the critical limit of lamina chloride for optimum leaf burn (> 4 seconds) is 1% for flue cured tobacco variety Kanchan grown in alfisols Andhra Pradesh, India.**

(***Key words:*** *Flue-cured tobacco, Lamina chloride, Leaf burn, Leaf moisture, Leaf thickness*)

Tobacco is an important commercial crop grown mainly in the states of Andhra Pradesh and Karnataka. Chloride is an essential element and there is considerable evidence that beneficial effects arise with tobacco from the presence of small amounts of chloride in the fertilizer (Mc Cants and Waltz, 1967). Chloride functions mainly as the highly mobile inorganic anion (Cl^-) in processes related to charge compensation and osmoregulation. Under natural conditions excess chloride is of concern rather than deficiency. In the cured leaf excess chloride produces muddy, dingy and uneven colour with an undesirable odor. Earlier studies on effect of chloride on flue-cured tobacco grown in vertisols showed that at lamina chloride concentration of 2%, the leaf burn recorded was zero (Kameswararao *et al.*, 1964). Later tobacco cultivation is shifted from vertisols to alfisols and it was reported that irrigation water containing chloride not more than 1.4 milli equivalents per liter may safely be used for tobacco cultivation (Krishnamurthy *et al.*, 1981) and 10-25% of irrigated light soils had higher (>100 ppm) accumulation of chlorides (Krishanmurthy *et al.*, 1987). The chloride concentration in irrigation water and soil affect the leaf chloride content and leaf burn. Response of flue-cured tobacco to chloride varies depending on the tobacco type, variety, and method of fertilization, cultivation and harvesting. So with the advent of new high yielding varieties, improved cultivation practices and shifting of tobacco cultivation from vertisols to alfisols it is aimed, to study the effect of chloride on growth characters, yield parameter and chemical quality constituents and determine the association between lamina chloride and leaf burn in flue-cured tobacco variety Kanchan.

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MATERIALS AND METHODS

An experiment was conducted for two years (2006-2008) with different levels of applied chloride to soil (0, 5, 10, 15, 20, 25 g Cl/plant). The pot culture experiments were conducted in completely randomized block design replicated five times. The cement pots were filled with 150 kg of soil collected from CTRI Research Farm, Jeelugumilli, West Godavari district, Andhra Pradesh. The soil is slightly acidic in reaction with low soluble salts and chlorides. Each pot received N, P_2O_5 and K_2O @ 115, 60 and 120 kg ha^{-1}, respectively. The plants were grown using recommended practices. Harvested leaf was cured in an electric barn and observations on yield and yield components were recorded. Cured leaf samples collected from bottom, middle and top positions were processed. Leaves were separated into two halves. Each half portion was again divided into three portions i.e. tip, middle and base of the leaf and were analyzed for chloride concentration

(Hanumantharao *et al.*, 1980) and leaf burn (Venkataraman and Tejwani, 1957). The other half portion of leaves was processed and analyzed for leaf thickness (Sastry and Murthy, 1961), leaf moisture content, nicotine and reducing sugars (Hanumantharao *et al.*, 1980). The data was analyzed statistically (Gomez and Gomez (1984). The correlations were calculated among lamina chloride, leaf burn, leaf moisture and leaf thickness. Regression equation was computed between lamina chloride and leaf burn. The statistical analysis was done using the methods given by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Effect of applied chloride on yield characters, leaf area, nicotine and reducing sugars are given in Table 1 and 2. Increasing level of applied chloride did not significantly influence green leaf yield, cured leaf yield, grade index, leaf area, nicotine and reducing sugars. Karaivazglou *et al.*, (2006) also reported that the effect of chloride on leaf nicotine concentration was minimum, inconsistent and depend on priming and cultivars.

With increased level of applied chloride the lamina chloride content increased in all plant positions (Fig. 1). Myhre *et al.*, (1956) also reported that the amount of chloride taken up by the crops was most closely correlated with that found in the 0-12 inch layer of soil. In the plant, bottom leaves contained higher chloride followed by middle and top position. In addition Collins and Hawks (1993), Peedin (1999) and Mulchi (1982) reported that leaf chloride concentration increased linearly with increasing level of chloride in the soil.

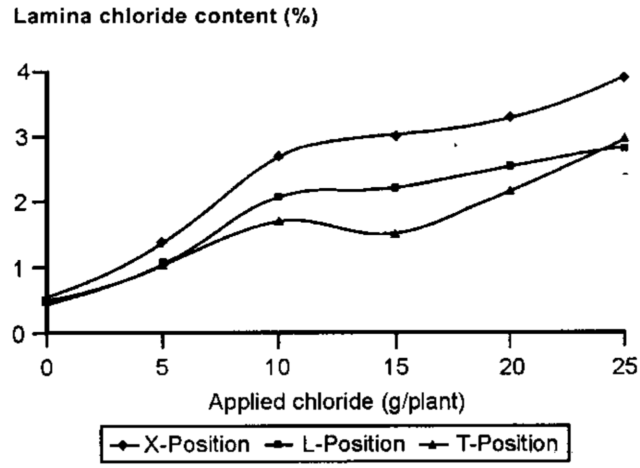

Fig. 1. Effect of applied chloride on lamina chloride

Table 1. *Effect of chloride on leaf area and yield characters*

Treatment	Green leaf yield (g/plant)	Cured leaf yield (g/plant)	Grade index (g/plant)	Leaf area (m^2/plant)
0 g Cl/plant	1223	220	163	2.91
5 g Cl/ plant	1159	224	148	2.71
10 g Cl/ plant	1258	229	149	2.80
15 g Cl/ plant	1161	209	141	2.75
20 g Cl/ plant	1212	210	137	2.78
25 g Cl/ plant	1276	213	139	2.73
SEm±	104	13	13.5	0.16
C.D.(0.05)	NS	NS	NS	NS

Table 2. *Effect of chloride on nicotine and reducing sugars at X, L and T positions*

Treatment	Nicotine (%)			Reducing sugars (%)		
	X	L	T	X	L	T
0 g Cl/plant	2.16	2.72	3.53	14.50	17.0	16.11
5 g Cl/ plant	1.87	2.85	3.61	16.16	16.8	14.28
10 g Cl/ plant	1.89	2.39	3.26	16.00	17.5	14.03
15 g Cl/ plant	1.78	2.53	3.37	16.37	16.05	14.21
20 g Cl/ plant	2.08	2.46	3.24	18.06	18.63	16.80
25 g Cl/ plant	2.42	2.79	3.38	15.48	16.76	15.56
SEm±	0.25	0.24	0.31	2.11	1.37	1.28
C.D.(0.05)	NS	NS	NS	NS	NS	NS

Table 3. *Effect of chloride on leaf thickness and leaf moisture content*

Treatment	Leaf thickness (X 0.01mm)			Leaf moisture content (%)		
	X	L	T	X	L	T
0 g Cl/plant	19.15	23.84	26.21	10.27	9.82	10.30
5 g Cl/ plant	21.22	26.87	30.23	11.28	11.91	11.19
10 g Cl/ plant	22.36	25.51	35.64	11.56	11.49	11.01
15 g Cl/ plant	25.15	28.67	33.63	12.48	12.37	11.58
20 g Cl/ plant	25.06	28.27	32.89	14.65	13.12	12.50
25 g Cl/ plant	24.70	29.53	34.55	15.69	14.52	13.25
SEm±	0.96	0.67	1.62	0.30	0.48	0.63
C.D.(0.05)	2.94	2.08	5.00	0.94	1.49	1.94

Table 4. *Correlation coefficients among leaf burn, lamina chloride, leaf moisture and leaf thickness*

	Leaf burn	Lamina chloride	Leaf moisture	Leaf thickness
Leaf burn	1.00			
Lamina chloride	- 0.787**	1.00		
Leaf moisture	- 0.692**	0.795**	1.00	
Leaf thickness	- 0.442**	-0.137	0.174	1.00

** Denotes significant at 0.01 probability

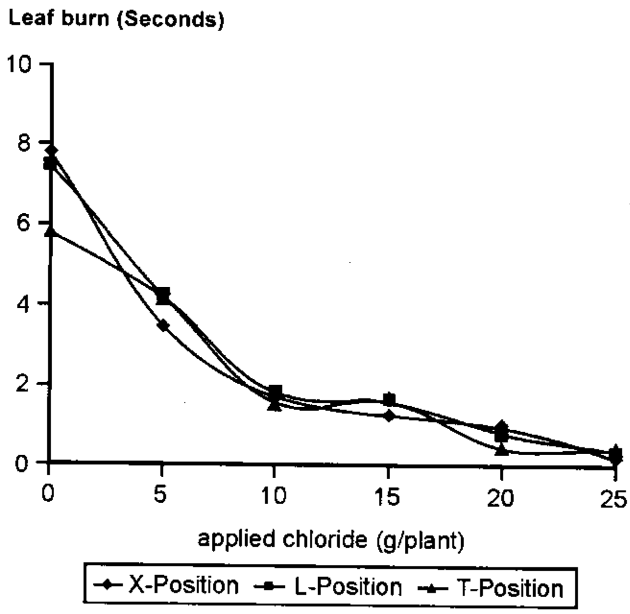

Fig. 2. Effect of applied chloride on leaf burn

Leaf burn reduced with increased level of applied chloride at bottom, middle and top position of the plant (Fig. 2). Similar results were reported by Collins and Hawks (1993), Peedin (1999) and Mulchi (1982). The reported results showed that higher concentration of chloride in soil reduced the burn rate in tobacco leaf.

The relationship between lamina chlorides and leaf burn in different portions of the leaf was shown in Fig. 3. Regarding different positions of the same leaf, the tip of the leaf showed more leaf burn followed by middle and base portion.There is strong negative correlation between lamina chloride and leaf burn in all plant positions. Pal *et al.*, (1963) also reported that the base of the leaf showed poorest leaf burn compared to middle and top portions of the leaf.

Leaf moisture content and leaf thickness increased with increase in applied chloride level (Table 3). Leaf thickness was more in top position leaves followed by middle and bottom position leaves at all the levels of applied chloride. In > 10g Cl / plant applied treatments, leaf moisture was more in bottom leaves followed by middle and top position leaves with. This trend was not observed in control and 5 g Cl/plant applied treatments.

The relationship among lamina chloride, leaf burn, leaf moisture and leaf thickness are shown in the form of a correlation matrix in Table 4. Leaf burn showed negative correlation with leaf chloride (r = - 0.787), leaf moisture (r = -0.692) and leaf thickness (r = -0.442). Lamina chloride showed positive correlation with leaf moisture (r = 0.795). The relationship between leaf burn and lamina chloride is shown in Fig. 4. The regression equation for leaf burn as the function of lamina chloride could be expressed as Y = 5.92 – 1.71 X. R2 = 0.658, where Y is leaf burn in seconds and X is lamina chloride

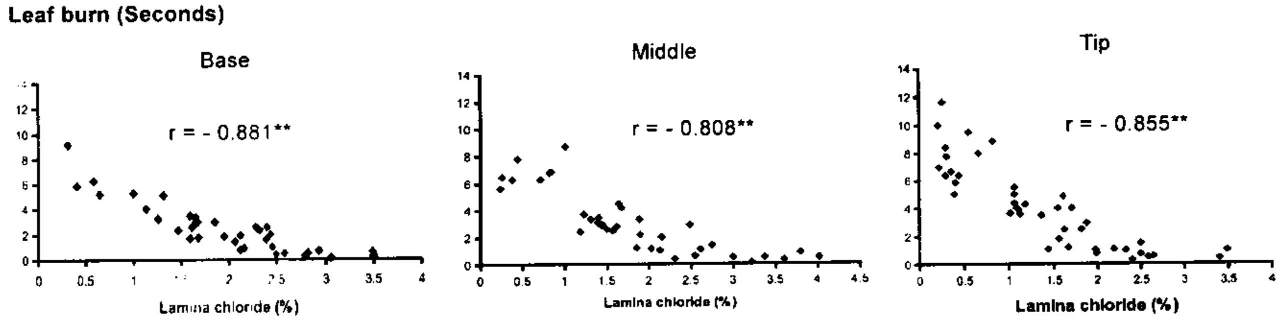

Fig. 3. Leaf burn at different positions of the leaf (** denotes significant at 0.01 probability)

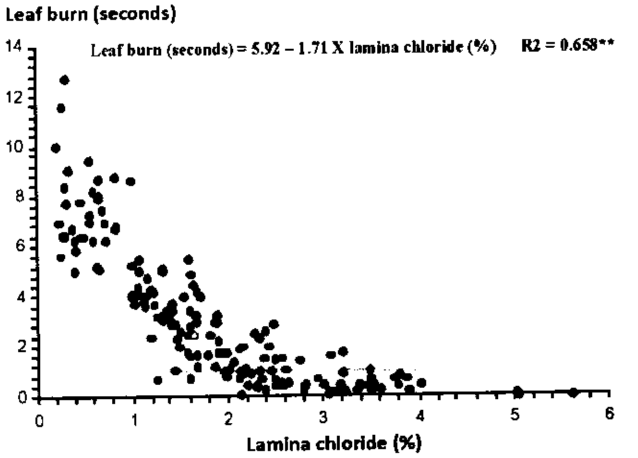

Fig. 4. Relationship between lamina chloride and leaf burn

(%). Based on the regression analysis, it is concluded that the higher limit of lamina chloride for optimum leaf burn (> 4 seconds) is 1% for flue cured tobacco variety Kanchan grown in alfisols of India.

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J. Indian Soc. Coastal agric. Res., 28(1), 55-57, 2010

Effect of Sowing Dates and Plant Spacing on Growth, Yield and Yield Attributes of *Rabi* Sweet Corn Under Lateritic Soils of Konkan

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An experiment was conducted during Rabi seasons of 2007 - 08 and 2008 - 09 to find out effect of sowing dates and plant spacing on growth and yield of sweet corn at Dapoli Dist. Ratnagiri, on sandy clay loam soils of south konkan coastal zone of Maharashtra. The study revealed that winter sweet corn sown in 45th meteorological week (5 Nov. - 11Nov.) gave maximum cob yield of 199.75 q ha-1 with maximum values of growth and yield attributes than the delayed sowing from 51st to 3rd meteorological week. The plant spacing of 60 x 20 cm (83,333 plants ha-1) produced significantly higher yield of 208.45 q ha-1 over the wider spacings of 60 x 40 cm (41,666 plants ha-1) and 60 x 20 cm (27,777 plants ha-1).

*(**Key words:** Sowing time, Plant spacing, Winter sweet corn, Yield)*

The cultivation of rainy season maize in south Konkan coastal zone is risky due to natural vagaries of the monsoon season and restricted sunshine hours for photosynthesis. Similarly, the heavy rainfall in Konkan disturb the plant initially and may not result into mature plant due to washing out of pollens with the heavy rains upto September. These coupled with fluctuation in the moisture content of soil reduces the yield. Its potential can, however, be exploited during the winter season owing to favourable climate, better water management and less attack of pest and diseases. Hence an experiment was conducted to exploit the possibility of growing sweet corn during winter in konkan region.

MATERIALS AND METHODS

The experiment was conducted at Agronomy farm, college of Agriculture, Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli Dist. Ratnagiri, during the winter seasons of 2007-08 and 2008-09, in split plot design with 3 replications. The soil was sandy clay loam, slightly acidic in reaction, high in available nitrogen (196.69 kg ha^{-1}), low in available phosphorus (17.12 kg ha^{-1}) and K (204.54 kg ha^{-1}). The main plot treatment consisted of 6 sowing dates in alternate meteorological week (45th MW, 47th MW, 49th MW, 51st MW, 1st MW and 3rd MW), while the sub-plot consisted to 3 plant spacings treatments (60 x 20 cm, 60 x 40 cm and 60 x 60 cm). The sweet corn variety 'Sugar 75' was used for experimentation. The gross plot size was 4.8m x 4.2m and net plot size varies with the plant spacing. The seeds were sown by dibbling method and plant spacing was maintained as per the treatment. For 60 x 20cm, 60 x 40 cm and 60 x 60 cm spacing 12 kg, 6 kg and 4 kg ha^{-1} seed was required, respectively. The nutrient sources were urea, single super phosphate and muriate of potash. The entire quantity of P2O5 and K_2O along with one-third N was applied as basal at the time of sowing. Remaining quantity of N was top-dressed in 2 equal splits, at knee stage and tasseling stages. Well decomposed FYM 10 tones ha^{-1} was incorporated in to the soil 10 day before sowing.

RESULTS AND DISCUSSION

Effect of sowing dates

The crop sown on 45th meteorological week (5 Nov.-11Nov.) obtained significantly higher plant height, number of functional leaves and dry matter accumulation/plant over the subsequent delayed sowing dates and it was closely followed by 47th MW and 49th MW (Table 1). The sweet corn planted on 51st MW, 1st MW and 3rd MW experienced high temperature during later stages (90 DAS and at maturity). This effect resulted quick desiccation of the leaves, unbalanced ratio of photosynthesis and respiration, and eventually reduced the plant height, number of leaves and dry matter production/plant. The sweet corn planted on 45th MW recorded significantly higher indices of cob girth, cob length, number of cobs/plant, weight/cob, number of grains/cob, cob yield and green fodder yield than that planted on subsequent sowing dates i.e. 47th MW to 3rd MW. The maximum harvest index was

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obtained in sowing of 47th MW and followed by 49th MW. The decrease in yield and yield attributes were due to significance decrease in growth attributes and other ancillary characters (Table 1). The most detrimental factor in restricting growth was low minimum temperature during January and February (6–8°C) compared with a minimum requirement of 10° C of the maize as reported by Berger (1962). The maturity period of the crop sown on delayed sowing (51st MW to 3rd MW) was reduced because of the crop experienced high temperature during later stages. The similar results were earlier reported by Sharma (1990), Khandale and Relwani (1991), Sandhu and Hundal (1991), Malaiya *et al.*, (2004) and Sutaliya and Singh (2005) Karthikeyan and Balasubramaniam (2006).

Effect of plant spacing

Plant height of sweet corn was significantly influenced due to the plant spacing at all the growth stages. The crop spaced at 60 x 20 cm (D1) recorded significantly more plant height of sweet corn as compared to 60 x 40 and 60 x 60 cm (D3). Wider spacing of 60 x 60 cm increased significantly the functional leaves/plant and dry matter production/ plant over the other closer spacing of 60 x 20 cm and 60 x 40 cm. However, 60 x 40 cm also sowed significantly higher dry matter and number of leaves than narrower spacing of 60 x 20 cm. the dry matter/plant decreased significantly with successive decrease in plant spacing.

The yield attributing characters viz. cob girth, cob length, weight of cob, number of cobs/plant, number of grains/cob of sweet corn was decreased significantly with reduction in plant spacing. The decrease in dry matter/plant and above referred yield attributes with the decrease in plant spacing which might be due to the plant competition for space, moisture, nutrients and light at higher densities. A significant linear decrease in grain yield was observed with increase in plant spacing from 20cm to 60cm. Thus the spacing of 60 x 20 cm appeared to be more advantageous in terms of green cob yield (208.45 q ha^{-1}) and green fodder yield (274.87 q ha^{-1}). This might be due to higher plants ha-1 in case of closer spacing was found beneficial to obtain more number of cobs and higher green fodder yield compared to wider spacing of 60 x 40 cm and 60 x 20 cm. Similar results were reported by Gaurkar and Bharad (1998), Huseyin *et al.*, (2003), Singh and Singh (2006) and Kunjir (2007).

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J. Indian Soc. Coastal agric. Res., 28(1), 58-61, 2010

Correlation and Path Analysis in F_3 Population of Brinjal (*Solanum melongena* L.) in Coastal Region of Maharashtra

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The genotypic and phenotypic correlations and path analysis were carried out in F_3 population of brinjal consisted of seven F_3 families with four progenies of each family and six parents of brinjal. The characters weight of fruit and number of fruits per plant showed significant positive correlation with fruit yield at genotypic and phenotypic level. The character days to last picking showed highly significant negative correlation with fruit yield at both level. The character days to initiation of flowering showed negative significant correlation with fruit yield per plant at genotypic level. The path analysis study concluded that characters viz. days to last picking, plant height, fruit weight and number of fruits per plant had positive direct effect on fruit yield at both level. While, days to initiation of flowering, days to 50 per cent flowering and days to first picking exhibited negative direct effect on fruit yield at both levels.

(***Key words:*** *Correlation, Path analysis, F_3 population, Brinjal*)

To know the mutual association between quantitative characters related to fruit yield and to assess the direct and indirect effects of various characters on yield, the correlation and path analysis were studied in F_3 population of brinjal.

MATERIALS AND METHODS

The experimental material consisted of seven F3 families viz. Arka Nilkanth x CHES 309, Arka Nilkanth x BB-60-C, CHES-309 x BB-64, CHES-309 x IIHR-7, CHES-309 x BB-60-C, CHES-309 x BDIRT and BB-60-C x BB-64 with four progenies of each family were grown in compact family block design as suggested by Singh and Singh (1994) with three replications at Research Farm, Department of Agril. Botany, during *rabi* 2006-07. The 45 days old seedlings were planted on a well prepared plot at 60 cm x 60 cm spacing. The plot size was 3 x 1.80 m. The experimental soil was lateratic loam. The preliminary tillage operations were carried out properly in order to bring the soil at proper condition. Fertilizers at the rate of 150 kg nitrogen, 50 kg phosphorus and 50 kg potash per hectare in the form of urea, single super phosphate and muriate of potash respectively were applied. One third dose of nitrogen and full dose of phosphorus and potash were applied at the time of transplanting and remaining dose of nitrogen was applied in two equal splits at an interval of one month. The plot was irrigated at an interval of 7 days. The observations were recorded on eleven characters from five randomly selected plants per progeny per replication and their means were computed and utilized for statistical analysis.

The correlation among different characters was calculated as per the procedure advocated (Johnson *et al.*, 1955). The direct and indirect effects under the path analysis was worked out as per method suggested by Dewey and Lu (1959).

RESULTS AND DISCUSSION

The analysis of variance revealed significant differences for fruit yield and yield contributing traits studied indicating the presence of high genotypic variability. The genotypic correlation coefficient were higher in magnitude than their corresponding phenotypic correlation coefficient for most of the characters (Table 1). This indicated the strong inherent association between the various characters studied. At phenotypic and genotypic level fruit yield per plant showed positive and highly significant correlation with number of fruits per plant and fruit weight indicated that, these characters were the primary yield determinant characters in brinjal. The similar results were also observed by Ingale and Patil (1995), Ahmed *et al.*, (1999), Sharma and Swaroop (2000), and Daliya and Wilson (2002). The character fruit yield per plant had positive non-significant correlation with number of branches per plant and fruit length at both genotypic and phenotypic level. At phenotypic and genotypic level, fruit yield per plant showed negative

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Table 1. *Estimation of phenotypic (rp) and genotypic (rg) correlation between different characters in F_3 population of brinjal*

Characters		Days to initiation of flowering	Days to 50 % flowering	Days to first picking	Days to last picking	Plant height (cm)	Number of branches per plant	Fruit length (cm)	Fruit breadth (cm)	Fruit weight (cm)	No. of fruits per plant	Correlation with fruit yield per plant (g)
Days to initiation of flowering	rp	1.000	0.651**	0.917**	0.791**	0.070	-0.140	0.069	-0.018	-0.086	-0.436*	-0.373
	rg	1.000	0.814**	0.827**	0.717**	0.149	-0.190	0.244	0.048	-0.186	-0.434*	-0.393*
Days to 50% flowering	rp		1.000	0.545**	0.580**	0.022	-0.266	-0.157	0.168	-0.053	-0.391*	-0.327
	rg		1.000	0.589**	0.627**	0.043	-0.473*	-0.088	0.404*	-0.069	-0.419*	-0.344
Days to first picking	rp			1.000	0.818**	0.276	-0.166	0.084	-0.184	-0.169	-0.371	-0.351
	rg			1.000	0.752**	0.452*	-0.273	0.246	-0.355	-0.317	-0.322	-0.351
Days to last picking	rp				1.000	0.496**	-0.094	0.153	-0.211	-0.421*	-0.437*	0.515**
	rg				1.000	0.624*	-0.098	0.263	-0.353	-0.605**	-0.421*	-0.557**
Plant height (cm)	rp					1.000	-0.052	0.206	-0.473*	-0.442*	-0.056	-0.235
	rg					1.000	-0.032	0.221	-0.780**	-0.547**	-0.073	-0.278
Number of branches per plant	rp						1.000	0.458	-0.228	0.094	0.250	0.225
	rg						1.000	0.978**	-0.411*	0.137	0.432*	0.369
Fruit length (cm)	rp							1.000	-0.311	-0.092	0.185	0.104
	rg							1.000	-0.562**	-0.172	0.130	0.026
Fruit breadth (cm)	rp								1.000	0.127	-0.123	-0.033
	rg								1.000	0.266	-0.375*	-0.195
Fruit weight (g)	rp									1.000	0.331	0.675**
	rg									1.000	0.454*	0.762**
Number of fruits per plant	rp										1.000	0.915**
	rg										1.000	0.924**
Fruit yield per plant (g)												1.000
												1.000

* Significance at 5% level
** Significance at 1% level

Table 2. *Path analysis of different characters at phenotypic (P) and genotypic (G) level in Brinjal*

Characters		Direct effect	Days to initiation of flowering	Days to 50 % flowering	Days to first picking	Days to last picking	Plant height (cm)	Number of branches per plant	Fruit length (cm)	Fruit breadth (cm)	Fruit weight (cm)	No. of fruits per plant	Correlation with fruit yield per plant (g)
Days to initiation of flowering	p	-0.002	-	-0.002	0.073	0.006	-0.002	0.001	0.001	-0.000	-0.036	-0.339	-0.373
	G	-0.053		-0.108	0.132	0.065	0.007	-0.015	-0.015	0.007	-0.089	-0.326	-0.393*
Days to 50% flowering	p	-0.049	-0.02	-	0.044	0.005	-0.000	0.002	-0.001	0.003	-0.022	-0.304	-0.327
	G	-0.043	-0.133		0.094	0.057	0.002	-0.037	0.005	0.057	-0.033	-0.314	-0.344
Days to first picking •	p	-0.001	0.080	-0.070	-	0.006	-0.006	0.001	0.001	-0.003	-0.071	-0.288	-0.351
	G	-0.078	0.160	-0.044		0.068	0.022	-0.021	-0.015	-0.050	-0.151	-0.242	-0.351
Days to last picking	p	0.065	0.008	-0.060	-0.001	-	-0.011	0.001	0.001	-0.003	-0.176	-0.339	-0.515**
	G	0.120	0.091	-0.038	-0.083		0.030	-0.008	-0.016	-0.050	-0.288	-0.315	-0.557**
Plant height (cm)	p	0.004	-0.022	-0.005	-0.000	0.022	-	0.000	0.002	-0.008	-0.185	-0.043	-0.235
	G	0.056	0.048	-0.008	-0.006	0.072		-0.003	-0.013	-0.110	-0.260	-0.055	-0.278
Number of branches per plant	p	0.001	-0.006	0.011	0.001	-0.013	-0.001	-	0.004	-0.004	0.039	0.194	0.225
	G	-0.002	0.078	0.010	0.063	-0.044	-0.009		-0.059	-0.058	0.065	0.324	0.369
Fruit length (cm)	p	-0.003	0.008	-0.005	0.000	0.007	0.001	-0.004	-	-0.005	-0.038	0.144	0.104
	G	0.077	-0.060	-0.013	0.012	0.039	0.024	0.011		-0.079	-0.082	0.098	0.026
Fruit breadth (cm)	p	-0.003	0.016	0.001	-0.000	-0.015	-0.002	0.010	0.001	-	0.053	-0.096	-0.033
	G	0.034	0.141	-0.003	-0.054	-0.057	-0.032	-0.038	-0.032		0.126	-0.281	-0.195
Fruit weight (cm)	p	0.002	0.418	0.007	0.000	-0.014	-0.003	0.010	-0.001	-0.001	-	0.258	0.675**
	G	0.038	0.476	0.010	0.009	-0.051	-0.055	-0.026	0.011	0.010		0.340	0.762**
Number of fruits per plant	p	0.138	0.777	0.033	0.001	-0.030	-0.003	0.001	-0.002	0.001	-0.002	-	0.915**
	G	0.216	0.750	0.023	0.056	-0.052	-0.038	-0.004	0.034	-0.008	-0.053		0.924**

Residual effect – 0.0008954108
* Significant at 5% level
** Significant at 1% level

highly significant correlation with days to last picking. While at genotypic level fruit yield per plant showed negative significant correlation with days to initiation of flowering.

At genotypic level, highly significant and positive correlation was found between days to initiation of flowering and days to 50 per cent flowering, between days to initiation of flowering and days to first picking, between days to initiation of flowering and days to last picking, between days to 50 per cent flowering and days to last picking, between day to first picking and days to last picking and between number of branches per plant and fruit length. Highly significant and negative correlation was found between plant height and fruit breadth, between fruit length and fruit breadth, between days to last picking and fruit weight and between plant height and fruit weight. While characters viz., days to first picking and days to last picking had positive significant correlation with plant height. Days to 50 per cent flowering and number of branches per plant had positive and negative significant correlation with fruit breadth respectively. Days to 50 per cent flowering had negative and significant correlation with number of branches per plant. While, the characters like days to initiation of flowering, days to 50 per cent flowering, days to last picking and fruit breadth had negative and significant correlation with number of fruits per plant. The character, fruit weight had positive and significant correlation with number of fruits per plant.

Path coefficient analysis revealed that (Table 2) the character days to initiation of flowering had negative direct effect on fruit yield at genotypic level. Similar results were also recorded by Vadivel and Kannanbapu (1988) and Tidke *et al.*, (2006). Days to last picking exhibited positive direct effect on fruit yield per plant at phenotypic and genotypic level. The character fruit weight had positive effect of low magnitude at phenotypic and high at genotypic level. Sharma and Swaroop (2000), Mohanty (2001), Singh and Singh (2001) and Tidke *et al.*, (2006) also reported high positive direct effect of fruit weight on fruit yield. The character number of fruits per plant showed high positive direct effect on fruit yield at both level. The similar result were also recorded by Vadivel and Kannanbapu (1988), Ingale and Patil (1995), Mohanty (1999), Sharma and Swaroop (2000), Singh and Singh (2001) and Tidke *et al.*, (2006).

The genotypic correlation coefficients, in general, were greater than their respective phenotypic correlation coefficients. Path analysis at phenotypic and genotypic level reveals the casual relationship between different characters related to yield. On the basis of path analysis and correlation study for fruit yield, it is concluded that selection on the basis of number of fruits per plant, weight of fruit, days to last picking and days to initiation of flowering could help in genetic improvement of fruit yield per plant in brinjal under study.

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J. Indian Soc. Coastal agric. Res., 28(1), 62-64, 2010

Relative Salinity Tolerance of Groundnut Varieties

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A lysimeter experiment was conducted during summer 2007 - 2009 to study the relative salt tolerance and identification of salt tolerant of groundnut varieties. The significant maximum pod yield was recorded under salinity level of irrigation water S_1 (EC 1.0 dSm^{-1}). In case of varieties, GG-4 gave significantly higher pod yield (38.91 g $lysimeter^{-1}$). The highest pod yield was observed in treatment combination of S_1 X V_4 (CG-6). Significantly higher haulm yield (99.00g $lysimeter^{-1}$) was recorded with S1 (EC 1.0 dSm^{-1}). Among the five varieties of groundnut, GG-4 gave significantly higher haulm yield. The significant lowest value of Na/K ratio in pod & haulm were observed under irrigation of S_1 (EC 1.0 dsm^{-1}) level. The lowest value of soil EC at different depth were observed under Tap water irrigation (EC 1.0 dSm^{-1}) and significantly the highest value of soil pH was recorded at saline irrigation level S_3 (EC 4.0 dsm^{-1}) in 0-15 cm soil depth.

***(Key words:** Relative salinity, Genotype, Tap water, Na/K ratio, Soil EC, Soil pH)*

In coastal belt salinity is one of the major constraint for inhibition of the crop growth and production in most of the crops. Interior parts of Saurashtra of Gujarat comes under Saline region. In Gujarat Groundnut is considered to be one of the important crops but there is scarcity of tolerant variety. As we know there are certain plants, which are tolerant to salt, these tolerance varies from species to species, variety to variety. Hence, relative salt tolerance of crops and their varieties/genotypes assume significant importance in increasing the productivity under this problematic soils and irrigation water. Therefore, we have conducted an experiment on Groundnut to find out the tolerant varieties. Keeping this view, a lysimeter study was taken for screening of different groundnut varieties under saline water irrigation.

MATERIALS AND METHODS

The experiment was conducted in Lysimeter during summer 2007 to 2009 with five levels of saline irrigation water (S_1: 1, S_2: 2, S_3: 4, S_4: 6 and S_5: 8 EC dSm^{-1}) and five Varieties of groundnut (i.e.V_1: GG-2, V_2: GG-4, V_3: GG-5, V_4: GG-6 and V_5: TG-26) were selected for the experiment, in completely randomized block design. The saline water of 2.0, 4.0, 6.0 & 8.0 EC dSm^{-1} was prepared by dilution of sea water and irrigated crop as per irrigation schedule. The initial soil with EC $_{1:2.5}$ - 0.36 dSm^{-1}, pH $_{1:2.5}$ -7.45, Ca + Mg (meq/100 g soil) -33.5, Na (meq 100 g^{-1} soil) -1.90 and K (meq 100 g^{-1} soil) -0.55. Recommended dose of N (50.0 kg ha^{-1}) and P_2O_5 (100 kg ha^{-1}) were applied in each lysimeter in the form of Urea and Diammonium phosphate. Ten seed of all five groundnut Varieties were sown in each Lysimeter. Yield of pod and haulm were recorded and representative samples were analyzed for Na & K content (Jackson, 1973). Soil samples were collected from two depth (0-15 & 15-30 cm) after harvest and analyzed for EC & pH.

RESULTS AND DISCUTION

The data (Table 1) revealed that the pod yield of groundnut was significantly influenced by different salinity level in individual as well as in pooled results. The significantly maximum pod yield was recorded under salinity level of irrigation water S_1 (EC 1.0 dSm^{-1}) in individual as well as in pooled results which was at par with S_2 (EC 2.0 dSm^{-1}) in year 2008, 2009 and pooled as well as with S_3 (EC 4.0 dSm^{-1}) in pooled.

In case of varieties, GG-4 gave significantly higher pod yield in individual year as well as in pooled result. The maximum pod yield 38.91 g per lysimeter was obtained by variety GG-4 over that of remaining varieties.

The interaction effect of salinity levels and varieties on pod yield was also found significant. The highest pod yield was obtained in treatment combination of S_1 X V_4 followed by S_1 X V_2, S_2 X V_2, S_1 X V_1 and S_2 X V_4 (Table 2).

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Table 1. *Pod and haulm yield (g pot^{-1}) of groundnut as influenced by salinity levels and varieties of groundnut*

Treatment	Pod yield (glyysimetert^{-1})				Haulm yield (g lysimeter^{-1})			
	2007	2008	2009	pooled	2007	2008	2009	pooled
Salinity level								
S1-EC1	27.39	67.70	53.41	49.40	77.69	130.3	89.00	99.00
S2-EC2	24.11	62.22	53.35	46.56	72.44	112.3	83.00	89.26
S3-EC4	22.29	54.30	36.46	37.68	63.65	100.3	70.80	78.26
S4-EC6	18.83	31.13	23.71	24.55	57.39	67.33	59.00	61.24
S5-EC8	12.25	15.39	12.13	13.26	41.89	61.47	48.00	50.45
S.Em+	0.624	0.710	1.08	5.11	1.13	1.61	1.54	5.17
C.D. @ 5%	1.78	2.01	3.09	15.93	3.21	4.56	4.37	16.14
Varieties								
V1: GG-2	18.21	47.36	32.98	32.84	68.09	102.7	74.80	81.55
V2: GG-4	28.27	48.22	40.25	38.91	70.33	107.3	76.33	84.66
V3: GG-5	18.68	42.13	37.84	32.88	67.49	99.66	74.00	80.39
V4: GG-6	24.52	47.46	39.85	37.27	69.07	104.3	76.00	83.14
V5: TG-26	15.18	45.56	27.83	29.52	38.07	57.80	48.67	48.18
S.Em+	0.624	0.710	1.08	1.79	1.31	1.61	1.54	2.66
C.D. @ 5%	1.78	2.01	3.09	5.58	3.21	4.56	4.37	8.32
C.V.%	11.53	5.95	11.70	9.40	6.99	6.60	8.51	7.38
Inter. S x V	NS	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.

Table 2. *Interaction effect of salinity levels and varieties on pod yield (g lysimetert^{-1}) – pooled*

Variety/salinity level	V_1 GG-2	V_2 GG-4	V_3 GG-5	V_4 GG-6	V_5 TG-26	S.Em.±	C.D.@ 5%
S_1: EC_1	49.93	55.16	47.10	55.68	39.12		
S_2: EC_2	44.20	52.34	46.80	47.78	41.68		
S_3: EC_4	37.79	42.10	35.38	38.92	34.23	3.00	9.12
S_4: EC_6	23.20	28.54	23.19	26.72	21.11		
S_5: EC_8	9.12	16.42	11.96	17.28	11.50		

The data presented in Table 1. indicated that the haulm yield of groundnut was also affected significantly by salinity levels in individual year and pooled results. Significantly higher haulm yield 99.00 g lysimeter^{-1} was recorded with S1 (EC 1.0 dSm^{-1}). Among the five varieties of groundnut, GG-4 gave significantly higher haulm yield in individual years as well as in pooled results. The highest haulm yield was recorded with variety GG-4 (84.66 g pot^{-1}) which was at par with V_4: GG-6, V_1: GG-2 and V_3: GG-5.

The interaction effect of salinity and varieties on haulm yield was also found significant in pooled results (Table 1). Significantly highest haulm yield (119.66 g pot^{-1}) was observed in treatment combination of S_1 X V_4 followed by S_1 X V_2 and S_1 X V_1 in pooled results (Table 3).

The Na/K ratio in pod and haulm of groundnut significantly affected by various salinity levels of irrigation water in pooled results (Table 4). The significantly lowest value was observed under irrigation water of S_1 (EC 1.0 dSm^{-1}) level. As salinity increased, the Na/K ratio also increased in pod and haulm of groundnut. The lowest Na/K ratio in haulm observed with variety V2: GG-4 as compared to remaining varieties whereas Na/K ratio in pod was found non-significant when pooled over years.

The data presented in table 5 depicted that the EC value of different soil depths (0-15 and 15-30 cm) were significantly influenced by various levels

Table 3. *Interaction effect of salinity levels and varieties on pod haulm (g lysimetert^{-1}) - pooled*

Variety/salinity level	V_1 GG-2	V_2 GG-4	V_3 GG-5	V_4 GG-6	V_5 TG-26	S.Em.±	C.D.@ 5%
S_1: EC_1	106.85	114.64	94.97	119.66	58.90		
S_2: EC_2	93.84	95.05	103.95	99.81	53.62		
S_3: EC_4	87.37	89.55	80.92	86.50	46.94	5.64	16.26
S_4: EC_6	65.83	70.43	67.03	60.55	42.34		
S_5: EC_8	55.34	53.64	55.04	49.14	39.08		

Table 4. *Na/K ratio in groundnut pod and haulm at harvest as influenced by salinity levels and varieties of groundnut (-pooled)*

Treatment	Na/K ratio	
	Pod	Haulm
Salinity level		
S_1-EC_1	0.19	0.66
S_2-EC_2	0.38	0.66
S_3-EC_4	0.63	0.91
S_4-EC_6	0.75	0.93
S_5-EC_8	0.85	1.11
S.Em±	0.054	0.049
C.D. @ 5%	0.18	0.16
Varieties		
V_1: GG-2	0.57	0.87
V_2: GG-4	0.54	0.79
V_3: GG-5	0.60	0.86
V_4: GG-6	0.54	0.82
V_5: TG-26	0.54	0.93
S.Em±	0.018	0.041
C.D. @ 5%	NS	0.12
C.V.%	6.11	5.75
Inter. S x V	NS	NS

of saline irrigation water in pooled results Significantly the lowest value of EC at different depth of soil were recorded under Tap water irrigation i.e. S_1 (EC 1.0 dSm^{-1}). In general the EC values of soil at both the depths, increased with increase in salinity levels of irrigation water. Soil EC of two depths did not affected significantly by varieties of groundnut in pooled results, Interaction effect was also found non-significant on soil EC of different depths.

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J. Indian Soc. Coastal agric. Res., 28(1), 65-70, 2010

Optimal Cropping Pattern for Coastal Areas of South Konkan Region of Western Maharashtra: A Linear Programming Approach

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The irrigation planning is essential component of water management in irrigated agriculture. In the present study, the linear programming (LP) model is developed for the evaluation of irrigation development strategy under coastal conditions and applied to the case study of Natuwadi medium irrigation project, in South Konkan region of Western Maharashtra, India, with objective of maximization of net benefits. Uncertainty in the inflow arising due to changing climatic conditions and other uses of water is tackled through chance constrained (stochastic) programming. The inflows at five levels of availability viz.70%, 80%, 90%, 100% and 110% were considered in the present study, to obtain various possible optimal cropping pattern and optimal operating policies. It was observed that, net benefit of Rs 130.5 million were obtained at 110% water availability levels which was 42% more than 70% availability levels. Comparison of result indicated that, the methodology is quite versatile and can be used in other similar situations, as well, with suitable modifications.

(***Key words:*** *Irrigation planning, Linear programming, Cropping pattern, Net benefit.*)

Water is one of the major and basic natural resource, on the basis of which each individual command area project should be planned, its judicious use is key to the to the well-being of the people in any area. The irrigation planning is essential component of water management in irrigated agriculture and involves consideration of other resource inputs including land area, seed, fertilizer, labour and power etc.

The Konkan region of Maharashtra having an area of 30,394 sq.km and has coast length of 720 km. The irrigated area in the region is only 4.5%. Hence, there is need of proper planning of the irrigation systems in the coastal areas. The assessment and the use of available inputs can be better planned by following some modelling techniques and ultimately by increasing the net benefits of the farmers. Rice is the main crop in the *kharif* season and during rest of period fields remain dry. The crops in the Rabi and Summer season can be planned on the basis of inputs like land area, water availability, labour, finance etc. by using linear programming (LP) models. An attempt is made here for integrated analysis of the system and giving the proper plan of agriculture development aiming to increase the financial status of the farmers of the coastal region. Natuwadi irrigation project of Konkan region of Western Maharashtra was constructed in the year 1983-84 to utilize the flow of Choriti river. At present, no irrigation planning is being followed for crop production in the command area, due to social problems and also uncertain inflow into the dam. In view of this, it is proposed to develop a linear programming model for irrigation planning for determining optimal cropping pattern and reservoir release. The model is subjected to number of constraints such as water requirement, area, production, labour etc.

Linear Programming (LP) technique is widely used by many researchers for irrigation planning problems for real case studies. Lakshmi Narayan and Rajagopalan (1971) used LP model for maximizing and irrigation benefits for Bari basin in Northen India. Sensitivity analysis on tubewell capacity, the area available for irrigation, the operation costs for canals and tube wells etc. are also carried out. Venkatesen and Ramlingam (1980) applied LP technique to plan the area under irrigation in the command area of Bhadar Project to obtain optimum benefits. Loucks *et al.*, (1981) discussed in detail the micro level planning with a detailed example. Multi objective analysis is also reported in their studies. Sethi *et al.*, (2002) developed a linear programming optimization model for optimal cropping pattern and groundwater management model for maximizing economic return. The developed models were applied to apportion of coastal river basin in Orrissa state, India and

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optimal cropping pattern for various scenarios of river flows. Cheng Yun *et al.*, (2008) proposed a linear programming model to study the consumptive use of surface water and groundwater for optimum water allocation in Taiwan. Azamhathullha (2009) developed a linear programming model and applied to real time reservoir operation in an existing Chiller reservoir system in Madhya Pradesh, India. The developed model can be successfully applied to irrigation supporting reservoir systems.

MATERIALS AND METHODS

In the present study, a LP model was formulated for arriving at an optimal cropping pattern for Natuwadi Project in South Konkan region of Western Maharashtra. The model was solved for different availability levels of inflows viz.70%, 80%, 90%, 100%, and 110% to obtain various possible cropping patterns.

Study area

Natuwadi project is the state sector medium irrigation project on Choriti river, situated in southern Konkan region of Ratnagiri district of Maharashtra, India between the latitude 17°50′ N and 73°24′ E. The salient features of Natuwadi Project are presented in the Table 1.

Inflow data

The daily inflow data for 20 years i.e. from 1988 to 2007 for Choriti river at Natuwadi dam site were collected from the office of the Irrigation Department. The average monthly inflow discharges were obtained by adding up daily inflows and used for model building. The total annual inflow was then calculated from the collected data. The water year was considered from June to May, with June, July, August, September and October as wet season and November to May as dry season.

Table 1. *Salient features of Natuwadi Medium Irrigation Project*

Sr. No.	Particulars		Value
1.	Location	:	Village -Natuwadi, N.H. 17, Tal-Khed, Dist-Ratnagiri, Maharashtra, India.
2.	Type of dam	:	Earthen dam with masonry gated spillway on left bank.
3.	SOI Toposheet No.	:	47/G-5 and 6
5.	Catchments area	:	16.32 sq. km.
6.	i) Mean annual rainfall	:	3632 mm
	ii) Average annual runoff	:	49.98 M cum.
	iii) 75 % dependable runoff	:	36.3 M cum.
7.	Dam and Reservoir		
	i) Gross capacity of reservoir	:	28.08 M cum.
	ii) Capacity of dead storage	:	0.85 M cum.
	iii) Capacity of live storage	:	27.23 M cum.
	iv) Evaporation losses	:	2.21 M cum.
	v) Area under submergence at FRL	:	217.2 ha.
	vi) Max. height of dam	:	45.27 m
	vii) Total length of dam	:	900 m
8.	Canals		
	i) Length of canal	:	Left bank canal, 12 km. Right bank canal, 24 km.
	ii) Discharge at head	:	Left bank canal, 0.88 cum./sec Right bank canal, 5.66 cum./sec
9.	Commanded area		
	i) Gross commanded area	:	2343 ha.
	ii) Cultivable area	:	2006 ha.
	iii) Irrigable area	:	2050 ha.
	iv) Cropped area	:	4621 ha.
10.	Intensity of irrigation to gross commanded area	:	76.17 %
14.	Benefit cost ratio	:	1.74 : 1

The statistics of the monthly inflow are presented in Table 2. From the Table 2, it can be observed that 95% percent of annual inflow occurs during the months June to October. There was no major variation in the standard deviation. There is no major variation in skewness and kurtosis coefficients. Therefore, the distribution of inflow in each month may be assumed same.

The climate of the area is characterized by humid sub-tropical monsoon with three-district season i.e. summer (March to May), rainy (June to October) and winter (November to February). According to agro climatic zones of Maharashtra, the Ratnagiri district comes under high rainfall zone with lateritic soil type. On an average annual precipitation of 2800 to 3500 mm is received, of which about 95% of the rainfall occurs during June to October. During rainy season, the humidity is as high as 90 to 98 per cent. It is least during winter afternoon; sometimes it may come down to about 60 per cent at many places. The mean daily maximum and minimum temperatures varies between 300C to 230C, respectively. The soils of the study area are literatic, moderately fine textured and well drained. The soils are having acidic reaction (pH = 4.75 to 6.50). The CEC ranges between 8.1 to 23.55 m/100 gm of soil. The soils are medium to low in available nitrogen, low in phosphorus and medium to high in available potassium content. The lateritic soils are dominant in the region having field capacity of 28 % and wilting point of 17.4 %. The basic infiltration rate is 4.4 to 7.7 cm/hr having soil depth of 30 to 100 cm (Annonymous, 1990).

The major crops grown in the command area are *Rabi* rice (Jan to April), banana (Oct to June), sugarcane (Oct to June), groundnut (Nov to April), watermelon (Nov to March) and chilli (Nov to March). Monthly water requirements for crops grown in the command area were worked out considering 75 per cent dependable rainfall for effective rainfall computation, based on the guidelines given by the Water Management Division (1971) and are listed in Table 3. The computations of net benefit in rupees per hectare for each crop was worked out based on data collected from the site and are given in Table 4. Storage at different availability levels was calculated and reported in Table 5.

Table 2. *The statistics of the monthly inflows*

Month	Mean M cum	Standard deviations M cum.	Variance s^2	Coefficient of Variation c.v.	Coefficient of Skewness C_s	Kurtosis	Lag one serial correlation coefficient r_1
June	5.41	3.43	11.76	0.63	1.86	2.88	0.136
July	15.39	3.62	13.12	0.23	-1.058	0.154	0.184
Aug.	23.07	1.73	3.0	0.075	-0.82	0.41	0.571
Sept.	27.05	2.10	4.39	0.077	-3.57	13.95	0.917
October	27.28	1.74	3.03	0.064	-3.24	11.34	0.945
Annual	98.20	6.61	43.68	0.067	0.44	1.87	0.196

Table 3. *Monthly crop water requirement (mm)*

Months	Rabi rice	Banana cane	Sugar-nut	Ground-melon	Water-Chilli	Green	Brinjal	Cucumber	Tomato	Fodder maize	Total
Janua.	294	49	39	100	95	84	109	114	122	78	1084
Feb.	327	58	56	99	105	116	161	140	140	132	1334
March	335	81	185	130	32	138	175	166	168	190	1600
April	156	119	188	116	-	-	-	-	176	-	755
May	-	155	191	-	-	-	-	-	-	-	346
June	-	48	47	-	-	-	-	-	-	-	95
July	-	-	-	-	-	-	-	-	-	-	-
August	-	-	-	-	-	-	-	-	-	-	-
Sept.	-	-	-	-	-	-	-	-	-	-	
Octo.	-	113	121	-	-	-	-	-	-	-	234
Nove.	-	106	102	14	14	24	-	-	-	-	260
Dece.	343	47	78	45	52	68	75	80	64	-	852
Total	1455	776	1007	504	298	430	520	500	670	400	6560

Table 4. *Details of net benefit from crops*

Sr. No.	Crop	Yield qt ha^{-1}	Average price, Rs qts^{-1}	Market Value Rs ha^{-1}	Cost of cultivation Rs ha^{-1}	Net benefit Rs ha^{-1}
1.	Rabbi Rice					
	1. Paddy	40	580	23200	18808	8392
	2. By produce	40	100	4000		
2.	Banana	300	600	180,000	99069	80931
3.	Sugarcane main produce	1000	100	10,0000	42137	62863
	By produce					
4.	Groundnut main produce	20	1600	32000	19269	15931
	By produce	40	80	3200		
5.	Watermelon	150	500	75000	44068	30932
6.	Green Chilli	100	1500	150000	35131	1,14,869
7.	Brinjal	200	600	12000	37627	82373
8.	Cucumber	200	800	16000	35406	1,24,594
9.	Tomato	100	100	100000	64063	35937
10.	Maize for Fodder	420	100	42000	29357	12643

Table 5. *Storage at different availability levels, ha-cm*

Gross storage	Availability levels (%)				
	70	80	90	100	110
1,18,700	83,090	94,960	1,06,830	1,18,700	1,30,570

Linear Programming (LP)

Brief details about linear programming and its application (mathematical modelling) to the present case are discussed below.

Linear Programming (LP) deals with that class of programming problems for which the constraints as well as the function to be optimized are linear relations among the variables. When the resources are scarce, there is a need for allocation of limited resources to priorities or activities. This technique is used either to maximize or minimize a given objective function. The solution to the linear programming (LP) model was obtained using simplex method with a TORA computer Software.

In a more convenient matrix notation, a typical LP problem (Maji and Heady, 1980) can be written as,

$$\text{Max/(Min) } Z = C^T x \quad \text{.... (1)}$$

Subject to the constraints

$$Ax \geq B \quad \text{.... (2)}$$

$$\text{and } x \geq 0 \quad \text{.... (3)}$$

Where, C is a (nx1) vector known constant,

x is a (nx1) vector of decision variables,

A is a (mxn) matrix of known constant and

B is a (mxn) vector of constants

The problem is to find a set of x, the decision variables, that maximize (or minimize) the objective function Z (Eq. 1) and satisfies the equation 2 and 3.

Assumptions

Various assumptions were considered in developing the model.

(1) The relationship between the variables in the objective function and the constraints are linear. (2) All parts of the land under consideration are put to the same management practices. (3) Soil of the project area is homogenous. (4) Time and period of crop sown is same in every year. (5) Crop yield considered is same throughout the command area in spite of variation in management practices.

The model has been developed considering the stochastic nature of the inflows to the dam. The model was solved for different storage water availability levels of inflows viz.70%, 80%, 90%, 100% and 110% to obtain various cropping pattern.

Objective function

1. The objective function has been formulated to allocate land resource for the existing crops, so as to maximize the net benefit and is given by:

$$\text{Max}Z = \sum_{j=1}^{12} B_j A_j \quad \text{.... (4)}$$

Table 6. *Area allotted to the different crops and net benefit from the planning model at different water availability levels*

Sr No.	Crop	Unit	Solution for maximization of net benefit at availability levels				
			110%	100%	90%	80%	70%
1.	Rabi rice	ha	36.5	36.5	36.5	36.5	36.5
2.	Banana	ha	1214.33	1018.6	823.0	627.35	431.7
3.	Sugarcane	ha	50.0	50.0	50.0	50.0	50.0
4.	Groundnut	ha	273.5	273.5	273.5	273.5	273.5
5.	Watermelon	ha	10.0	10.0	10.0	10.0	10.0
6.	Chilli	ha	45.0	45.0	45.0	45.0	45.0
7.	Brinjal	ha	32.8	98.1	163.3	228.5	293.7
8.	Cucumber	ha	50.0	50.0	50.0	50.0	50.0
9.	Tomato	ha	5.0	5.0	5.0	5.0	5.0
10.	Maize for fodder	ha	127.6	127.6	127.6	127.6	127.6
	Net benefit (million rupees)		130.5	120.0	109.5	99.1	88.64
	Total area	ha	1844.73	1834.3	1583.9	1453.45	1323.0

Where, Z = Net benefits from the command area (Rs.)

Bj= Net benefits from jth crop (Rs. ha^{-1})

Aj= The area under jth crop in the command (ha)

Constraints

The objective function is subjected to the following constraints:

(i) *Capacity constraints*

The storage in the dam at any month should not exceed the maximum storage, Smax and storage should be greater than dead storage, Smin for all months.

$$S_t \leq S_{max}, t = 1, 2, \ldots\ldots, 12$$

$$S_t \geq S_{min}, t = 1, 2, \ldots\ldots, 12$$

Where, S_t represents storage in the dam at time t (ha-cm).

(ii) *Water requirement constraints*

The release in each month should be greater than or equal to the amount of water needed in that month.

$$Rt - \sum_{i=1}^{m} \sum_{j=1}^{n} CWR_{jt}.A_{ij} \geq 0 \quad t = 1,2,\ldots\ldots,12 \quad \ldots(5)$$

Where, Rt represents release from the dam during month t (ha-cm) and CWR_{jt} represents crop water requirement for the crop j during the month t.

(iii) *Continuity constraints*

The continuity equation can be written as follows:

$$S_{t+1} = S_t + I_t - R_t - E_t - PL_t \quad t = 1,2\ldots12 \quad \ldots(6)$$

Where, S_t = Storage in the dam at time t

S_{t+1} = Storage in the dam at time t +1

I_t = Inflow into the dam at time interval Δt.

R_t = Release from the dam at time interval Δt.

E_t = Evaporation from the dam at time interval Δt.

PL_t = Percolation losses from the dam at time interval Δt.

In the above equation the combined evaporation and percolation losses are assumed to be 15% of the average storage for the period ?t as suggested by Loucks et al. (1981). The time period ?t is taken as a month in this model.

$$E_t + PL_t = 0.15\ [(S_t + S_{t+1})/2] \quad \ldots(7)$$

(iv) *Land availability constraints*

The sum of area under each crop should not exceed the total available land. This can be represented by the following equations.

$$\sum_{j=1}^{n} A_{ij} \leq A_i \quad i = 1, \ldots\ldots, m \quad \ldots(8)$$

Where, Ai represents total available land in the command of ith canal (ha).

RESULTS AND DISCUSSION

Optimization of objective function was performed with a linear programming (LP) model. Storage at different availability levels is shown in Table 5. Area allocated to different crops and net benefits from the planning model form the command area of Natuwadi Project is shown in Table 6, so as to maximize the net returns.

The maximum total area of 1844.73 ha was allocated at 110 % water availability level, which goes on decreasing as 1834.3, 1583.9, 1453.45 and 1323 ha at 100 %, 90 %, 80 % and 70 % water availability levels, respectively.

In between the area allocated to individual crops, maximum area was allocated to banana crop, as it is most renemurative crop. Rice crop was allocated the restricted area of 36.5 ha, as it was not profitable and needs more water. However, due to sustainability constraint in coastal area, rice has taken the minimum area, which was necessary to meet the staple food requirement of the existing population. Sugarcane takes the more area than rice, as this is annual crop. Though, the returns from sugarcane are more, due to the non-availability of sugar factories in the nearby locality, area under sugarcane has not gone up much. Groundnut crops are now gaining popularity in Konkan region. Hence this crop was introduced for meeting the oil requirement of existing population.

As regards to number of bullocks and buffalos, it is necessary to have 2100 bullocks for performing various farming operations and 800 buffalos, which are giving additional returns of Rs.4 millions from milk and F.Y.M. production in the area. For meeting the feed requirement the fodder maize is introduced in the command.

The other vegetable crops like water melon, chilli, brinjal, cucumber and tomato have been introduced not only for meeting the nutritional requirement of the population but also due to the vicinity of Mumbai-Goa highway to the command population and this provides a good market avenue for the area.

Table 6, also gives the net returns from allocated area. It is observed that the maximum net benefits of Rs. 130.5 millions are obtained in 110% water availability level indicating the importance of water availability from the point of view of receipt generation. The maximum net benefits gets decreased as Rs. 120 million, Rs. 109.5 million, Rs. 99.1 million and Rs. 88.64 million at 100%, 90%, 80% and 70% water availability, respectively in the command area (Singh *et al.*, 2001).

Based on the analysis of the results following conclusions are drawn,

First, Irrigation plan for 110 % availability level with maximum net benefits of 130.5 millions rupees can be implemented in the command area; second, Optimum irrigation plan for 100% water availability levels with net benefit of 120 million rupees can be implemented in the coastal region for general planning level; third, Net benefit at 110% water availability level is 42.5% more than 70% availability level; fourth, Banana crop appears to provide the most consistent profit in the command area; and finally, Comparison of results indicates that, the methodologies are quite versatile and can be used in other similar situations with suitable modifications.

The authors are thankful to the Irrigation Department, Govt. of Maharashtra, for providing necessary data.

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J. Indian Soc. Coastal agric. Res., 28(1), 71-74, 2010

Genetic Parameters in F_3 Population of Brinjal (*Solanum melongena* L.) in Coastal Region of Maharashtra

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An experiment was carried out in F3 population of brinjal consisted of seven F_3 families with four progenies of each family and six parents of brinjal (*Solanum melongena* L.). Estimates of phenotypic and genotypic variances revealed that the character fruit yield per plant showed maximum phenotypic as well as genotypic variances, whereas number of branches per plant recorded the least phenotypic and genotypic variance. Estimates of phenotypic and genotypic coefficient of variation were higher for fruit yield per plant, number of fruits per plant, fruit length fruit breadth, weight of fruit and days to initiation of flowering. While plant height and days to last picking showed minimum coefficient of variation at both levels. The highest heritability was recorded for the character number of fruits per plant. The highest values of genetic advance was recorded for fruit yield per plant. High heritability values and high percentage of genetic advance were recorded in case of number of fruits per plant, fruit length, fruit yield per plant, days to last picking, fruit weight and days to 50 percent flowering.

(Key words: Phenotypic and, genotypic variance, Pphenotypic and genotypic coefficient of variation heritability, Genetic advance, F_3 population, Brinjal.)

Yield is the ultimate criterion, which a plant breeder has always to keep in view while evolving improved types of crop plant. However, fruit yield is the most complex character governed by polygenes. It is generally difficult to select for such a complex character directly. Therefore, greater variability among character is pre-requisite. Hence, the extent of genetic variability present in the material is of vital importance in formulating effective selection programme. Hence, study was under taken in F_3 population of brinjal.

MATERIALS AND METHODS

The experimental material consisted of seven F_3 families (Arka Nilkanth x CHES 309, Arka Nilkanth x BB-60-C, CHES-309 x BB-64, CHES-309 x IIHR-7, CHES-309 x BB-60-C, CHES-309 x BDIRT and BB-60-C x BB-64) with four progenies of each family and six parents were grown in compact family block design as suggested by Singh and Singh (1994) with three replications at Botany Farm, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli during *Rabi* 2006-07. About 45 days old seedlings were planted on a well prepared plot at 60 cm x 60 cm spacing. The plot size was 3 x 1.80 m. Each progeny had 15 plants per plot, thus constituting 45 plants per progeny in three replications. The experiment was conducted at normal fertility level on lateratic loam soil. Fertilizers at the rate of 150 kg nitrogen, 50 kg phosphorus and 50 kg potash per hectare in the form of urea, single super phosphate and murate of potash were applied. One third dose of nitrogen and full dose of phosphorus and potash were applied at the time of transplanting and remaining dose of nitrogen was applied in two equal splits of an interval of one month. The plot was irrigated at an interval of 7 days. The observations were recorded on eleven characters from five randomly selected plants per progeny and their parents per replication and their means were computed and utilized for statistical analysis.

The environmental, phenotypic and genotypic variances were calculated by utilizing the respective mean. The genotypic and phenotypic coefficients of variations were calculated as per the Burton and De vane (1953). Heritability in broad sense estimated as suggested by Lush (1949). The genetic advance was calculated in per cent by the formula suggested by Johnson *et al.*, (1955).

RESULTS AND DISCUSSION

The characteristic of fruit yield per plant has maximum phenotypic variance followed by days to last picking, fruit weight, days to first picking, days to initiation of flowering and days to 50 per cent flowering. The genotypic variance was maximum for the characters of fruit yield per plant followed by days to last picking, fruit weight, days to first picking, days to 50 per cent flowering and days to

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Table 1. *Variability parameters between families for different characters in Brinjal.*

Sr. No.	Character	σ^2 g	σ^2 p	σ^2 e	GCV (%)	PCV (%)	h^2b (%)	GA	GAM (%)
1	Days to initiation of flowering	24.782	56.805	32.023	10.44	15.80	43.62	6.77	14.19
2	Days to 50% flowering	28.128	46.828	18.700	8.82	11.38	60.07	8.46	14.08
3	Days to first picking	29.291	60.216	30.925	8.73	12.53	48.64	7.77	12.54
4	Days to last picking	86.154	117.077	30.924	7.14	8.28	73.58	16.40	12.55
5	Plant height (cm)	5.262	5.667	0.405	3.96	4.11	92.85	4.55	7.84
6	No. of branches /plant	0.183	0.799	0.616	8.87	18.54	22.90	0.42	8.71
7	Fruit length (cm)	5.202	6.349	1.147	17.61	19.47	81.93	4.25	32.83
8	Fruit breadth (cm)	0.460	1.167	0.706	14.99	23.88	39.42	0.87	19.23
9	Fruit weight (g)	78.568	113.959	35.391	11.99	14.45	68.94	15.16	20.51
10	Number of fruits per plant	3.788	5.206	1.418	22.33	26.18	118.15	3.42	39.24
11	Fruit yield per plant (g)	34557.410	45327.850	10770.440	28.53	32.68	76.24	334.36	51.32

initiation of flowering. High values of genotypic and phenotypic variance for fruit yield per plant, fruit weight and low for fruit length, number of branches per plant, fruit breadth and number of fruits per plant were reported by Vadivel and Kannanbapu (1993) and Singh and Kumar (2005).

The highest GCV and PCV were recorded for the character fruit yield per plant, number of fruits per plant, fruit length, fruit breadth, fruit weight and days to initiation of flowering. Highest PCV and GCV were also observed for weight of single fruit and total fruit yield by Gopimony *et al.*, (1984), also for fruit length, diameter of fruits and yield of fruits by Behera *et al.*, (1999), for number of fruits per plant and yield per plant by Singh and Gopalkrishnan (1999), for number of fruits per plant, yield per plant and fruit weight by Baswana *et al.*, (2002), and for average fruit weight and number of fruits per plant by Singh and Kumar (2005).

The high haritability estimates were exhibited by characters, number of fruits per plant, plant height, fruit length, fruit yield per plant, days to last picking, fruit weight and days to 50 per cent flowering. Similar results were also reported for average fruit weight by Kalda *et al.*, (1988) and for fruit yield per plant by Vadivel and Kannanbapu (1993). Fruit yield per plant recorded high heritability with high genetic advance. Similar results also reported by Vadivel and Kannanbapu (1989). High heritability coupled with high genetic advance as per cent of mean recorded for fruit yield per plant. Similar results were also recorded by Rajput *et al.*, (1996), Behera *et al.*, (1999), Negi *et al.*, (2000) and Singh and Kumar (2005). Plant height manifested high heritability coupled with low genetic advance. Similar results were also observed by Mohanty (2002) and Choudhary and Pathania (1999).

The phenotypic variance was more than genotypic variance. The character fruit yield per plant showed maximum phenotypic as well as genotype variance. The character showed varying percent of coefficient of variation both at phenotypic and genotypic level. High heritability and high percentage of genetic advantage were recorded for number of fruits per plants fruit length, fruit yield per plant days to last picking & fruit weight which indicated the additive factors for these characters and further improvement in the yield could be brought by selection.

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J. Indian Soc. Coastal agric. Res., 28(1), 75-78, 2010

Role of Mangrove Plants in Phytoremediation of Kolkata Sewage

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The city sewage of Kolkata drains at the rate of 1100 MLD (Million Litres per Day) without any treatment, east ward towards Sundarban. While about 25% of the Kolkata sewage is utilized within East Calcutta wetlands for fresh water fisheries, garbage gardening and agro-pisciculture, rest, being a mixture of domestic and industrial wastes, is drained untreated to Sundarban. The outfall is at Ghusighata where the sewage mixes with the Sundarban creek Kultigungue. The wastewater is loaded with chromium from tanneries, besides lead, mercury, cadmium etc. from battery and other industries.

Apparently down to few kms from outfall, these pollutants caused zooplankton mortality. The river sediments of the upper estuary exhibited enrichment of heavy metals (Cr, Hg, Pb, Cd), while waters of the Sundarban rivers were apparently free from pollutants. This might be attributed to self-detoxication of sewage during travel downstream, and phytoremediation by the mangrove plants. Down to 5 Km distance from the outfall at Ghusighata, zooplankton population was scanty and bioaccumulation of heavy metals took place within the mudflat Fiddler crab (Uca rosea). Interestingly, maximum accumulation of heavy metals like Cr, Pb, Zn and Cd was observed in mangrove plants Acanthus ilicifolius and Sonneratia caseolaris, and edible alga Enteromorpha intestinalis.

***(Key words:** Phytoremediation, Bioaccumulation, Detoxication)*

Kolkata city discharges its major sewage load into the Sundarban ecosystem at the rate of 1100 MLD (Million Litres per day). The sewage flows eastward through the DWF (Dry Weather Flow) channel which originates from Topsia Point meeting Kultigangue creek of Sundarban. This part, during monsoon the excess flow courses through a parallel canal called SWF (Storm Water Flow Canal). Reportedly, about 75% of the city's waste water flows to Kultigangue river of Sundarban through above combined sewer system of DWF and SWF channels. Balance 25% is utilized in the East Calcutta Wetland's 'wise use' system of converting waste to wealth that comprises of Sewage fed fisheries, Garbage gardening and Agro-pisciculture[2]. Zooplankton density of sewage waters at the outfall point is extremely meager.

MATERIALS AND METHODS

Measurements were made at various points downstream of Ghusighata outfall, at 1st km, 5th km, and 10th km distances for the (a) surface water, (b) leaf/stem/roots of the true mangrove plant *Sonneratia caseolaris*, and minor mangrove element *Acanthus illicifolius*, (c) algal macrophyte *Enteromorpha intestinalis*, (d) Fiddler crabs (*Uca rosea*) of mudflats and (e) benthic soil[2].

Sampling Methodology

The materials which might contain the heavy metals were sampled from 4 different points mentioned above. Following materials were sampled for analysis.

1. Surface water within 2 m from the shore in order to get the maximum pollution load.
2. Crab samples of sediments of Kultigangue river within 2m of the shore lines.
3. Samples of periphytic algae from mud flats and sewage-fed prawn farm.
4. Samples of root, stem and leaves of 2 species of mangrove[3], namely *Sonneratia caseolaris, Acanthus ilicifolius.*
5. Samples of fiddler crab (3 numbers) specimens were collected at the 5th Km downstream of the outfall point.
6. Samples of benthic soil were collected from outfall point, 1st km, 5th km, 10th km.

Procedure for Analysis of Heavy Metals of plant materials and sediments

Organic matter present in the sample is destroyed by dry ash process. 10 gm of accurately weighed sample is taken in a silica crucible and it is placed in a muffle furnace at 550°C for 4 hours. The ashes of the sample are then quantitatively transferred into a conical flask. 25 ml of 1:1 HNO_3 is added. Heating is continued until digestion is complete as shown by a light coloured, clear solution. Then it is filtered through Whatman filter paper No. 42 and portions of this filtrate are taken

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for required metal determinations by AAS from a 50 ml volumetric flask.

Heavy metals determination of surface Water was made by nitric acid digestion followed by Absorption Spectrophotometric Method[5].

Heavy Metals Determination of fiddler crab was made by nitric acid - perchloric acid digestion followed by Absorption Spectrophotometric Method[5].

RESULTS AND DISCUSSION

Linear Regression Analysis was done where maximum absorption in each species has been considered as response variable in the analysis.

Only the following significant results ($p<0.05$) have been considered :

For the species *Sonneratia caseolaris-*

a. Chromium absorption

The regression equation is –

y = 14.0-1.14x (based on 11 Nos. of observations being 3,3,3,2 for 4 sampling points with SE = 1925, 2, 1, 0.8 downstream wards)

where x = distance in km i.e. 0 km, 1km, 5km, 10km, and y = absorption (ppm in dry matter)

R^2 = 82.6%

Rate of Cr absorption is decreasing downstream.

b. Lead absorption

The regression equation is-

y=7.76+0.265X (based on 11 Nos. of observations being 3,3,3,2 for 4 sampling points with SE = 1.2, 1.2, 1.8, 1.4 downstream wards)

R^2=78.5%

Rate of Pb absorption is increasing downstream due to lack of plant utilization as evident from result increase in the sediments (ref. Table-3). No absorption was noticed upto leaf end of the ascent of sap.

c. Cadmium absorption

The regression equation is-

Y = 1.23-0.0910X

(Based on 11 Nos. of observations being 3,3,3,2 for 4 sampling points with SE = 0.1,0.3,0.2, 0.06 downstream wards)

Rate of Cd absorption is decreasing downstream.

R^2=85.8%

R^2 value gives a higher order correlation being the square of "Pearson" correlation coefficient R, which itself is significant at 5% level of probability.

No significant trend could be found out for the absorption of zinc.

B. For the species *Acanthus ilicifolius*

No significant trend could be found out for Cr, Pb, Zn and Cd .

From the above statistical analyses, it is apparent that in case of *Sonneratia caseolaris* absorption of Cr (R^2 = 82.6%) and Cd (R^2 = 85.8%) significantly decreases in the plant species with increase in distance from outfall whereas absorption of Pb (R^2 = 78.5%) significantly increases in the plant species with increase in distance from outfall.

It is noticed that highest absorption of Cr took place in the leaves of Sonneratia caseolaris (10.02 ppm) which speaks for successful physiological utilization of the heavy metal by the true mangrove plant. Normally the root zone accumulation of heavy metal is common in most of the plants. But substantial absorption in the leaf and stem indicates physiological utilization of pollutants resulting in biomass development. In fact, *S.caseolaris* flourish near outfall zones. Such species richness is an important parameter for biological monitoring[6].

Table 1. *Surface Water Parameters*

Sl. No.	Parameters in ppm	Ghusighata 0 km	Brick field of ghusighata 1 km	Malancha 5 km	Hatgachhi 10 km
2	Lead	Nil	0.40*	0.05	0.03
3	Cadmium	<0.01	<0.01	<0.01	<0.01
4	Zinc	0.062*	0.046	0.029	Nil
5	Total Chromium	0.08	0.16	0.39*	0.08
6	Cod	112*	80	80	52
7	Initial Do	1.0	1.1	1.4	3.7*
8	Bod	5.6*	5.2	4.8	4.2

Table 2. *Estimation of Heavy Metals in plant parts*

Sl. No.	Description of Sample	Type of Sample	Chromium (as Cr) ppm in dry matter	Lead(as Pb) ppm in dry matter	Zinc (as Zn) ppm in dry matter	Cadmium(as Cd) ppm in dry matter
	0 Km -Ghusighata					
1	*Sonneratia*	Leaf	2.89	4.32	15.56	1.06*
2	*Sonneratia*	Stem	3.45	2.76	10.51	0.64
3	*Sonneratia*	Root	16.88*	7.00*	20.59*	0.85
7	*Acanthus*	Leaf	8.25	7.11*	32.31*	0.39
8	*Acanthus*	Stem	1.77	2.17	9.95	0.26
9	*Acanthus*	Root	60.05*	4.78	16.66	1.06*
	1 Km-Ghusighata Brick Field					
10	*Sonneratia*	Leaf	10.02*	4.63	22.41*	0.33
11	*Sonneratia*	Root	3.02	8.64*	19.82	1.23*
12	*Sonneratia*	Stem	6.01	7.26	11.62	0.17
13	*Acanthus*	Leaf	1.12	2.35	62.09*	0.17
14	*Acanthus*	Root	4.86*	3.56	15.30	1.66*
15	*Acanthus*	Stem	1.61	8.46*	38.36	0.93
	5 Km Malancha					
19	*Sonneratia*	Leaf	5.06	3.86	23.20	0.31
20	*Sonneratia*	Root	7.90*	9.39	25.67	0.97*
21	*Sonneratia*	Stem	4.27	9.49*	33.32*	0.88
22	*Acanthus*	Root	4.74*	4.07*	25.85	0.37*
23	*Acanthus*	Stem	2.91	3.64	42.92*	0.23
	10 Km Hatgachhi					
27	*Acanthus*	Leaf	6.74*	6.94	21.94*	0.22
28	*Acanthus*	Root	6.31	7.19*	17.46	0.57*
29	*Acanthus*	Stem	1.97	5.16	10.02	0.28
30	*Sonneratia*	Leaf	3.21*	6.71	26.86*	0.06
31	*Sonneratia*	Stem	1.58	10.14*	18.63	0.22*

*maximum absorption values

Table 3. *Estimation of heavy metals in algae, animal, soil*

Sl. No.	Description of Sample	Chromium (as Cr) ppm in dry matter	Lead (as Pb) ppm in dry matter	Zinc (as Zn) ppm in dry matter	Cadmium (as Cd) ppm in
	Periphytic Epiphytes				
1	Enteromorpha sp Ghusighata (0 km)	6.05	26.67	29.90	2.52
2	Enteromorpha sp Kanmari (10 km)	7.06	26.26	23.80	2.73
3	Fiddler crab	1.02	7.07	29.55	2.65
4	Sediment				
	0 Km	56.30	13.84	30.60	0.94
	1 Km	35.9	21.3	69.5	0.99
	5 Km	36.50	17.60	57.70	1.18
	10 Km	39.8	24.2	68.2	1.20

Sundarban ecosystem is filtering the heavy metals. Level of Dissolved Oxygen is gradually increasing downstream of Ghusighata outfall along with consequent removal of BOD. Mangrove plants particularly *Sonneratia caseolaris* as well as the algae *Enteromorpha intestinalis* are significantly absorbing and are physiologically utilizing the heavy metals like Pb, Cr, Cd from sewage.

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J. Indian Soc. Coastal agric. Res., 28(1), 79-84, 2010

Socio-economic Impact of Salinity on Agriculture in Western Gujarat

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Soil is one of the crucial natural resources essential for the existence of mankind. Contents of the soil profile determine the quality of life of people nourished on it. Changes in the quality of soil led to long run changes in socio-economic and cultural traits of its habitats. This has been experienced in several parts of the world like Egypt, Holland, Sindhu Sanskruti, etc., where the soils was deteriorated either by sea water intrusion or water logging. The soil degradation affects first on agriculture and then it spreads over the rest of the facets of the society. Over 3 Mha of India's coastal area is plagued by salinity (ECe 1 to 45 dsm^{-1}) and the chief cause of concerns is that, it is on the increase (Yadav and Singh, 2000).

(***Key words:*** *Socio-economic, Soil salinity, Western Gujarat*)

In Gujarat, recently the soil degradation through salinity has caught hold over 1.2 Mha of land. Of which, about 0.3 mha occurs in the coastal area (Rao *et al.*, 2001). The problem of salinity in coastal region has created a very adverse condition in respect of agriculture, drinking water supply and other aspects having bearing on the lives of people. (Anon, 1983). Thus, the spread of salinity has caused social hardship and several negative effects such as decrease in farm production, resource productivity and decrease in input use, shifting of labour from agriculture, income inequality, etc. This all reflect the gravity of problems and indicates the red signals to habitats of this tract in general and agriculture in particular.

Individual research efforts and Government efforts were mainly focused on the genesis of salinity problems, to suggest remedial measures, to quantify the impact on the basis of field experiment, etc. But, they are inadequate to assess the broad spectrums impact of salinity without considering socio-economic aspects which is highly imperative for the comprehensive management policy and developmental projects for this tract. With this view, socio-economic features, occupational patterns sources of income and land use pattern were studied in the present investigation.

MATERIALS & METHODS

Gujarat state has a coast line of 1600 km. About 1125 km long coastal line is in Saurashtra and Kutchh which occupied about 0.1079 Mha out of 0.3 Mha of state's sea water ingress salinity affected area. The whole study area falls under three Agro-Climatic Zones namely; North-West Gujarat Zone V (situations 3 and 6), North Saurashtra Zone VI (situation 10) and South Saurashtra Zone VII (situations 3, 5, 7 and 8). The area of present investigation is comprised of 20 km wide soil strip along the sea coast of Saurashtra and Kutch. Two-stage stratified random sampling technique was used with the village as first strata and the farmers as ultimate sampling unit. Along the coastal belt of 20 km width, a total of 9 locations were selected as starting point of village selection. In perpendicular line from sea shore to 20 km interior, one village was selected from each strata of 0-5, 6-10, 11-15 and 15-20 km width. Thus, a total of 36 villages were selected by selecting 9 from each strata, considering the ingress of salinity along the coastal line. Ten farmers were selected randomly from each village and a sample of 360 farmers was acquired for the present study. A ample of farms is further devided into three salinity classes of the soils viz. A-class (non saline/negligible saline- <4 ECe), B-class (moderately saline- 4-8 ECe) and C-class (stronger to very strong saline- >8 ECe).

RESULTS AND DISCUSSION

The portrait of socio-economic diversity in respect to extent of salinity in different agro climatic zones is depicted here.

The socio-personal characteristics of family heads across the salinity class in different zones are given in Table 1. The average age of the family head was found in the range of 40-49 years. This indicated that management or control of household was under comparatively young group. The average year of schooling of family head varied between 1 and 5 only, indicating the lower level of education. This may be due to the poor availability of education facilities in coastal region in the early years of independence. The castes distributions data showed that higher percent of backward castes population (all castes other than general categories) was found in salinity affected areas of Zone - V and Zone - VI, whereas a reverse trend was observed in Zone - VII. This may be due to developed coastal region of this zone having good port and industries. A declining trend of social participation was observed with the extent of salinity level in all the Zones. The average size of family across the salinity class and zones was around 6 to 8 members. The male-female ratio was relatively greater than one across the salinity class in all the Zones. This ratio was comparatively higher in Zone - VII than Zones - V and - VI. The percentage of family literacy was found between 53 and 75 per cent across the zones. The rate of literacy has no uniform trend with the salinity level in all the zones. The proportion of male literacy was observed quite higher than the female literacy in all the salinity levels and zones. Moreover, on an average, a little higher literacy rate was observed in salinity affected area in case of both male and female.

The economic features of the household in coastal region are given in Table 2. The average size of holding varied from 3.32 to 4.50 ha in Zone - V, 4.77 to 7.25 ha in Zone - VI and 3.98 to 4.27 ha in Zone - VII. Thus, on an average relatively higher size of holding was noticed in Zone - VI. The proportion of the irrigated land was found higher in all the classes of all the zones. The proportion of irrigation was found indifferent to class of salinity. The landsman ratio was found comparatively lower in salinity affected areas of Zone - V and - VII, than that of the Zone - VI. The livestock population was found higher in Zone - VII. Similarly, comparing across the salinity classes, it was slightly higher in class C over A and the lowest in class B in all the zones except Zone - VII. This may be due to tendency of farmers to adopt mix farming to sustain their livelihood in the hardship. The proportion of cow was found comparatively lower than buffaloes across most of the salinity classes and zones for both mulch and dry animals' categories. The number of bullock per farm was found the highest in case of Zone - VII, followed by Zone - VI and Zone - V. This may be due to the fact that agricultural prosperity is better in Zone - VII due to good rainfall, soil and water resources as compared to Zone - V and - VI. The proportion of dry animals was found higher than mulch animals across the classes and zones.

Occupational Pattern

The salinity class wise occupational patterns of sample farmers in different zones are given in Table 3.3. It is evident from the table that all the households have agriculture as main occupation. Total number of sources of employment were found highest in Zone - VII (12), followed by Zone - V (7), and Zone - VI (4). The numbers of sources have decreased with the increase in salinity level in all the Zones. The employment generated in terms of mandays was found higher in class A compared to class B and C in all the Zones and for overall study area. The employment day per person was found the highest in Zone - V among all the salinity

Table 1. *Socio - Personal characteristics of family head across the salinity classes in different zones*

Characteristics	Categories								
	Zone V			Zone VI			Zone VII		
	A	B	C	A	B	C	A	B	C
Age (year)	47.63	48.82	45.20	48.35	42.70	40.40	45.90	45.45	47.00
Education (std)	4.03	5.40	2.10	1.70	2.80	2.50	2.86	1.16	2.76
Caste : BC %	23.33	52.50	100.00	95.00	100.00	100.00	74.66	25.00	
: General %	76.67	47.50		5.00			25.34	75.00	100.00
Social Participation (%)	0.06	0.10		0.05			0.17	0.08	
Av. size of family (No.)	7.00	6.40	6.40	7.15	6.50	7.25	7.62	7.91	7.80
Male-female ratio	1.28	1.70	1.39	1.40	1.06	1.15	1.59	1.50	1.46
Family literacy (%)	63.90	74.80	55.22	53.47	63.33	59.42	58.40	61.65	57.83
(a) Male (%)	84.95	89.38	74.36	66.66	78.12	72.97	70.52	75.00	74.32
(b) Female (%)	38.04	50.00	28.57	35.00	43.33	43.75	39.02	41.57	33.66

Table 2. Economic features of the sample households across the salinity classes in different zones

Characteristics	Categories								
	Zone - V			Zone - VI			Zon - VII		
	A	B	C	A	B	C	A	B	C
Av. Size of holding (ha)	4.50	3.71	3.32	4.96	4.77	7.25	4.21	3.98	4.27
Irrigated land (%)	50.34	20.80	91.50	92.66	100	62.95	61.60	40.84	44.07
Land man ratio	0.64	0.58	0.51	0.60	0.73	0.75	0.55	0.50	0.51
Livestock strength (no ha^{-1})	0.90	0.69	1.91	0.82	0.68	0.70	1.21	1.27	1.54
Milch animals (No ha^{-1})									
Cow	0.15	0.09	0.08	0.10	0.09	0.09	0.13	0.10	0.10
Buffaloes	0.14	0.10	0.09	0.09	0.09	0.22	0.25	0.21	0.19
Sheep/goat	0.00	0.03							
Total	0.29	0.22	0.17	0.19	0.18	0.30	0.38	0.31	0.29
Dry animals (No ha^{-1})									
Cow	0.04	0.02	0.28	0.02	0.06	0.02	0.12	0.02	0.14
Buffaloes	0.19	0.11	0.42	0.08	0.07	0.01	0.19	0.20	0.33
Sheep/goat									
Calves	0.19	0.14	0.85	0.25	0.14	0.17	0.25	0.42	0.40
Bullocks	0.19	0.20	0.19	0.28	0.23	0.19	0.27	0.32	0.38
Total	0.61	0.47	1.74	0.63	0.50	0.40	0.83	0.96	1.25

classes, followed by Zone - VI and Zone - VII. However, while comparing the class, the availability of employment per person showed declining trend with increase in salinity levels in all the Zones and for overall level. The percent of working days per year was found very low i.e. 37.42, 34.85 and 32.05 per cent in class A, B and C, respectively. This indicated that the intensity of unemployment has increased with increase in salinity.

Among the various sources of employment, agriculture was found the major one in all the zones and salinity classes. However, the quantum of employment from agriculture was lower in salinity class B and C as compared to class A in all the zones. This may be because of poor performance of agriculture due to limited crop alternatives in salinity affected area. Among the other sources of employment, dairying and farm labour were the major sources in salinity affected area whereas in non-saline region (class A), they were farm labour, services, diamond industries, etc

On the whole, in the salinity affected area, the varieties of sources of employment and availability of employment are comparatively less. This demands for the development of new sources of employment in the salinity affected area.

Sources of income

The source wise income of households in different zones and classes are presented in Table 4. The number of sources of income was the highest in Zone - VII (11), followed by Zone - V (5) and Zone - VI (2). The number of sources has declined with the increase in salinity level. This indicates that limited off-farm activities are available in this salinity affected tracts. The income of salinity affected areas (i.e. average of B and C class) was found slightly lower in case of Zone - V (Rs. 7221.88), and Zone - VII (Rs.15290.50) but it was observed slightly higher in case of Zone - VI (Rs. 4375.00). Looking to the important sources of income in different zones and salinity classes, in non-saline regions (A class), the main sources of income were the services and farm labourers and industries (diamond industries and other industries), whereas in salinity affected areas, they were the dairying (except in Zone - VI), farm labour and industries.

Land use pattern

Salinity class wise, land use patterns in different Zones are given in Table 5. In Zone - V, the average size of farm was highest in class A (4.50 ha) and the lowest in class C (3.32 ha), whereas in Zone - VI and - VII, the highest size of farm was found in class C and the lowest in class B. Proportion of irrigated land

Table 3. *Occupational patterns and employment sources across the salinity classes*

Occupation/zone	Salinity class					
	A		B		C	
	No. of persons engaged	Employment days/year	No. of persons engaged	Employment days/year	No. of persons engaged	Employment days/year
Zone-V						
Agriculture	4.20	677.66	3.45	433.00	4.50	617.00
Dairying					0.10	24.00
Service	0.13	42.00	0.10	30.00		
Farm labour	0.40	50.00	0.35	38.75	0.20	24.00
Dimond industries	0.03	8.33	0.07	22.50		
Kariyana shop	0.03	6.00				
Garage	0.06	14.00				
Total	4.85	797.99	3.97	524.25	4.8	665
Employment days/person/year	-	164.53	-	132.05	-	138.54
Zone-VI						
Agriculture	4.30	509.00	3.00	383.00	4.00	468.00
Farm labour	0.35	53.00	0.20	36.00		
Industries					0.1.0	30.00
Kariyana shop	0.05	15.00				
Total	4.70	577.00	3.20	419.00	4.00	498.00
Employment days/person/year	-	122.77	-	130.94	-	124.50
Zone -VII						
Agriculture	3.96	444.00	3.90	402.83	4.40	375.66
Dairying	0.01	4.00	0.15	38.16	0.06	13..33
Service	0.05	15.10	0.05	12.50		
Farm labour	0.26	30.00	0.18	16.66	0.93	105.33
Dimond industries	0.17	40.13	0.28	71.00	0.06	20.00
Kariyana shop	0.03	5.53	0.02	5.00	0.03	6.66
Garage	0.02	4.66				
Industries	0.03	7.66	0.01	5.00		
Boating	0.01	1.33				
Gallo	0.02	6.00	0.02	4.16		
Rikshaw	0.02	4.00				
Petrol pump	0.07	2.33				
Total	4.65	564.74	4.61	555.31	5.48	507.65
Employment days/person	-	121.45	-	120.46	-	92.64
Grand total	14.20	1939.73	11.78	1498.56	14.28	1670.65
Employment days/ person/year	-	136.60	-	127.21	-	116.99
% of employment days in a year	-	37.42	-	34.85	-	32.05

was found comparatively higher in salinity affected area (class C) of both the Zones - V and - VII.

The area under orchard crops was meager in all the classes of Zone - V and - VII. The occurrence of wasteland was noticed in Zone - V and in class C of Zone - VII only. The cropping intensity has shown increasing trend with increase in salinity in Zone - V and - VI, whereas the reverse trend was observed in Zone - VII, but on an average, comparatively higher cropping intensity was observed in Zone - VII.

Table 4. *Income sources other than agriculture in different zones (per farm) (Rs./farm)*

Sources of Income	Zone - V			Zone - VI			Zone - VII		
	A	B	C	A	B	C	A	B	C
Dairying			2800.00				500.00	6500.00	1333.33
Service	3466.66	5875.00					2666.67	1933.33	
Farm Labour	2933.33	1668.75	1100.00	1650.00	750.00		1760.00	925.00	3890.00
Diamond industries	1200.00	3000.00					6133.33	10333.30	1333.33
Industries						8000.00	1893.33	2500.00	
Boating							466.66	0.00	
Kariyana	500.00			2500.00			793..33	666.66	833.33
Gallo							566.66	333.33	
Rikshaw							566.66		
Petrol pump							466.66		
Garage	23.33						826.00		
Total	8123.32	10543.75	3900.00	4150.00	750.00	8000.00	15845.97	23191.62	7389.99

Table 5. *Land use pattern across the salinity classes in different zones (ha)*

Particulars	Zone - V			Zone - VI			Zone - VII		
	A	B	C	A	B	C	A	B	C
Av. farm size	4.50	3.71	3.32	4.96	4.77	7.25	4.21	3.98	4.27
Un irrigated area	2.11	2.88		0.36	0.00	2.68	1.60	2.35	2.30
Irrigated area	2.19	0.69	3.04	4.59	4.77	4.57	2.60	1.63	1.87
Orchard land	0.03	0.13					0.01		0.05
Waste land	0.17	0.01	0.28						0.05
Gross cropped area	3.78	3.63	3.37	4.81	4.72	9.71	4.89	4.14	4.54
Cropping Intensity (%)	84.00	97.84	101.51	96.98	98.95	133.93	116.15	104.02	106.32

The education level of family head was found low. But the family literacy rate was between 53 to 75 per cent. Male literacy rate was observed quite higher than female. The proportion of backward castes was relatively more in salinity affected areas. The rate of social participation was observed low. The number of sources of employment, employment days per person and sources of income showed declining trend with increase in salinity in the study area. This may be due to lack of availability of off-farm activities. The average size of holding found larger (3.5 to 7 ha). High cropping intensity was observed in saline tract. It is evident that alkalinity is not a major problem in the study area but the salinity.

Policy implications

1. As average size of farm in coastal area is large, most of the farmers may not avail the benefits given to the small and marginal farmers. Hence the government should revised standard of farm size specially for coastal area.
2. Low level of literacy in case of women calls for increase in educational facilities giving more weight age to gender education. This may help them to avail the off-farm activities and social participation.
3. For generating the employment, government should launch the industries based on marine resources and products like brackish water prawn production, small scale marine product processing unit, mini agro processing plants, rural handicrafts, diamond industries which does not require water and entrepreneurship development programme specially for this tract.

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J. Indian Soc. Coastal agric. Res., 28(1), 85-93, 2010

Participatory Technology Transfer for Widespread Adoption of Co 86032 Sugarcane Variety in Coastal Regions of Tamil Nadu

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Participatory technology development and participatory technology transfer are terms that are increasingly being used in agricultural development. Sugarcane is one of the major commercial crops grown in TamilNadu, India. Co 86032 is a high yielding sugar rich variety with field resistance to red rot. With an effort to popularize this variety in the study area, Sugarcane Breeding Institute, Coimbatore implemented this participatory approach during 2001 to 2006 in M.R.K. Cooperative Sugar Mills Ltd., Sethiathope, a sugar factory situated in the coastal district Chidambaram in Tamil Nadu. The study focused on opinion leaders as messengers of the new technology. Visualizing a remarkable increase in the area under this variety, efforts were done to study in detail about the inter-personal network and the perception of the growers about the new variety. This forms the crux of the paper giving details on the conduct of the trials in participatory mode and the success thereof.

(**Key words:** *Diffusion of innovations, Participatory technology transfer, Sugarcane variety Co 86032*)

Scientific sugarcane cultivation starts with choosing an appropriate variety suited for the location and season concerned. Varieties play a major role in the expansion and sustenance of sugar industry. Genetic improvement of crop varieties through directed breeding program has played a pivotal role in increasing production and expanding the cultivation of crops to non- conventional areas (Sreenivasan *et al.*, 1995).

It is imperative to select a sugarcane variety suited to the agro climatic condition to improve the sugarcane productivity in farmer's field and sugar recovery in sugar factories. Instead of few widely adapted varieties like Co 419, Co 740, Co 1148 and CoS 767 which prevailed earlier, we now have a wide spectrum of varieties suited for different environmental conditions and which can be planted and harvested at different periods as per the requirements. (Bhagylakshmi and Sreenivasan, 2003).

Crop varieties must be adaptable over diverse farm environment if they are to be accepted by farmers within a region. The adoption of new techniques has been slow in diverse, less productive, heterogeneous and risk prone areas (Dambo and Sajica 1985; Chambers and Jiggins, 1986). Since a very high level of genetic improvement for cane productivity has been achieved, high yielding varieties with wider adaptation are hard to come by. Greater emphasis is being given to location specific varieties to capitalize on their inherent genetic potential. At the same time, care should be taken not to loose the limited chances of obtaining a variety with wider adaptation (Thiagarajan *et al.*, 2005).

Not all the varieties have been commercially successful. There are specific characteristics in a sugarcane variety which makes it popular. The spread and acceptance of any variety depends on the perception of the farmers about that variety (Rajulashanthy and Thiagarajan, 2003).

In line with the above, the objectives of the present study were to popularize the new sugarcane variety Co 86032 and to accelerate the dissemination of farmer's choice variety through exchange of information among themselves.

MATERIALS AND METHODS

The study was conducted in M.R.K Cooperative sugar mill area, which is situated in the coastal areas of Tamil Nadu state in India. Perur division of the mill was purposively selected for two reasons: (i) the area was dominated by CoC 90063, a variety highly susceptible to red rot disease and (ii) the farmers in this division were reluctant to change and accept a new sugarcane variety. A sensitization workshop and a series of village level meetings were organized with farmers and cane development personnel of M.R.K. Cooperative Sugar Mill during

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the formation of farmer research groups. Fifty volunteer opinion leaders from the selected 25 villages with two from each village were included. The opinion leaders were selected in such away that they should own less than five acres of land and they should be influential in the social system so that the messages can spread faster through inter-personal network.

Focus group discussions

A series of village level meetings and focus group discussions throughout the crop period were conducted in the selected villages with the participation of chosen opinion leaders. Cane assistants of the concerned division of the sugar factory and extension scientists from Sugarcane Breeding Institute (SBI) served as facilitators. Forty opinion leaders accepted the new sugarcane variety mentally and agreed to cultivate the variety Co 86032. The seed material for planting was supplied through the concerned sugar factory and was planted in plots each measuring 0.5 acres. Recommended agronomic practices for the location were applied uniformly. Farmers evaluated the variety right from germination count to harvest. Research guidance was provided to farmers in evaluating the performance of the variety. Frequent field visits to nearby trial farms were carried out by farmers, scientists and extension agents of the concerned area, the purpose being to share their experiences. The yield data was recorded after 360 days at harvest.

Twelve socio-economic characteristics were selected as independent variables to study its influence on interpersonal network, perception of farmers on the performance of Co 86032 and messages spread on the performance of Co 86032. The independent variables were measured using appropriate scoring techniques and the dependent variables were scored with appropriate weightages.

Societal Threshold Percentage (STP)

Diffusion of an innovation is based on the societal threshold percentage (STP). STP is measured based on the individual's perception of introduced technology. The perception of the individual on introduced technology is to be measured in all possible dimensions. The two dimensions of STP are Positive factor percentage (PFP) and Negative factor percentage (NFP). The STP cannot be fixed at mean level because some individuals in the society may have neutral perception on the introduced technology. Hence, the mean societal threshold percentage may detract the diffusion of an introduced technology.

The positive factor percentage and negative factor percentage are calculated by using the following formula.

$$\text{PFP} = \frac{\text{Total number of individuals showing favourable perception in perception dimension}}{\text{No. of perception dimensions x Number of individuals}}$$

$$\text{PFP} = \frac{\text{Total number of individuals showing unfavourable perception in all perception dimension}}{\text{No. of perception dimensions x Number of individuals}}$$

These formulae also can be used to measure the individual threshold percentage (ITP). Summing up all the individual threshold percentages, the societal threshold percentage can be known.

Societal threshold perception

If the calculated PFP is more than the NFP the society favors the spread of the introduced technology. In this study the perceptions are measured on 20 dimensions with three point continuum as high, no difference and low indicating favorable, neutral and unfavorable perceptions towards the introduced technology.

RESULTS AND DISCUSSION

Varietal scene in the study area

Table 1 indicated that area under the variety Co 86032 increased from 230.50 acres during 2000-01 to 782.15 acres during 2003-04. This remarkable increase in area due to participatory technology transfer made us to study the process spread or diffusion of the sugarcane variety.

Socio-economic profile of opinion leaders

Table 2 indicated that the selected opinion leaders were middle aged, had school education up to ninth standard, mainly engaged in agriculture, had mean farming experience of 18 years and had a mean of 13 years of experience in sugarcane cultivation. The average land size was 1.69 hectares and they were living in tiled houses with annual income of Rs. 46,000/- per year. They had high social participation, extension agency contact and mass media utilization.

Interpersonal network

The interpersonal networks used by the opinion leaders are presented in Table 3. The opinion leaders often shared information with their friends (92.5%), followed by relatives (95.0%), neighbors (57.5%) and persons from other villages (50.0%). Likewise

Table 1. *Percentage of total area under different varieties in Perur division*

Variety	2000-01		2003-04	
	Area (acres)	%	Area (acres)	%
CoC 90063	652.8	46.01	625.10	32.78
CoSi 95071	214.50	15.11	19.00	0.99
Co 86032	230.50	16.27	782.15	41.14
Co 97009	209.55	14.77	150.10	7.90
CoSi 98071	44.50	3.14	6.0	0.32
Co 86010	13.50	0.95	5.50	0.29
CoC 671	4.50	0.32	125.05	6.58
CoC 98061	30.00	2.11	29.3	1.54
Co 86011	3.75	0.26	-	-
Co 86249	8.00	0.56	-	-
Co 8021	7.00	0.49	-	-
CoV 92102	-	-	156.50	8.23
Co 86002	-	-	3.00	0.16
Total	1418.90	100.00	1901.17	100.00

Table 2. *Socio-economic profile of selected opinion leaders (n = 40)*

Characteristics	Mean score	Standard deviation
Age	44.73	9.94
Education	9.09	4.40
Occupation	5.88	0.99
Farming experience	18.85	10.44
Experience in sugarcane cultivation	13.40	8.05
House owned	3.25	1.01
Land owned	1.69	0.72
Annual income	0.46	0.31
Social participation	12.20	2.75
Contact with extension agency	21.53	5.20
Urban contact	4.80	1.16
Mass media utilization	17.93	4.06

Table 3. *Interpersonal network utilized by the opinion leaders (n=40)*

Sl. No.	Particulars	Often		Occasionally		Rarely	
		No.	%	No.	%	No.	%
1.	Friends	37	92.5	3	7.5	-	-
2.	Relatives	30	75.0	5	12.5	5	12.5
3.	Neighbors	23	57.5	10	25.0	7	17.5
4.	Persons from other villages	20	50.00	10	25.0	10	25.0
5.	Agricultural Officer	5	12.5	8	20.0	27	67.5
6.	Agricultural Assistant	11	27.5	10	25.0	19	47.5
7.	Cane Officer	4	10.0	9	22.5	27	67.5
8.	Cane Assistant	14	35.0	13	32.5	13	32.5
9.	Cane Development Officer	4	10.0	6	15.0	30	75.0
10.	Chief Cane Officer	2	5.0	3	7.5	35	87.5

majority of them often shared information with Cane Assistant (35.0%), Agricultural Assistant (27.5%) and Agricultural Officer (12.5%). They rarely utilized Chief Cane Officer (87.5%), Cane Officer (67.5%) and Agricultural Officer (67.5%) as their interpersonal network.

Factors influencing interpersonal network

The relationship between the characteristics of the opinion leaders and their interpersonal network utilization were worked out and presented in Table 4. Age, farming experience and interpersonal network utilization of the opinion leaders were negatively and significantly correlated. This indicated that when the opinion leaders are young, they had strong interpersonal network, likewise when they were having less farming experience, they interacted with other people to learn more about crop cultivation. Education and occupation of the opinion leaders showed positive and significant relationship with interpersonal network. The calculated 'F' was significant indicating that the selected independent variables exerted 72.8 per cent variation. Among the selected independent variables, education showed significant and positive influence whereas contact with extension agency showed significant and negative influence on interpersonal network utilization. This was due to the fact that the person

Table 4. *Correlation co-efficient and regression analysis on socio-economic characteristics and interpersonal network*

Characteristics	Correlation Co-efficient	Partial Beta Co-efficient	't'
Age	-0.58**	-0.19	-0.76
Education	0.78**	0.57	2.41*
Occupation	0.52**	0.09	0.68
Farming experience	-0.48**	-0.14	-0.51
Experience in sugarcane cultivation	-0.26	-0.01	-0.47
House owned	0.16	0.04	0.30
Land owned	0.16	-0.06	-0.48
Annual income	0.03	0.09	0.50
Social participation	0.09	0.08	0.54
Contact with extension agency	-0.18	-0.29	-2.31*
Urban contact	0.25	-0.05	-0.44
Mass media exposure	0.20	0.13	0.82

Analysis of variance

Source	SS	Df	MSS	F
Regression	4949.17	11	380.71	5.35**
Residual	1849.23	26	71.12	
Total	6798.40	39		

R^2 = 72.8 *Significant at 0.05% level **Significant at 0.01% level

Table 5. *Societal acceptability of the variety Co 86032 (n=40)*

Sl. No	Particulars	High/ Favourable		Moderate/ Neutral		Low/not favourable	
		No.	%	No.	%	No.	%
1.	Appreciation by fellow farmers	35	87.50	3	7.50	2	5.00
2.	Performance of the variety in fellow farmers field	33	82.50	4	10.00	3	7.50
3.	Opinion of the fellow farmers about the performance of the variety	36	90.00	2	5.00	2	5.00
4.	Opinion of the family members about the performance of the variety	37	92.50	2	5.00	1	2.50
5.	Preparedness of other farmers to adopt the variety	36	90.00	3	7.50	1	2.50

with high extension contact had little interaction with their peer group.

Societal acceptability of the variety Co 86032

The societal acceptability of the variety Co 86032 is presented in Table 5. Nearly 90.00% of the fellow farmers and family members had a favorable opinion about Co 86032 and the fellow farmers intended to adopt the variety.

Performance of the variety Co 86032 in terms of yield and duration

The performance of the variety Co 86032 in terms of yield and duration as perceived by the farmers are presented in Tables 6 & 7.

Nearly 75% of the farmers realized an increase in cane yield of up to 5 t ha^{-1} both in the plant and raton crop compared to the earlier variety CoC 90063. The quantum of increase was 6-10 t ha^{-1} as perceived by 15% for plant crop and 17.50% for raton crop. This is an indication of the better raton performance of Co 86032. The cane yield in the trial plots ranged from 103 to 142 t ha^{-1}.

Performance of variety Co 86032 in terms of plant characters

Table 8 indicates that all the farmers perceived Co 86032 to be self stripping and detrashing to be easy. Detrashing is an activity done exclusively by women labourers in the study area. The other criteria perceived with better perception (>80%) are utility of plant tops as cattle feed, raton performance, high tillering, tall canes and thick cane girth. Cane yield was perceived to be high by 75.00% of the farmers. The negative characters like spines on leaf lamina, flowering and red rot incidence were reported to be nil. On the whole, the variety with its attractive reddish purple cane was easily accepted for wide scale adoption by the farmers. Today, the variety Co 86032 is widely grown in Tamil Nadu state occupying nearly 90% of the cane growing area (Nair, 2008).

Factors influencing the perception of opinion leaders

The socio-economic characteristics viz., age, farming experience, house owned and mass media exposure showed negative and significant association with their perception on the performance of new sugarcane varieties (Table 9). This indicated that the young aged with low farming experience, who owned tiled type of houses, with less mass media exposure had favourable perception regarding the performance of Co 86032. Urban contact and occupation showed positive and significant association with perception of opinion leaders. The calculated 'F' value was significant. This indicated that all the selected socio-economic characteristics showed 50.3 per cent variation on the perception of opinion leaders whereas the individual variables did not show any significant influence.

Messages transferred by opinion leaders

Table 10 indicates that the farmers gave foremost importance for economic characters viz., yield performance and additional income. During the focus group discussions as well, the farmers opined that all other selection criteria are considered only if the variety is a high yielder than the existing cultivars. Since the study area was situated in the coastal region which is prone to the incidence of red rot disease, they were more bothered about the incidence of diseases. The other major criteria

Table 6. *Perception of farmers on the performance of Co 86032 in terms of yield when compared to CoC 90063*

Sl. No.	Particulars	Up to 5 t ha^{-1}		6 to 10 t ha^{-1}		11-15 t ha^{-1}	
		No.	%	No.	%	No.	%
1.	Increase in plant crop cane yield	30	75.00	6	15.00	4	10.00
2.	Increase in raton crop cane yield	31	77.50	7	17.50	2	5.00

Table 7. *Perception of farmers on the performance of Co 86032 in terms of duration when compared to CoC 90063*

Sl. No.	Particulars	Up to 1 month		Up to 2 months		Up to 3 months	
		No.	%	No.	%	No.	%
1.	Capacity to maintain yield if harvest is delayed	32	80.00	6	15.0	2	5.00
2.	Possibility of early harvest	8	20.00	18	45.0	14	35.00

***Table 8.** Perception of opinion leaders on the performance of Co 86032 compared to CoC 90063 (n = 40)*

Sl. No.	Particulars	High		No Difference		Low	
		No.	%	No.	%	No.	%
1.	Germination percentage	31	77.50	9	22.50	-	-
2.	No. of tillers per clump	33	82.50	4	10.00	3	7.50
3.	No. of nodes per cane	21	52.50	12	30.00	7	17.50
4.	Length of internodes	29	72.50	6	15.00	5	12.50
5.	Spine ness of leaves	-	-	-	-	40	100.00
6.	Flowering percentage	-	-	-	-	40	100.00
7.	Easiness in removing leaf sheath	40	100.00	-	-	-	-
8.	Girth of the cane	32	80.00	4	10.00	4	10.00
9.	Height of the cane	33	82.50	5	12.50	2	5.00
10.	Hardiness	5	12.50	10	75.00	25	62.50
11.	Brittleness	4	10.00	9	22.50	27	67.50
12.	Sprouting of buds in plants	3	7.50	7	27.50	30	75.00
13.	Stalk pithiness	2	5.00	7	17.50	31	77.50
14.	Lodging	21	52.50	9	22.50	10	25.00
15.	Utilization of plant top as cattle feed	35	87.50	3	7.50	2	5.00
16.	Ratoonability	34	85.00	4	10.00	2	5.00
17.	Susceptibility to early shoot borer (ESB)	20	50.00	10	25.00	10	25.00
18.	Susceptibility to internodes borer (INB)	22	55.00	10	25.00	8	20.00
19.	Susceptibility to red rot	-	-	-	-	40	100.00
20.	Yield	30	75.00	5	12.50	5	12.50

Positive factor percentage = (552 X 100) / 860 = 69.00, Negative factor percentage = (107 X 100) / 860 = 13.38
Societal threshold percentage = 13.39

***Table 9.** Correlation co-efficient and regression analysis on the socio- economic characters and perception about the performance of the sugarcane variety Co 86032*

Characteristics	Correlation Co-efficient	Partial Beta Co-efficient	't'
Age	-0.59**	-0.61	-1.83
Education	0.35*	0.12	0.39
Occupation	0.32*	0.03	0.17
Farming experience	-0.31	0.13	0.36
Experience in sugarcane cultivation	-0.24	0.09	0.03
House owned	-0.32*	-0.27	-1.50
Land owned	-0.003	-0.01	-0.9
Annual income	-0.02	-0.02	0.09
Social participation	-0.15	-0.2	-0.96
Contact with extension agency	-0.10	-0.06	-0.36
Urban contact	0.32*	0.148	0.87
Mass media exposure	-0.33*	0.08	0.36

Analysis of variance

Source	SS	Df	MSS	F
Regression	2296.14	11	176.62	2.02
Residual	2270.83	26	87.34	
Total	4566.97	39		

R^2 = 50.3% *Significant at 0.05% level **Significant at 0.01% level discussed among them include raton performance, cane height, erectness of cane, crop maturity, utility of plant tops as cattle feed, cane girth and spine ness on leaves. Farmers were less interested in other agronomic traits.

Factors influencing the messages transferred by opinion leaders

The messages transferred by the opinion leaders were strongly influenced by age, education, occupation and mass media exposure of the opinion leaders. The significant relationship of these characters indicated that the young opinion leaders, with high education and those who engaged exclusively in agriculture with less mass media exposure transferred the messages frequently with other farmers. When all the characters taken together they did not show any significant variation with the messages transferred to other farmers.

Adoption threshold

The social system normally adopts a technology if the positive factors of a particular technology exceeds the negative factors. The adoption threshold is defined as the mid point between positive and negative factors which decides the adoption or rejection of any technology. If the positive factors of any technology crosses this mid point the entire social system favours the adoption of the introduced technology.

From Table 8 it could be seen that the threshold score of the opinion leaders was 846, whereas the total positive score was 1617 and the total negative score was 75. This indicates that the opinion leaders of the study area favour the adoption of the variety Co 86032.

The adoption threshold was again studied with 30 non-participating farmers who observed the performance of Co 86032 (Table 11). The data indicated that the fellow farmers in the villages also reported good performance of the variety Co 86032 in terms of plant characters. Here also the total positive factor score for the variety Co 86032 (1215) exceeded the total negative factor score (103) with an adoption threshold score of 659. The better performance of the variety resulted in increased area within a span of four years.

At present, the variety Co 86032 is the predominant variety in the reserved area of the factory occupying more than 50% of the area and the yield is sustained in the factory area. The results fall in line with other participatory studies, which

Table 10. *Messages transferred by opinion leaders to other farmers (n=40)*

Sl. No.	Messages	Often		Occasionally		Low	
		No.	%	No.	%	No.	%
1.	Yield performance	40	100.00	-	-	-	-
2.	Crop maturity	31	77.50	6	15.00	3	7.50
3.	Ration performance	33	82.50	4	10.00	3	7.50
4.	Additional income	40	100.00	-	-	-	-
5.	Germination percentage	30	75.00	5	12.50	5	12.50
6.	Number of tillers	23	57.50	10	25.00	7	17.50
7.	Number of nodes	20	50.00	10	25.00	10	25.00
8.	Length of internodes	15	37.50	15	37.50	10	25.00
9.	Spine ness of leaves	30	75.00	5	12.50	5	12.50
10.	Easiness in removing dry leaves	25	62.50	10	25.00	5	12.50
11.	Flowering percentage	20	50.00	10	25.00	10	25.00
12.	Girth of the cane	31	77.50	5	12.50	4	10.00
13.	Height of the cane	33	82.50	4	10.00	3	7.50
14.	Hardiness of the cane	20	50.00	15	37.50	5	12.50
15.	Brittleness of the cane	19	47.50	10	25.00	11	27.50
16.	Bud sprouting	21	52.50	10	25.00	9	22.50
17.	Stalk pithiness	30	75.00	6	15.00	4	10.00
18.	Lodging nature	35	87.50	3	7.50	2	5.00
19.	Utilization of plant top as cattle feed	31	77.50	6	15.00	3	7.50
20.	Susceptibility to diseases	40	100.0	-	-	-	-

Table 11. *Perception of other farmers on the performance of Co 86032 plantcharacters compared to CoC 90063 (n = 30)*

Sl. No.	Plant characters	High		No difference		Low	
		No.	%	No.	%	No.	%
1.	Germination percentage	25	33.31	5	66.7	-	-
2.	No. of tillers per clump	23	76.7	4	13.3	3	10.0
3.	No. of nodes per cane	19	63.3	6	20.0	5	16.7
4.	Length of internodes	22	73.3	4	134.3	4	13.3
5.	Spine ness of leaves	-	-	-	-	30	100.0
6.	Flowering percentage	-	-	-	-	30	100.0
7.	Easiness in removing leaf sheath	30	100.0	-	-	-	-
8.	Girth of the cane	21	70.0	5	16.7	4	13.3
9.	Height of the cane	24	80.0	3	10.0	3	10.0
10.	Hardiness	3	10.0	4	13.3	23	76.7
11.	Brittleness	4	13.3	4	13.3	22	73.3
12.	Sprouting of buds in plants	2	0.7	4	13.3	24	80.0
13.	Stalk pithiness	5	16.7	5	16.7	20	66.6
14.	Lodging	20	66.6	5	16.7	5	16.7
15.	Utilization of plant top as cattle feed	30	100.0	-	-	-	-
16.	Ratoonability	20	66.6	5	16.7	5	16.7
17.	Susceptibility to ESB	20	66.6	6	20.0	4	13.3
18.	Susceptibility to INB	25	83.3	2	6.7	3	10.0
19.	Susceptible to red rot	-	-	-	-	30	100.0

Total positive factor score = 1215, Total negative factor score = 103, Adoption threshold score = 659

have shown that above a certain minimum yield, the acceptability of a variety is determined by factors other than yield (Kitch *et al.*, 1998). When farmers' selection criteria are strongly influenced by market demand, there is a high consistency of the criteria over years, locations and gender. The variety Co 86032 is a high yielder (mean cane yield 140 t ha^{-1}) and has sucrose content more than 21% and gives a good recovery. Hence, it is being equally preferred by the sugar factories also.

Sugarcane varieties best suited for the benefit of the farmers and the vibrant sugarcane based industries are to be continuously evolved to meet the increasing demands of sugar and energy (Premachandran, 2009). Varietal picture for any region is not static. However, varietal replacement takes considerable time and effort. Emphasis on varietal improvement is directed towards evolving varieties, which can produce higher sugar yield per hectare under various stress situations and ensure stability in crop production. To introduce any technology into a social system, the technology must perform well than the already existing technology. The system members need to observe its performance directly in their own situation and evaluate them in terms of their own reference. If the results are convincing, the technology gets easily diffused into the social system within a short time.

ACKNOWLEDGEMENTS

We would like to thank all the growers who allowed trials to be conducted on their farms and the cane development personnel of the concerned sugar factory. The encouragement and moral support of Dr. N.V. Nair, Director, SBI is acknowledged. Specially remembered is Late Dr R. Thiagarajan, who was the architect of this study.

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J. Indian Soc. Coastal agric. Res., 28(1), 94-96, 2010 **Short Communication**

Effect of Calcium and Sulphur on Yield of *Rabi* Groundnut (*Arachis hypogea*) under Coastal Zone of Maharashtra

The trial was conducted during *Rabi* 2007-08 at the Agronomy Farm, College of agriculture, Dapoli. The soil of experiment plot was clay loam in texture, acidic in pH (5.51), high in organic carbon (1.27%), medium in available nitrogen (318.38 kg ha^{-1}) and phosphorus (P_2O_5 14.25 kg ha^{-1}) and moderately high in potassium (K_2O 232.89 kg ha^{-1}). The experiment was carried out in randomised block design with four replications. There were five treatments consist of gypsum application @ 500 kg ha^{-1} with 25 kg N ha^{-1} + 50kg P_2O_5 ha^{-1} (T_1), elemental sulphur as a basal dose @ 25 kg ha^{-1} with 25 kg N ha^{-1} + 50kg P_2O_5 ha^{-1} (T_2), gypsum @ 500 kg ha^{-1} + 5 tone F.Y.M ha^{-1} (T_3), elemental sulphur as a basal dose @ 25 kg ha^{-1} + 5 tone F.Y.M ha^{-1} (T_4) and recommended dose of fertiliser i.e. N:P:K:: 25:50:50 kg ha^{-1} (T_5). The plot size was 4.2 x 3.6m with crop spacing 30 x 10cm. Nitrogen fertiliser applied through Urea @ 25 kg ha^{-1}. Phosphorus was applied through SSP and potassium was applied through MOP. Gypsum was used as a source of calcium. All these fertilisers were placed in single dose just below the seed. At the time of sowing the seeds were treated with thirum @ 3 gm kg^{-1} of seed as a preventive measure against seed and soil borne diseases, seeds were also treated with rhizobium culture @ 2.5gm kg^{-1} of seed to improve N fixation. Sowing was done by dibbling method, hand weeding was done 3 to 4 times to remove the weeds, pre planting herbicide baseline was sprayed @ 1.0 kg ha^{-1} and spraying of monocrotophos @ 0.05% was done to control leaf eating insects. The crop was harvested when the pods matured fully, the plant was uprooted and pods were separated manually. The produce was sun dried for 4 to 5 days. The observations on growth yield attributes were recorded periodically and statistically analysed.

Application of gypsum with N and P_2O_5 significantly influenced the number of branches, height of plant, spread of plant and dry matter production of groundnut crop. The mean number of branches varied from 10.28 to 12.68 at harvest. Highest spread of plant (44.48 cm) was observed in treatment T_1 which received gypsum @ 500 kg ha^{-1} with 25 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1}, and at par with treatment T_2 i.e. elemental sulphur @ 25 kg ha^{-1} with 25 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1}. In plant height among the different treatment T_1 was significantly superior over rest of the treatments except T_2 (elemental sulphur @ 25 kg ha^{-1} with 25 kg N ha^{-1} + 50 kg ha^{-1}) and T_5 (RDF i.e. N:P:K:: 25:50:50 kg ha^{-1}) which are statistically at par with each other. The application of gypsum over sulphur increased the number of branches, per plant and mean plant height. The highest dry matter production (68.32 g $hill^{-1}$) was recorded from treatment T_1 (gypsum @ 500kg ha^{-1} with 25 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1}), which was significantly superior over rest of the treatments (Table 1).

The yield attributing characters like number of mature pods, weight of 100 pods, 100 kernel weight and shelling percentage were significantly influenced due to gypsum application combined with dose of N and P_2O_5. Number of mature pods was recorded highest (30.15) in treatment T_1, which was stastically at par with treatment T_2 and significantly superior over remaining treatments. Due to gypsum application weight of pod per hill significantly increased and varied from 34.98 to 38.07 gm. Among the different treatments, dry pod yield obtained from treatment T_1 was highest (48.90 q ha^{-1}). Increase in pod yield due to gypsum can be attributed to presence of calcium in fruiting zone and addition of sulphur which improved the quality of groundnut as reported by Singh *et al.*, (1993). For enhancing the dry pod yield of groundnut, application of calcium through gypsum @500kg ha^{-1} was good source and had significant impact on pod yield as reported by Ghulaxe *et al.*, (1995)

In relation with haulm yield, the treatment T_1 was found to be significant and superior to other treatments which gave highest haulm yield (53.80 q ha^{-1}). Increase in haulm yield may be due to increased synthesis of chlorophyll and amino acids. There by increasing photosynthetic activity, ultimately growth and development of plant took place as reported by Sailaja *et al.*, (1996). Similar results were found in kernel yield which was recorded highest (37.16 q ha^{-1}) from treatment T_1 and significantly superior over rest of the treatments.

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

Treatment	Growth parameters				Yield contributing character			yield		Economics	
	No of branches hill^{-1}	Spread of plant (cm)	Dry matter production hill^{-1} (g)	Height of plant (cm)	Mature pods hill^{-1}	Weight of pod hill^{-1} (g)	Dry pod yield (q ha^{-1})	Haulm yield (q ha^{-1})	Kernel yield (q ha^{-1})	Net returns (Rs ha^{-1})	B:C ratio
Gyp.@500kg ha^{-1} + 25 kg N ha^{-1} + 50 kg P_2O_5 ha^{-1} (T_1)	12.68	44.48	68.32	26.47	30.15	38.67	48.90	53.80	37.16	56,448.85	3.53
Ele. S @ 25 kg ha^{-1} + 25 kg N ha^{-1} + 50 kg P_2O_5 ha^{-1} (T_2)	12.17	43.28	66.52	25.67	29.70	38.10	47.75	53.12	36.10	53,255.65	3.24
Gyp. @ 500 kg ha^{-1} + 5 tone F.Y.M h^{-1} (T_3)	10.68	39.32	63.88	22.50	26.88	35.72	45.67	51.95	35.06	49,615	3.05
Ele. S @ 25 kg ha^{-1} + 5 tone F.Y.M ha^{-1} (T_4)	10.28	38.86	63.15	22.25	26.46	34.98	44.41	51.07	35.03	41,129.50	2.61
RDF i.e N:P:K 25:50:50 kg ha^{-1} (T_5)	11.72	42.45	65.82	24.92	29.14	37.85	47.38	52.87	36.08	54,462.10	3.48
SEm ±	0.188	0.744	0.188	0.732	0.318	0.139	0.305	0.353	0.260	-	-
CD at 5%	0.578	2.292	0.578	2.258	0.980	0.429	0.939	1.088	0.800	-	-

GYP- Gypsum, Ele.S- Elemental sulphur, RDF- Recommended Dose of Fertilizer

Protein and oil content in groundnut kernel was significantly affected by various treatments. Treatment T_1 increased the protein (21.74%) and oil (50.84%) content and significantly superior than other treatments. Increase in protein content with gypsum application might be due to synthesis of sulphur containing amino acids like cystine, cysteine and methionine which helps in conversion of amino acid into protein. The increase in protein content of groundnut kernel as a result of sulphur fertilization was reported by Karle and Babula (1985) and Patil *et al.*, (1981). Sulphur act as a catalytic enzymes involved in the metabolism of carbohydrates into oil as reported by Patil *et al.*, (1981). Bhattacharya and De (1997) reported that the positive role of sulphur in increasing oil content in groundnut.

Groundnut crop when supplied with Gypsum @ 500 kg ha-1 with 25 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1} gave the highest net return (Rs. 56,448.85) followed by elemental S @ 25 kg ha^{-1} + 25 kg N ha^{-1} + 50 kg P_2O_5 ha^{-1}. The lowest net return was recorded under treatment T4 i.e. Elemental S @ 25 kg ha^{-1} + 5 tonne FYM ha^{-1} (Rs. 41,129.5).

From above data it revealed that application of gypsum as a source of calcium along with recommended dose of N and P is very essential for increasing dry pod yield. Calcium requirement of the groundnut plant is quite heavy besides the major nutrient viz. nitrogen and phosphorus. Application of gypsum or elemental sulphur was not much effective. The response of recommended dose of fertiliser i.e. 25:50:50 kg ha^{-1} was significantly superior over gypsum + FYM and elemental sulphur + FYM application.

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Book Chapter: As: Inasi, K. A. and Philip, J. (1996). Crop production strategies of tuber crops. In: *Tropical Tuber Crops*, G. T. Kurup and V. P. Potty (eds.), Kalyani Publishers, Ludhiana. pp 264-274.

Bulletin: As: (i) Bandyopadhyay, B. K., Maji, B., Sen, H. S. and Tyagi, N. K. (2003). *Coastal Soils of West Bengal—Their Nature, Distribution and Characteristics*. Technical Bulletin No. 1/2003, Central Soil Salinity Research Institute, Regional Research Station, Canning Town, India. 62 p. (ii) Bandyopadhyay, B. K., Sahu, G. C. and Maji, B. (1998). Status, nature and composition of organic matter in coastal areas. In: *Soil Organic Matter and Residue Management*. Bulletin No. 19, Indian Society of Soil Science, New Delhi. pp 58- 67.

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Thesis: As: Sarangi, S. K. (2003). Studies on the effect of modes of iron application and growth regulators on the performance of direct seeded upland rice (*Oryza sativa* L.) varieties under rainfed condition. *Unpublished Ph. D. Thesis*, Banaras Hindu University, Varanasi, India.

Units to be used: SI Units (Le *Système international d'unités* or the International System of Units) to be used. For this, Clark's Tables: '*Science Data Book*' by Orient Longman, New Delhi (1982) may be consulted as a guideline.

In expressing doses of nitrogen, phosphorus and potassic fertilizers, those should be in the form of N, P, K, respectively and be expressed in terms of kg ha^{-1} for field experiments and mg kg^{-1} for pot culture studies. Some of the common units with the corresponding symbols are reproduced below for convenience.

Common units and symbols: length= l, time= t, metre = m, second = s, centimeter = cm, cubic centimeter= cm^3, cubic metre =m^3, decisiemens = dS, degree-Celsius = ^0C , day = d, gram = g, hectare = ha (10^4 m^2 = 2.47 acre), 1 ha plough layer (15cm) of soil = 2.25 x10^6 kg (assuming bulk density of soil is 1.5 Mg m^{-3}) , Hour = h, Kilometer = km, kilogram= kg, litre= L (=dm^3), Megagram = Mg (=10^3 kg or 10^6 g), microgram= μg (=10^{-6} g), Micron = μm (=10^{-6} m), milimole = mmole, miliequivalent = meq, micromol= μmol, milligram= mg, milliliter= mL, minute= min, nanometer= nm ((10^{-9}m), square centimeter= cm^2 , square kilometer = km^2, Tonne = t (Mg, 10^6 g or 10^3kg),*electrolytic conductivity* = dS m^{-1} (= mmhos cm^{-1}), *gas diffusion* = g m^{-2} s^{-1} or mol m^{-2} s^{-1}, *water flow*= kg m^{-2} s^{-1} (or) m^3 m^{-2} s^{-1} (or) m s^{-1}, *hydraulic conductivity* = m s^{-1}, *ion uptake (per kg of dry plant material)* =mol kg^{-1}, *leaf area* = m^2 kg^{-1}, *nutrient content in plants* = μg g^{-1}, mg g^{-1} or g kg^{-1} (dry matter basis), *root density or root length density* =m m^{-3}, *soil bulk density* = Mg m^{-3} (= g cm^{-3}), *transpiration rate* = mg m^{-2} s^{-1}, *water content of soil* = kg kg^{-1} or m^3 m^{-3}, *water tension* = kPa (or) Mpa, *yield (grain or forage)* = Mg ha^{-1} (= t ha^{-1}), organic carbon content of soil = g kg^{-1} (= percent (%) x 10), milligram per kg = mg kg^{-1}= parts per million (ppm), cation exchange capacity of soil = cmole(p+) kg^{-1} (= meq 100 g^{-1})

The authors are advised to look into a latest issue of the Journal of the Indian Society of Coastal Agricultural Research for preparation of manuscript for publication.

A set of manuscript (one soft copy (CD) + two hard copies) complete in all respect is to be submitted to 'The Secretary, Indian Society of Coastal Agricultural Research, Central Soil Salinity Research Institute, Regional Research Station, Canning Town, West Bengal, India, PIN- 743329'. Authors are also required to submit a copy of the Manuscript to the Society through e-mail <iscar.c@gmail.com>. The receipt of the manuscript will be communicated (electronically), provided the corresponding author's e-mail address is given in the manuscript. All the subsequent correspondences regarding the Manuscript will be done electronically only. Utmost attempts are made to expedite review of Manuscripts and publish the accepted ones at the earliest opportunity.