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Improving Agricultural Productivity in Degraded Coastal Land of India - Experiences gained and Lessons Learned

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The coastal lands in India are subjected to various types of degradation resulting in poor cropping intensity and yield. The livelihood security of the farming communities in the area is very poor. Majority of the farmers in the area is marginal to landless. Having no other viable alternative livelihood for the farming communities there is wide spread over- exploitation of natural forests and natural water bodies (rivers, estuaries, canals, etc.), deforestation, destruction of biodiversity, etc. which are further enhancing the deterioration of fragile coastal ecology. The essential measures required for mitigation of land degradation in coastal areas are maintaining *good soil health* (which includes alleviation of the problems of salinity/alkalinity/acidity with suitable amendments, adding organic manure/green manures to soil for improving physical, chemical and biological properties of soil, using balance fertilizers, following integrated nutrient management practices, etc.), *reducing drainage congestion* (to keep the brackish ground water near the surface at a safer depth so that it can not contribute to the salinity build up in soil and the effect on plant growth due to poor aeration/soil salinity is minimized), *improved water management practices* (for economic use of limited quantity of fresh water, rain water harvesting for creation of irrigation resources and reducing salinity build up in soil, etc.), *growing multiple and diversified crops* (with inclusion of legumes, vegetable crops, horticultural crops, etc. in the cropping schedule instead of mono-cropping with rice alone), *selection of suitable crops and their varieties* tolerant to the major abiotic stresses of the area, adopting *integrated farming system* (with inclusion of agricultural crops, fishery, poultry and animal husbandry; increasing *forestry/ agro-forestry* plantations; etc.). Experiences gathered at CSSRI, regional Research Station, Canning Town show that a major issue of land degradation and reduced productivity of coastal lands can be mitigated to a great extent through appropriate land shaping. The selection of a land shaping technique should be decided on the basis of the area, soil properties and the farm land conditions.

(**Key words:** *Coastal soils, Productivity, Land shaping, Soil management, Rainwater harvesting, Integrated cropping system*)

The coastal lands are usually landward extension of the continental shelf or the sea but not always distinctly differentiated from the main land. It is in dynamic equilibrium with the sea and the main land and, in fact, is an intermediated zone between the two. The coastal lands suffer from degradation of various kinds. The land degradation, climatic adversities and eco-system vulnerability influence the agricultural productivity and livelihood of coastal farmers to a great extent. In India, the coastal regions occupies about 5.5 percent of the total land area along the 8129 km coast line of the country spreading over 9 coastal states and 4 Union territories (UT) viz. West Bengal, Orissa, Andhra Pradesh, Tamil Nadu, Pondicherry (UT) and Andaman & Nicobar island (UT) along the Bay of Bengal and Kerala, Karnataka, Maharashtra, Goa, Gujarat, Daman & Deu (UT), and Lakshadip & Minicoy Island (UT) along the Arabian sea.

The coastal ecosystem, in India, has a wide variability in climatic, topography and it is rich in biodiversity of flora and fauna. The ecology is extremely fragile in nature and prone to the ill effects of human activities. About 90% of the farming communities in the coastal region of India are marginal to small and are living below the poverty line. Almost the entire region is mono-cropped growing mostly traditional rice with low productivity (2 - 2.5 t ha^{-1}) during *Kharif* (monsoon) season.

The coastal areas very frequently suffer from climatic disasters like cyclone, storms, sea thrust, etc. following depression in sea, Tsunami, etc. and/ or other climatic disturbances (Govt. of India, 1981). This causes colossal losses to lives and properties of rural people. The submergence of land with saline water due to breach of embankments following climatic disturbances results in loss in productivity of land to a great extent. For example, the cyclone

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Aila struck the coastal areas of West Bengal (Sundarban), India on May 25, 2009 due to which more than 22,000 homes were ravaged and more than two lakh people were affected. Saline seawater entered the crop fields & fresh water bodies (ponds, reservoirs, canals, etc.) which snatched away the means of livelihood – agriculture, animal husbandry and pisciculture, from the poor farmers of the area, large area turned highly saline and unproductive. The Tsunami disaster (following the earthquake measured 9.0 on the Richter scale with epicentre at Banda Aceh, Sumatra), which occurred on December 26, 2004 claimed over 2,80,000 human lives in South Asia. Several countries in this region viz. India, Sri Lanka, Indonesia, Thailand, Malaysia, Myanmar, Somalia and Bangladesh. In India, the Tsunami struck the coastal areas of Tamil Nadu, Kerala and Andaman & Nicobar Islands causing loss of lives of large number of human being and animals. Large number of houses was completely destroyed and crop fields were flooded with sea water turning them saline and unproductive/ highly degraded. About 8720 ha in along the east coasts of Andra Pradesh, Tamil Nadu and Kerala and about 11,000 ha in Andaman & Nicobar Islands have been affected by Tsunami (FAO, 2005).

Land degradation

Land degradation may broadly designated as 'any form of deterioration that affects the natural potential of land productivity, biological richness and resilience. In short, land degradation is a process of diminishing the productive capacity of a land. Land degradation is primarily due to two major causes *viz.* a) *Natural causes* (steep slopes, drought, high rainfall, poor natural drainage, hurricane/cyclones/tsunami, salt deposition in soil, earthquake, volcanic ashes, etc.) and b) *Human activities* (deforestation, unscientific agricultural practices, overgrazing, overuse of reasonable quality of land, misuse of marginal and easily degraded land, over commitment of water, population pressure, constructing dams/canals/ roads/buildings, commercial/industrial developments etc., land pollution including industrial waste, spill outs in the port areas, quarrying of minerals, etc.).

The coastal soils in India are of varied types and degraded due to salt accumulation, drainage congestion, droughtness, soil acidity etc., but mostly due to soil & water salinity and drainage congestion. Out of 10.78 m ha of land in coastal agro-ecosystem of India 3.1 m ha (Yadav *et al.*, 1983) is salt affected with drainage congestion. The nature of some of the salt affected coastal soils in India is briefly described in Table 1.

The salinity build up in soil is due to accumulation of salts in the surface soil on consequent upon upward capillary flow of brackish water from ground water at shallow depth following evaporation loss of moisture from soil surface and/ or submergence of land with brackish water from sea or estuaries. The salinity of soil & ground water

Table 1. *Geo-climatic distribution and characteristics of coastal salt affected soils in India*

Main characteristics	Rainfall (mm annum^{-1})	Distribution
1. *Saline marsh of the Rann of Kutch:* Neutral to slightly alkaline pH, high EC, preponderance of chloride and sulphate salts, light textured	< 300	Rann of Kutch in Gujarat
2. Medium to deep black soils of deltaic and coastal semi-arid region: Neutral to alkaline pH, high EC, preponderance of chloride and sulphate salts, and montmorillonitic clay minerals	700-900	Saurashtra coast in Gujarat and delta of Godavari and Krishna rivers in Andhra Pradesh
3.Deep black soils (Vertisols): Neutral to highly alkaline pH, high EC, preponderance of chloride and sulphates with or without bicarbonates, and montmorillonitic clay minerals	700-1000	Andhra Pradesh, Gujarat and Karnataka
7. Saline micaceous deltaic alluvium of humid region: Neutral, slightly to highly acidic pH, high EC, dominance of chloride and sulphate salts, rich in morntmorillonitic and illitic clay minerals	1400-1600	Sundarbans delta of West Bengal and parts of Mahanadi delta in Orissa
8. Saline humic and acid sulphate soils of humid tropical region: Highly acidic pH, high EC, presence of humic (organic) horizon, dominance of sulphate and chloride salts.	2000-3000	Malabar coast in Kerala, Sundarban delta of West Bengal and some parts of Andaman and Nicobar islands

and depth to ground water table are temporal in nature and vary with the season. Soil salinities developed due to brackish ground water are maximum in dry seasons and minimum in monsoon (Bandyapadhyay *et al.*, 1987). Depending on the nature of salts accumulated the salt affected soils may be saline or sodic. The drainage congestion is primarily due to flat topography, low elevation and presence of ground water table (brackish) at shallow depth. The rise in sea-level following global warming is likely to result in inundation of large area of coastal land under saline water, loss of biodiversity and environmental pollution are resulting in rapid deterioration of fragile coastal ecosystems, reduction in productivity of land their productivity of land, etc. leading to a crisis for livelihood options of people living in coastal areas.

Factors limiting agricultural productivity in coastal areas

The major problems adverse to successful crop cultivation in the coastal region are:

- High soil and water salinity
- Presence of brackish ground water table at shallow depth contributing to salinity build-up in soil during dry season
- Drainage congestion and low lying situation of land
- Periodical inundation of land by tidal water/ sea water
- Acute shortage of good quality irrigation water during dry months (summer and winter seasons)
- Short winter and prolonged monsoon
- Heavy and intensive rain during monsoon resulting in deep water logging of cultivated fields
- Frequent cyclonic storm along with heavy rain causing damage both to rice and upland crops

Beside these, the soils also suffer from various constraints like, sodicity, acidity, nutrient toxicities & deficiencies etc. (Bandyopadhyay *et al.*, 2001; 2003).

Strategies for increasing crop production

The major farming practices to be followed for increasing the productivity of degraded coastal land are: improving fresh water supply, decreasing salinity build up in soil, decreasing drainage congestion, improving water management/ water use efficiency (irrigation practices like, sprinkler, drip, irrigation, methods, mulching etc.), integrated farming with crop- fish- livestock, growing diversified crops & their improved varieties, improved soil management through addition of organic sources (green manuring, vermi-composting etc.), chemical amendment of problem soils (gypsum application for sodic soils, lime & phosphate application for acid sulphate soils), etc.

Rain water harvesting for irrigation resources

Most of the coastal areas in India, except parts of Gujarat and Tamil Nadu, experience high rainfall (>80%) during monsoon (*Kharif*) season with very little rainfall in rest of the period of year. Due to these lands are subjected to submergence in monsoon season and high soil salinity with very little available irrigation water during the rest of the period (dry months) of year. The cropping pattern in coastal areas is primarily mono-cropped with rice in monsoon (*Kharif*) season. The cropping intensity in rest of the period of year is very low (20-30 %) due to non-availability of rain/irrigation water and higher soil salinity.

There is high rainfall in most of the coastal areas but the major portion of rainwater is lost as run off to the sea. There are also tremendous regional disparities among the coastal areas of the country in terms of the amount of rainfall received and the percent utilized. The rainfall in many parts of the coastal areas during *Kharif* season is far in excess of the requirement of *Kharif* crop. 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 (Yadav *et al.*, 1979; 1981). The excess rain water can be stored in dug out farm pond/channels for creating irrigation resources and, drainage congestion. The stored water can be very successfully used for agriculture and aquaculture opening a tremendous scope for increasing the productivity of coastal lands.

It has been observed through large-scale demonstrations in farmers' field by CSSRI, RRS, Canning Town that adoption of appropriate land shaping technologies is very effective in mitigation of degraded coastal lands and improving their productivity. The land shaping technologies are aimed at rain water harvesting for creation of irrigation resources, improving drainage condition of farm land through land raising while harvesting the excess rain water in furrows/farm pond created out of land shaping, reducing effect of brackish ground water at shallow depth on salinity build up in soil, creating facilities in the farm for growing multiple & diversified cropping round the year instead of mono-cropping with rice in monsoon season (*Kharif*) and following integrated crop-fish-livestock farming system for higher productivity and profit. A few suitable land shaping technologies for successfully demonstrated in the farmers' fields in the coastal region of West Bengal after Bandyopadhyay *et al.*, (2009) are briefly described below.

(i). Farm pond (FP)

About 20% of the farm area is converted into on-farm pond (FP) to harvest excess rainwater. The dug-out soil is used to raise the land to form high and medium land situations besides the original low land situation in the farm for growing multiple & diversified crops throughout the year instead of mono-cropping with rice in *Kharif* season (Fig. 1). The pond is used for rainwater harvesting for irrigation and Pisciculture. Poultry/ livestock farming can also be practiced in the farm along with crops and fishes with the use of pond water. The integrated crop-fish-livestock/poultry-duckery farming is environmental friendly and efficient for integrated nutrient management in the farm. The high land free from water logging in Kharif with less salinity build up in dry seasons and thus can be used for multi & diversified crop cultivation throughout the year.

(ii). Deep furrow & high ridge (DF)

About 50 % of the farm land is shaped into alternate ridges (1.5 m top width ×1.0 m height × 3m bottom width) and furrows (3m top width × 1.5 m bottom width × 1.0 m depth) (Fig. 2). These ridges remain free of water logging during Kharif with less soil salinity build up in dry seasons (due to higher elevation and presence of fresh rain water in furrows). Remaining portion of the farmland including the furrows are used for growing more profitable paddy-cum-fish cultivation in Kharif. The rainwater harvested in furrows is used for irrigation. The remaining portions of farm land (non furrow and non ridge area) are used for low water requiring crops (like cotton, groundnut, etc.) during dry (Rabi/ summer) seasons. The rain water stored in furrows is used for initial irrigations during Rabi. The water stored in furrows is also used for fish cultivation and supplementary irrigation in Kharif. The ridges are used for cultivation of vegetables and other horticultural crops round the year instead of mono cropping with rice in Kharif. 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. The furrows provide better drainage and protect the crops from damages congestion following occasional heavy rains in Rabi/summer due to climatic disturbances. Water harvested in furrows from such rains also provides additional source of irrigation. This technology is very effective for increasing the productivity of poorly drained coastal saline lands. The effect of soil salinity is minimized thereby increasing the income, livelihood security and employment opportunities of poor coastal farmers (CSSRI, 2008).

(iii) Shallow furrow & medium ridge (SF)

About 75 % of the farm land is shaped into medium ridges (1.0 m top width × 0.75 m height × 2.0m bottom width) and furrows (2.0m top width ×

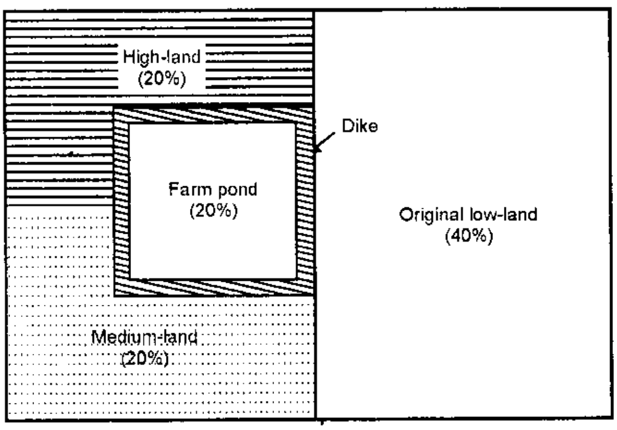


Fig. 1. Land shaping model : Farm pond

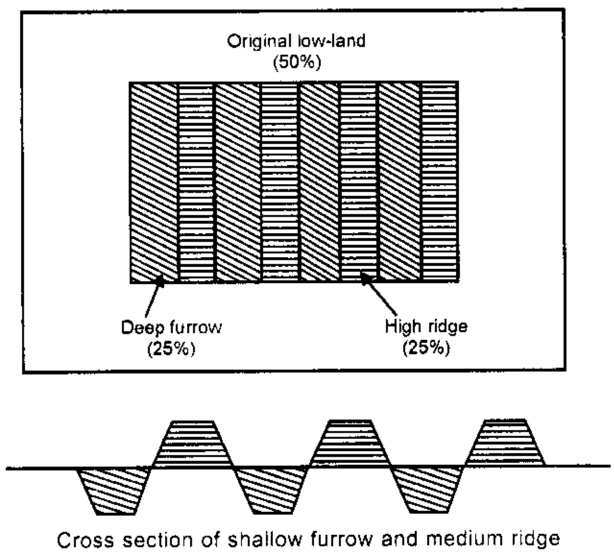
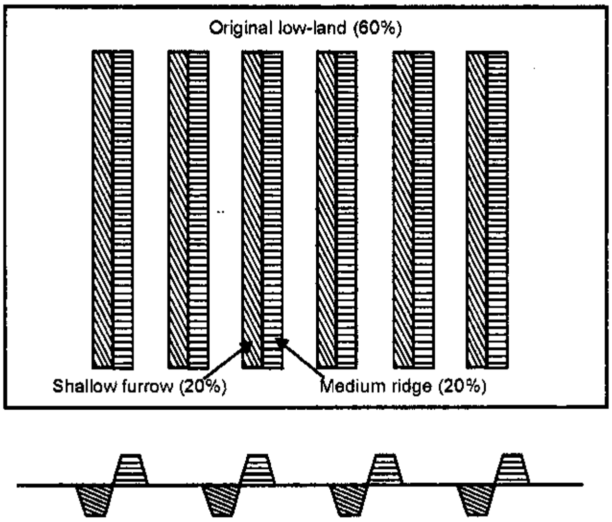


Fig. 2. Land shaping model : Deep furrow and high ridge

1.0 m bottom width × 0.75 m depth) with a gap of 3.5 m between two consecutive ridges and furrows (Fig. 3). As in DF above the furrows are used for rainwater harvesting and paddy-fish-cultivation during *Kharif.* The cropping schedule is similar to that followed in DF except rice can be grown in furrows in *Rabi*/summer with lesser supplementary irrigation.



Cross section of shallow furrow and medium ridge

Fig. 3. Land shaping model : Shallow furrow and medium ridge

(iv) Paddy-cum-fish cultivation (PFC)

Furrows (3m top width × 1.5 m bottom width × 1.0 m depth) are dug around the periphery of the farm land leaving about 3.5m wide outer from boundary and the dug out soil is used for making a bund (about 1.5 m top width ×1.0 m height × 3m bottom width) to protect free flow of water from the field and harvesting more rain water in the field and furrow (Fig. 4). The bunds are used for vegetable cultivation through out the year. Remaining portion of the farm land including the furrows is used for more profitable paddy-cum-fish cultivation in *Kharif.* The land (non furrow and non ridge area) is used for low water requiring crops during dry (*Rabi*/summer) seasons with the rain water harvested in furrows Presence of deep furrows in the field provides better drainage condition in the field during the non-monsoon months. During the dry seasons the land can also be used for remunerative brackish water fish cultivation with the plenty of brackish water (ground/river water) available in the area. The land can again be used for paddy-cum-fresh water fish cultivation in *Kharif* if the brackish water is pumped out (required for harvesting of fishes) and the land is allowed to wash out the salts with a few initial pre-monsoon heavy showers common in the area.

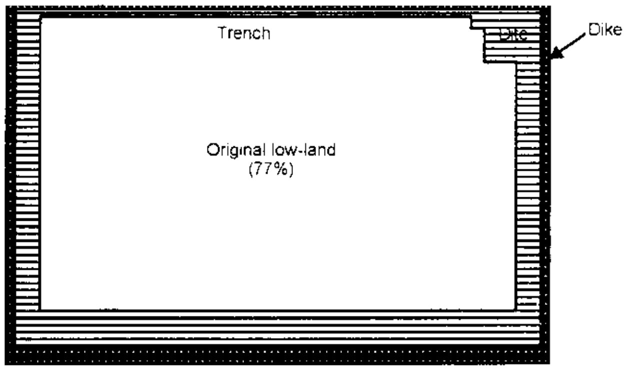


Fig. 4. Land shaping model : Paddy-cum-fish cultivation

b) Improved soil and water management for higher productivity

During the dry season with progressively drying of soil due to evapo-transpirational losses, the concentration of salts in the soil solution increases and, therefore, its osmotic pressure increases making the soil water increasingly difficult to be absorbed by the plants Any practices that reduce evaporation from the soil surface and / or encourage downward flux of soil water will help to control root zone salinity. Sandoval and Benz (1966) and Benz *et al.*, (1967) studied soil salinity changes as affected by bare fallow and straw mulch on fallow over a three years period. Their results showed under straw mulch there was a significant reduction in soil salinization, which resulted in an increased wheat yield by about two folds. Fanning and Carter (1963) reported significant reduction in root zone salt concentration of plots where cotton-burr mulch was applied at the rate of 90 tons per hectare. These workers also reported that periodic sprinkling of mulched soils resulted in greater salt removal and therefore higher leaching efficiency than did flooding or sprinkling of bare soil (Carter and Fanning, 1964). Irrigation method can also play a very important role in controlling salts in the root zone. Trickle or drip and Sprinkler irrigation methods are very appropriate for efficient use of limited amount of irrigation water in coastal areas. These methods are more suitable for perennial or seasonal row crops. The water of poorer quality can be better used with these two methods (sprinkler and trickle) compared to the conventional flood or furrow methods of irrigation. Although sprinkler and trickle irrigation methods are highly efficient, from the views of water use efficiency, use of poor quality water and soil salinity control, their high initial costs often preclude their use in coastal regions.

The coastal soils are usually rich in available K and micro nutrients (except Zn), low to medium in available N and are having variable available P status (Bandyopadhyay *et al.*, 2001; 2003; Maji and Bandyopadhyay, 1990; 1992). The soils usually do not require K application except when the soils are deficient in K (Bandyopadhyay and Maji, 1993). In many cases phosphorus may show very poor response or no response of crops, particularly, of rice, but a minimum quantity of basal P application is necessary to maintain the P fertility level (Bandyopadhyay and Maji, 1993) Nitrogen is the single most important element determining crop production in many coastal areas. Major portion of applied N fertilizer is lost through volatilization (Sen and Bandyopadhyay, 1987).

Saline soils have low organic matter content and the efficiency of N fertilizer usage by crops is very poor. Bandopadhyay and Bandopadhyay (1983) showed that the rates of both mineralization and immobilization in nitrogen in soils considerably reduced at soil salinity of ECe > 10 dSm^{-1}. A major portion of the applied nitrogen is lost through ammonia volatilization in saline soils (Sen and Bandyopadhyay, 1987) and the losses increase with soil salinity. Volatilizationloss of nitrogen could be substantially reduced (by about 90 %) if the nitrogenous fertilizer is placed at a depth of 5-10 cm in soil. The efficiency of inorganic nitrogenous fertilizers could also be increased substantially through combined use of inorganic sources with organic manures ((Patil *et al.*, 1991) like vermi-compost, FYM, green manures, etc. The efficiency of inorganic N fertilizer can be increased by 25-50 % ((Patil *et al.*, 1991) when used in combination with organic sources. In view of high shortage of organic resources in coastal areas green manuring and vermi-composting have tremendous scope in the area. Integrated nutrient management has been found to be very effective for preserving soil soil health, maintaining soil biodiversity, increase in fertilizer use efficiency and sustaining higher yield of crops on coastal saline soils (Bandyopadhyay and Rao, 2001; Bandyopadhyay et al., 2006; Tripathi *et al.*, 2007). The application of lime and higher dose of phosphatic fertilizers and green manure are highly beneficial for acid sulphate soils (Bandyopadhyay and Maji, 1999; Burman et al., 2010). Half dose of lime was as beneficial as full dose. Application of gypsum or other suitable amendments been recommended for the amelioration of sodic soils (Gupta and Abrol, 1990). The gypsum equivalents of different amendments are given in Table 2.

Table 2. *Gypsum equivalents of different amendments*

Amendment	Equivalent
Gypsum ($CaSO_4.2H_2O$)	1.00
Calcium chloride ($CaCl_2.2H_2O$)	0.85
Sulphur	0.19
Sulphuric acid	0.57
Iron sulphate ($FeSO_4.7H_2O$)	1.62
Aluminium sulphate ($Al_2SO4.18H_2O$)	1.29
Calcium polysulphide (CaS_5, 24%S)	0.77
Iron pyrites (FeS_2, 30% S)	0.63

d) Crops and their management for higher yield

Crops vary not only in their tolerance to salinity but also in their water requirements. Plants are usually less tolerant to soil salinity at initial stages, flowering stages and other active growth stages. Since there is temporal variation in soil salinity in the coastal region the crops having less tolerance (to salinity, should be grown during the period when soil salinity is minimum. The soil salinity in the field varies with the season being minimum in monsoon months (July- October) and maximum in summer months (April- May) (Fig. 5). Considering the salinity build up pattern of soil, the normal time of planting time may be advanced or delayed, so that plant roots encounters less salinity. The cropping pattern in rabi/summer seasons should essentially be based on crops with low water requirements. As irrigation water is scarce, the advantage of the moisture present in the soil at the time of harvest of Kharif rice is to be utilized.

Suitable varieties of rabi field crops like, sunflower, cotton, groundnut, etc. and vegetable crops like cucurbits, tomato, brinjal, knolkhol, sweet potato, leafy vegetables, etc. are to be developed and introduced in coastal salt affected areas for higher yield. The crop varieties to be developed should have

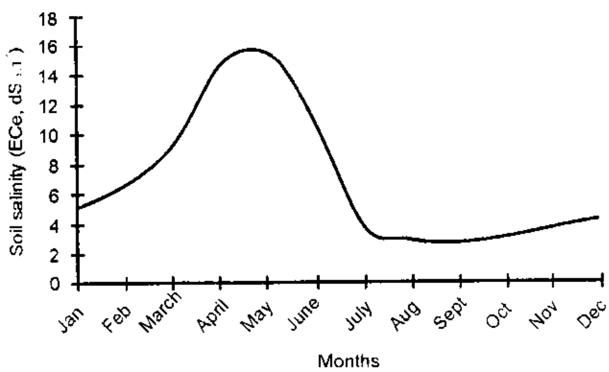


Fig.5. Mean soil salinity in different months

the characteristics of salt & drought tolerance, high yield, short duration and low water requirement. Findings of CSSRI revealed that seasonal flowers and spices crops could also be grown at suitable land situation after harvesting of the Kharif paddy (CSSRI, 2007). There is a great scope for cultivation of wide varieties of fruit, vegetable, plantation, spices and medicinal crops, etc. in coastal area after suitable land shaping. Fruit/plantation crops like coconut, areca nut, sapota, guava, jamun, oil palm, cashew & cocoa, and spices like black pepper, cardamom (small and large), termeric, black cumin, coriander, fennel & fenugreek, etc. can be grown in different coastal areas but their selection should be location specific and according to the land situation (Ghosh, 1999).

e) Integrated cropping system for higher productivity and income

The cropping system in coastal areas is predominantly rice based mono-cropping. But the growth rate in rice on decline due to several soil and climatic constraints. A change in cropping system is needed for higher productivity and income. For increasing productivity of coastal land integrated farming involving 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 farming system, which should be compatible with the available land and water resources. Importance of simultaneous development of both agriculture and fisheries has been recognized by the researchers (Prain,1994; Natarajan and Ghosh, 1980; Sinha, 1981; Srivastava *et al.*, 2004; Pandey *et al.*, 2005; Halwart and Gupta (2004). 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 fish cultivation along with prawn can give much higher income. Composite fish culture instead of monoculture needed to be followed in inland fresh water fisheries for higher productivity and income. Increase in fish production can play a key role for improvement of economic and nutritional status of poor coastal farmers. Mixed crop-fish cultivation/paddy-cum-fish/prawn culture is necessary for higher return out of the limited amount of land and water resources (Biswas *et al.*, 1988).

g) Agro-forestry/ forestry

Development of agro-forestry, has significant productive as well as protective functions in the coastal areas. Salinity and waterlogging resistant trees are to be introduced for meeting the local requirement (Burman *et al.*, 2007a).

Some of the promising agro-forestry plants in the area are: Casuarinas, Eucalyptus, Acacia (Burman *et al.*, 2007b). Detailed research work on site specific agro-forestry system of cultivation and suitability indices of agro-forestry plant species in different coastal agro-ecosystems will help to develop more productive, and resource and environment conserving strategies for the coastal areas.

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. These forests have also rich heritage of biodiversity. Mangroves colonies stabilize the saline silted lands/ wetlands adjoining the coastal line and are also valuable repositories of biodiversity. They act as a bio-shield in protection of the shoreline against erosion caused by wave action and cyclones. These mangroves have undergone substantial degradation as a result of human interferences, and many species are in alarming state of extinction, resulting immense danger to the sensitive ecosystem of the coastal belt.

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Improved Soil Management Practices for Enhancing Crop Production and Reducing Soil Degradation in Coastal Regions of India

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The coastal ecosystem, which has a significant role in food grain production, is, highly risk-prone and vulnerable due to extremely fragile ecological situation and changing climate scenarios. Most of the areas have problematic soils, such as, saline, alkaline, acid sulphate and marshy and waterlogged soils, situated in the low-lying flooded and waterlogged areas, mainly along the deltas. Agriculture on the coastal plain is also constrained by a number of technological, social and climatic factors limiting the productivity. Certain location-specific problems viz. Fe toxicity in the soils of Orissa, highly permeable sandy soils in parts of Gujarat and highly leached low-fertility lateritic soils in Maharashtra, Karnataka and Kerala are also encountered in the coastal soils. Crop failures due to acidification and salinization are common in acid sulphate soils and tidal marshy areas of Kerala and West Bengal. The role of drainage for desalinization of salt affected soils, use of surface water for irrigation with minimum dependence on groundwater and locaton-specific integrated water and nutrient management models under varying soil salinity and water management scenarios have been discussed. For improved fertility management of crops in salt affected and low lying soils, integrated approach for supply of nutrients has been suggested to attain higher nutrient-use efficiencies and crop productivity. Key strategies for integrated coastal area management for livelihood security have also been discussed.

(***Key Words:*** *Coastal ecosystem, Problem soils, Soil and Water management, Nutrient management, Coastal saline soils)*

About 50-70 % of the global population lives within 100 km of the coastline covering only about 4% of earth's land, out of 328 mha of geographical area of India. According to Velayutham *et al.*, (1998), 10.78 million hectare land area is under the coastal ecosystem (including the islands) in India (Table 1). The coastal ecosystem has a wide variability in climatic, topographical and edaphic conditions and supports diverse cultivated crops as well as natural vegetation ranging from tropical rain forests to coastal mangroves (Table 2). The vast deltaic region of east coast forms the rice bowl of the country. Of all the major ecosystems, coastal has a significant role in food grain production. The ecosystem is, however, highly risk-prone and vulnerable causing colossal damage to lives and properties, and this is further compounded due to climate change (Yadav *et al.*, 2009). Despite unique endowments suited to diversified and productive farming systems, the productivity growth rate in the coastal areas are lagging behind due to extremely fragile ecological situation.

Most of the areas have problematic soils, such as saline, alkaline, acid sulphate and marshy and waterlogged soils, situated in the low-lying flooded/ waterlogged areas, mainly along the deltas (Sen *et al.*, 2000). Agriculture on the coastal plain is constrained by a number of technological, social or anthropological, and climatic factors limiting the productivity. The salient factors are: (i) Excess accumulation of soluble salts and alkalinity in soil, (ii) Pre-dominance of acid sulphate soils, (iii) Toxicity and deficiency of nutrients in soils, (iv) Intrusion of seawater into coastal aquifers, (v) High depth to underground water table rich in salts, (vi) Periodic inundation of soil surface by the tidal water vis-à-vis climatic disaster and their influence on soil properties, (vii) Heavy soil texture and poor infiltrability of soil in many areas, (viii) Eutrophication, hypoxia and nutrient imbalance, (ix) Erosion and sedimentation of soil, and (x) High population density (Yadav *et al.*, 2009). It is, therefore, essential to address these issues in relation to the holistic development of coastal ecosystem and to formulate relevant strategies with a long-term perspective to improve the quality of life of the coastal people.

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Table 1. *Distribution and extent of Indian coastal area*

Sr. No.	State/Union territories	AESR No.	Area (km²)	pH(1:2.5)	EC(dSm⁻¹)	O.C.(%)	CEC (cmol(P+)kg⁻¹	B.S. (%)
1.	West Bengal		14,152					
	i) Bengal Basin	15.1		6.3-7.4	1.5-9.8	0.15-0.52	19.4-22.7	70-80
	ii) Gangetic delta	18.5		6.5-7.6	4.1-35.0	0.3-0.78	6.6-10.6	74-82
2.	Orissa		7,900					
	i) Utkal plains	18.4		6.7-7.4	-	0.10-0.22	12.8-13.4	75-85
	ii) Gangetic delta	18.5		4.5-6.3	-	Tr.-0.20	33.8-55.5	49-69
3.	Andhra Pradesh		35,500					
	i) Andhra Basin	18.3		8.0-8.4	4.6-27.0	0.9-1.1	2-6	-
	ii) Godavari delta	18.4						
4.	Tamil Nadu		7,424					
	i) South Tamil Nadu	18.1		5.1-6.1	-	0.06-0.09	4.0-6.6	89-100
	ii) North Tamil Nadu	18.2						
5.	Kerala	19.3	7,719	2.4-3.2	-	9.2-19.9	26.4-58.0	8-57
				5.1-5.6	-	0.3-2.6	3.9-7.6	48-58
6.	Karnataka		7,424					
	i) Karnataka coastal plains	19.3		3.9-5.7	-	0.07-1.23	0.7-4.6	29-89
7.	Maharashtra		10,000					
	i) Konkan coast	19.1		6.6-7.0	-	0.4-0.7	20.8-28.0	40-45
	ii) Konkan coast plains	19.3						
8.	Goa		2201					
	i) North Saihadris and Konkan coast	19.1		5.4-5.9	-	0.28-0.60	0.5-7.8	48-69
	ii) Konkan cost plains	19.3						
9.	Gujarat		17,465					
	i) Kachcch Peninsula	2.2		8.2-8.7	0.20-6.50	0.18-1.10	1.3-3.7	-
	ii) North Kachcch & north Kathiwar Peninsula	2.4		7.7-8.0	0.46-3.20	0.13-0.15	12.26-19.26	
	iii) Coastal Kathiwar Peninsula	5.3						
10.	Andaman & Nicobar							
	i) Coastal of Andaman & Nicobar Islands	20.1						
11.	Lakshadweep							
	i) Coastal level Lakshadweep & group of islands	20.2	262	8.5-9.1	0.1-0.2	0.11-0.77	0.4-1.5	100
12.	Pondicherry and karaikal	18.4	3	-	-	-	-	-
	Total	-	1,07,833	-	-	-	-	-

Table 2. *Forest area and cropping intensity in the coastal zones of India*

Item	East coast	West coast	Islands
Geographical area (x1000 km²)	197	117	8
Forest area (%)	18.7	29.0	88.1
Cropping intensity (%)	134	123	142

Soil Resources and Problem Soils

The coastal soils show tremendous variability. Broadly, the soils in the east coast are fertile, predominantly in the deltaic alluvium. The other soils belong to red loam, red sandy loam, sandy clay, coastal sand and black group. The soils of the west coast, on the other hand, consist mainly of laterites, lateritic, clay loam, gravelly clay, sandy loam, and coastal sand. The salt affected soils occupy extensive area spread over both east and west coast regions, and include saline, sodic, acid sulphate, marshy and waterlogged subgroups situated in the low-lying areas (Yadav *et al.*, 2009). Soil salinity hampers crop production in the coastal ecosystem to such an extent that the term 'coastal saline soil' has become almost synonymous with the entire ecosystem (Table 3). Impeded drainage, inundation, and ingress of sea water have led to the development of salinity and alkali conditions, rendering vast tracts of Khar, Pokhali and Kole lands unsuitable for cultivation. Certain location-specific problems are also encountered in the coastal soils, viz. Fe toxicity in the soils of Orissa, highly permeable sandy soils in parts of Gujarat, and highly leached low-fertility lateritic soils in Maharashtra, Karnataka and Kerala. Crop failures due to acidification and salinization are common in the acid sulphate and tidal marshy areas of Kerala and West Bengal. High intensity rains result in heavy leaching, causing nutrient losses and formation of acid lateritic and laterite soils in the highly permeable areas, especially in Orissa and Kerala. Phosphorus and zinc deficiencies are common and widespread, while Fe and Al toxicities are confined to the acid laterite and lateritic soils. Inadequate amount of K and Ca occurs in acid soils and coarse-textured soils. The acid sulphate soils with distinct characteristics occur in the low-lying areas of Kerala, Sundarbans of West Bengal, Andaman & Nicobar Islands, and are highly acidic having toxic content of soluble Fe and Al (Maji and Bandyopadhyay, 1991). These soils mostly develop as a result of drainage of those soils that are rich in pyrites (FeS_2), which on oxidation produce sulphuric acid. These soils are very poor in available P but rich in organic matter (Bandyopadhyay and Maji, 1995).

Soils of coastal areas are generally deep to very deep having coarse sandy to fine loamy texture, non-calcareous to calcareous, poor to rich in organic, slightly to moderately saline, and highly acidic to alkaline. In many coastal areas uncontrolled extraction of ground water has resulted in intrusion of seawater and development of high salinity. Important physical and chemical properties of coastal soils of India are given in Table 1 (Velayutham *et al.*, 1998). Some details in respect of (1) coastal saline soils, (2) acid sulphate soils, and (3) coastal sand dunes are given below:

Coastal saline soils

Out of 49 million hectare area under the salt affected soils in the South and Southeast Asia, about 27 million hectares (55%) are within coastal areas. In India, the salinity status in saline soils varies widely from ECe 0.5 dSm^{-1} in monsoon to 50 dSm^{-1} in summer. NaCl followed by Na_2SO_4 are the dominant soluble salts, with abundance of soluble cations in the order Na>Mg>Ca>K with chloride as the predominant anion, and bicarbonate in traces. The soils are, in general, free of sodicity problem except in a few pockets in the south and west coast.

Acid sulphate soils

Acid sulphate soils contain sulfides (mainly pyrites), which become very acid when sulfides are oxidized to sulphates on drying; and usually have a pH below 4 in water. Acid sulphate soils cover large areas of temperate lands. In India, presence of acid sulphate soils has been reported in the lowlying coastal areas of Kerala, Andaman and Nicobar islands, and recently in the coastal areas of Sundarbans, West Bengal (Bandyopadhyay and Maji, 1995). Acidification of these soils is caused by a combination of abiotic and microbial oxidation of pyrites (FeS_2).

Many plants appear to be able to tolerate relatively large concentrations of H^+, although work using solution cultures indicates some root injury at low pH. It is probable that Al and Mn toxicity is more important than that due to H^+. In acid sulphate soils, phosphate deficiency is widespread and also there are deficiencies of Ca and K; whereas the levels of exchangeable Mg may be high (Sen, 2009).

Coastal sand dunes

Coastal sand dunes are deficient in plant nutrients due to extensive leaching which occurs during their formation, transport and deposition. Dune fertilization is a useful management tool for

Table 3. *Major a biotic stresses common to coastal problem rice soils in India*

Ecosystem	Major Problem	Deficiencies	Toxicities	Other stresses
Rainfed and Irrigated	Acid and Acid Sulphate	P, N	Acidity, sulfate, Al,Fe, salinity	Inhibition of nutrient uptake, flooding
-do-	Peat (Histosols)	N, P, K, Zn, Mo, Cu, and B	Acidity, Fe, H_2S, organic substances	Water logging, low thermal conductivity
-do-	Salinity	P, Zn, N	Salts (Ca, Mg, Na)	Submergence, Stagnant flooding, Drought

improving the establishment and growth of new plants. If fertilization of sand dunes with urea is contemplated as a management tool, it may be prudent to apply a nitrification inhibitor such as N-serve in order to minimize NO_3-N losses. On the other hand, such a combination might enhance NH4-N volatilization, thereby necessitating the addition of urease as well as nitrification inhibitor.

Soil and Water Management

Drainage and desalinization:

Leaching requirement depends largely, among other factors, on the irrigation water quality and method employed, soil texture, salinity tolerance limit of the crop grown, etc. Adequate drainage for desalinization of the soil and removal of water congestion needs necessary attention along with appropriate flood control measures in the coastal low-lying areas. Different aspects of flood control and drainage in coastal areas have been discussed (Rao, 1991) with respect to India. It was suggested that the land should be protected from tidal inundation through protective embankments, generally, with 3:1 slope at the river end and 2:1 slope in the country end having 1 m free board above the high tide level. Brick pitching of the earthen embankments, wherever possible, and planting of wind breaks (Nanda and Rai, 1979) in areas having problems of coastal sand dunes proved useful. It was suggested to install one-way sluice gates on the river banks or any other suitable location to drain out excess water from the land during low tides in river. Specific design of the sluice gates will depend on the drainage coefficients, which have been worked out for different coastal tracts in India (Rao and Dhruvanarayana, 1979).

Modelling for desalinisation

Significant efforts were made to develop models to desalinize the salty soil through drainage under specified conditions. Different agro-hydro-salinity models, viz. 'SALTMOD', 'DRAINMOD-S' or 'SAHYSMOD' have been developed (Oosterbeen, 2002, 2005). It was developed based on sound principles of moisture and solute transport, for unconfined and semi-confined aquifer, which have been tested in the field mostly under arid or semi-arid conditions in order to predict the water distribution and salt balance in the soil profile following different practices of drainage and their response on crop function. SALTMOD model was also applied in coastal clay soils of Andhra Pradesh in India where subsurface drainage system was laid out at several drain spacing. The study suggested that the model could be used with confidence to evaluate various drain spacing of subsurface drainage system and facilitate reasonable prediction of the reclamation period (Singh *et al.*, 2002).

Use of amendment

For non-saline sodic soil, incorporation of relatively soluble calcium salt like gypsum, phosphogypsum, iron salt like pyrite, $CaCl_2$, sulphuric acid (H_2SO_4), or other acid formers like sulphur (S), lime-sulphur (9% Ca + 25 % S), ferric sulphate, aluminum sulphate, etc. to replace exchangeable sodium from the clay complex, along with recommended water and crop management practices, have been reviewed by many workers for reclamation of these soils in general. Occurrence of non-saline sodic soil is, however, much less in the coastal plain than in inlands, and, in case of the former, attempts made for experimental verification have mostly been limited to the use of locally available organic waste, like paper mill sludge or other industrial effluent as well.

Management for acid sulphate soils

For reclaiming or improving potential and young acid sulphate soils following approaches have been suggested: (i) pyrite and soil acidity can be removed by leaching after drying and aeration, and (ii) pyrite oxidation can be limited or stopped and existing acidity inactivated by maintaining a high water table, with or without (iii) additional liming and fertilization with phosphorus, though liming may be often uneconomic in practical use. The reclamation method cited at (ii) above, for maintaining a high water table to stop pyrite oxidation and inactivate existing soil acidity, has the advantage that its effects are usually noticeable much quicker. Upon waterlogging, soil reduction caused by microbial decomposition of organic matter lowers acidity and may cause the pH to rise rapidly to near-neutral values. The method is particularly suitable with rice cultivation. The crucial factor is, of course, the availability of fresh water for irrigation. The less toxic and deeper developed older acid sulphate soils are moderately suitable for rice and can be improved by sound agronomic practices. Improved water management and intensive irrigation have dramatically increased the productivity of these highly acid soils.

Large scale engineering schemes for reclaiming potentially acid, and usually strongly saline, coastal swamp are however rarely economic. The injudicious reclamation of seemingly suitable land in coastal swamps by excluding salt water through dicing and by excavating fishponds has led to the destruction and abandonment of thousands of hectares of mangrove land in Southeast Asia and Africa. However, unless sufficient fresh water is available and other pre-requisites for good water management exist, the potential acid sulphate soils as young and strongly acidic in character should not be reclaimed, but are better left for other types of land use, say conservation, forestry, fisheries and, sometimes, salt pans, etc.

In India, for the coastal acid sulphate soils of Sundarbans, application of lime, super phosphate and rock phosphate have been found beneficial in improving the soil properties and rice growth (Bandyopadhyay, 1989). Application of Ca-rich oyster shell, which is available in plenty, was found beneficial, if applied in powdered form, as an inexpensive alternative soil-ameliorating agent. In this soil continuous submergence for one year could not improve the soil properties substantially.

Mongia *et al.*, (1989), while reporting for two soils in Andaman Islands observed that application of lime and phosphorus may be beneficial for lowland rice, but the soils should be leached of excess salts in case of high soil salinity before using these amendments. In another study on mangrove (*Avecenia marina*) mud's in this island, it has been reported that liming significantly depressed the concentrations of Al, Mn and Fe. Exchangeable Al content also decreased with lime application. The depression of exchangeable Al may be due to precipitation of trivalent Al and $Al(OH)_3$ in the presence of high concentration of OH^- ions. Lime application, in general, also reduced the exchangeable and extractable Fe contents of the soil.

Integrated water management

The coastal plain represents, in majority of the cases, aquifer present at large depths containing fresh water, which has no consequence to salt accumulation in the crop root zone, but are often combined with water table, rich in salts, present at a very shallow depth (generally not exceeding a depth of 2 m below the soil surface). The net salt loading in the root zone will be positive (salinity will build up) or negative (desalinization will take place) depending upon the relative rate of recharge of salts by upward rise to rate of downward flux of salts by leaching. The relative salt loading will thus be treated generally as positive during dry season, and negative (waterlogging on the soil surface) during wet season due to high rainfall, and the process will be repeated each year in a seasonally cyclic mode.

On the other hand, in view of the susceptibility of the coastal plains to seawater intrusion and its adverse impact on soil and plant growth, the practice for use of ground water, even if in small quantity, for irrigation should be very carefully exercised, for which suitable optimization model may be used as discussed earlier, if not eliminated altogether. It should not be difficult to avoid using the underground water, if properly planned, by increasing the surface storage of runoff water by an equivalent amount or more. Thus, water management in the coastal plains should principally revolve round creating more fresh surface water sources and their proper management with little dependence on the subsurface source in order to maintain stability of the ecosystem.

In spite of the coastal ecosystem presenting a delicate equilibrium among the different components, there is, however, no firm strategy, as of now, for exploitation of water resources for irrigation and other purposes for long term solution in any sector.

Ambast and Sen (2006) developed a computer simulation model and a user-friendly software 'RAINSIM', primarily for Sundarbans region for small holdings, based on the hydrological processes, and the same tested duly for different agro-climatic regions in India. The software may be used for (i) computation of soil water balance, (ii) optimal design of water storage in the 'On-farm reservoir (OFR)' by converting 20% of the watershed, (iii) design of surface drainage in deep waterlogged areas to reduce water congestion in 75% of the area, and (iv) design of a simple linear programme to propose optimal land allocation under various constraints of land and water to arrive at a contingency plan for maximization of profit. They also reported use of remote sensing and GIS in mapping lowland lands, vegetation, and crop yield estimation, along with performance assessment of irrigation/ drainage systems. Similar models may be tested and validated under wide variety of situation in India and other countries.

Improved irrigation

No single irrigation method can be expected to be universally the best, particularly as the criteria applied may not be the same. We do not intend to make any detailed discussion on different practices here but would like to highlight that in actual practice, application efficiencies of surface systems range between about 30 and 60% with the latter figure being found in modern, well designed and managed systems; sprinkler systems generally achieve efficiencies in the range of 60–85%, and drip systems commonly operate at 85–95% efficiency (Rawitz, 2008).

Fertility Management

Integrated nutrient management

Sources of biofertilizers, *viz. Rhizobium* cultures for pulse or legume, and blue-green algae for waterlogged rice field may play a significant role in terms of integrated nutrient management for rice in coastal saline soils (Kundu and Pillai, 1992).

Long term field experiment in coastal saline soils in India showed that rice and wheat yield could be maintained even at 50% NPK used in conjunction with FYM or green manure. In a detailed long term experiment conducted in Sundarbans (India) it was observed that grain yield of crops in a rice-barley rotation increased significantly only due to the application of N. Application of P did not show any significant increase in the yield of crops in the initial 8 years, after which the yield of barley alone increased due to P application. Available K content was high in the soil. The experiments conducted so far showed that a basal dose of 11 kg P ha^{-1} for rice and 5.5 kg P ha^{-1} for barley or for similar upland crops should maintain the fertility status of the soil, whereas the K application may be omitted without any detrimental effect on soil fertility or crop growth. The K removal by the crop was compensated by K added through accumulation and release of non-exchangeable sources (CSSRI, 1990).

Options for improved nutrient management

Adequate phosphorus nutrition has been found essential for effective ion compartmentation by contributing to efficient carbohydrate utilization in salt-stressed plants. P translocation from roots to young shoots should increase in the presence of an additional supply of Ca^{2+}. An increased Ca^{2+} supply to the plant could be more efficient than P fertilization itself in restoring the P supply to young tissues under saline conditions.

Elevated Ca^{2+} levels may protect the plant from NaCl toxicity by reducing the displacement of membrane-associated Ca^{2+} by reducing Na+ uptake and transport to the shoots or by a combination of these effects. Ca^{2+} also improves K^+ uptake under NaCl salinity, effectively improving on the Na/K value in the tissues. An increase in the Cl^- concentration, on the other hand, in the nutrient media may lead to a reduction in the NO_3 content of plants, observed in case of tomato. Under saline conditions, a high Ca^{2+} supply should alleviate the inhibition of NO_3^- uptake and increase Na/K selectivity. Supplementation of Ca^{2+} may also improve the growth rate of the plants in the NO_3 treatment based on which it may be suggested that NO_3^- is possibly a better N source than NH_4^+.

In coastal flooded saline soils measures should be taken to reduce volatilization loss, in particular, either through placement of N-source (urea) at sub-surface depth, through application of slow release source, through use of urea inhibitor, or by adjusting the time of application coinciding with the plants' active growth stage, for higher N-uptake.

Under flooded condition, soil organic matter contributes to Fe and Mn availability through the formation of metallo-organic complexes with organic substances. This phenomenon may be attributed to the production of chelating agents from compost that generally keep the micronutrient elements soluble and, consequently, more available to crop plants. Increased Fe and Mn solubility in flooded soils benefits rice, which has a higher requirement for these elements. There is concomitant increase in pH, CO_3^{2-}, and DTPA extractable Fe and Mn on the submergence of a lowland rice plants. Under flooded conditions, the production of organic complexing compounds and reductions of Fe and Mn tend to enhance the solubility of Zn and Cu in the growth media. Contradictory results are also, however, available. When a soil undergoes reduction by flooding, the breakdown of Fe and Mn oxides may provide an increased surface area with a high adsorptive capacity onto which Cu and Zn may be firmly adsorbed in some soils.

Plant-growth promoting microorganisms (PGPMs) may contribute to solubilize and/or acquire essential minerals, making scarce nutrients more available to the plant. On the host, they stimulate several physiological changes that could lead to better growth and render the plant more tolerant to abiotic stresses. Amongst PGPMs, *Azospirillum* is one of the most studied genera. Even though it colonizes different plant species in an ample variety of soils, its favourable effects on vegetable germination, emergence and growth have not been thoroughly studied. The review (Barrasi *et al.*, 2007) describes the beneficial effects PGPM inoculation could have on vegetables growing either under normal or stressful conditions including salinity, with an emphasis on the use of *Azospirillum*. Focus may be made on the recent advances on *Azospirillum*-plant interactions and the bacterial mechanisms of plant growth promotion. For sustainable soil health in order to ensure improved plant nutrient status and its use by the plants the importance of improved soil quality in the coastal plains through higher SOC level of the soils, for which C sequestration is one of the important pathways, may be emphasized since low lying coastal soils may be a useful sink for higher organic carbon pool for the terrestrial system.

Based on earlier observations on acid sulphate soils attempt may be made, in the absence of soil liming, to explore the utility of organic wastes which may improve the performance of Al-tolerant crops while permitting the cultivation of more Al-sensitive crops on these soils. Further research should aim at identifying most appropriate substrate types and application rates for specific acid soil conditions and crop tolerance levels (Sen, 2009).

Conclusions and Recommendations

Multi-disciplinary resource inventory needs to be generated to facilitate micro level planning for higher and sustainable productivity. Mapping of the coastal areas for the whole country in a smaller scale with the help of modern tools like remote sensing and GIS should be taken up for characterization of the coastal soil resources for effective coastal ecosystem planning for improved irrigation and land drainage practices, nutrient management and other land use options.

Appropriate data bank should be created with land use suggestions for the different coastal ecosystems. Soils having problems of acidity may be delineated with suggestive management practice(s) for improved productivity. Location-specific toxicity problems of iron, aluminum, sulphide, magnesium and deficiency of phosphorus and other micronutrients, nature and extent of problems like high salinity, alkalinity and acidity should be identified and the areas delineated.

Massive afforestation programmes with suitable species particularly in the hilly and other vulnerable areas may be taken up to protect the landmass by appropriate plant cover. Flora, including the plantation and grass species, suited to a particular site, should be identified and exploited for soil conservation to prevent water and wind erosion to protect the sandy sea shores. Forest species such as *Casuarina equisetifolia, Anacardium occidentale, Acacia mangium, Acacia auriculiformis, Leucocephala* spp. and *Thespesia populnea* were some of the preferred species as coastal wind breaks.

Improvised Doruvu technology for irrigation by skimming of water at shallow depths, floating over saline water, should be utilized suitably particularly for sandy soil areas in Andhra Pradesh and similar tracts. Use isotope tracer technique for precise estimation of groundwater recharge, salinity and pollution problems, interconnection between different water resources, dating of groundwater, seepage losses and extent and nature of sedimentation in rivers and lakes, etc. should be taken up. Micro-watershed approach for harvesting and recycling of stored excess rain water in dug-out pond, with suggestion for a suitable crop calendar for judicious use of this water, should be the model approach for increasing crop productivity in the coastal ecosystems having acute shortage of irrigation water.

Development of integrated watershed management practices with particular reference to the areas prone to periodical inundation with tidal water, areas having shallow water table enriched with salts and areas with poor drainage and lack of good quality water was stressed. For utilization of poor quality water for irrigation it was suggested to (i) monitor the quality of water in rivers, canals and creeks periodically, (ii) develop model on crop-soil-climate relationship under different qualities of irrigation water and suggest suitable package including poor quality water as a component for sustainable productivity, and (iii) identify suitable amendments, if any, to counter the problems due to irrigation by poor quality water.

EPILOGUE

The opportunities for salinity researches due to the size and diversity of our country where all types of salt affected soils and waters of varying quality are encountered require specific solutions. The vast amounts of salt affected soils, which are yet to be reclaimed as well as areas undergoing secondary salinization represents an opportunity to demonstrate the technology developed and bring benefits to the country. The large areas undergoing secondary salinization gives an opportunity to test the scope of strategies like irrigation system improvement interventions and other preventive strategies to check the spread of salinity and waterlogging. Increasing industrialization due to economic liberalization will lead to increasing environmental problems; have adverse effect on soils and water quality, requiring developing newer technologies. Enormous biodiversity of plant resource, liberalization in government policy for exchange of germplasm, newer tools like remote sensing, biotechnology, etc. create additional research opportunities.

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State-wise Distribution of Soils under Coastal Agro-ecosystem, Land use Planning under Coastal Ecosystem: Assess and Way Forward

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The coastal zone represents the transition from terrestrial to marine influences and *vice-versa*. It comprises not only shoreline ecosystems, but also the upland watersheds draining into coastal waters and the near shore sub-littoral ecosystems influenced by land-based activities. Functionally, it is a broad interface between land and sea that is strongly influenced by both. The region experiences mild and short winters during December to February; hot and humid summers during March to May; rainy period during June to September with extended rainy period of October to November in the southern most peninsula. Normal annual rainfall is usually more than 100cm in all coastal ecosystem excluding north Gujarat; west coast receives more than 250 cm of rainfall. The average maximum temperature is 25-35°C and relative humidity is 65-95%. Coastal region in India is bounded by the Arabian Sea in the west, the Bay of Bengal in the east and Indian Ocean in the south. The country also has two district major island ecosystems - the Andaman and Nicobar group of islands in the Bay of Bengal and the Lakshadweep in the Arabian Sea. India with a 8129 km long coastline is endowed with rich natural resources constituting one of the most important agro ecosystem viz. coastal agro ecosystem, which supports the livelihood of several million poor and contributes substantially to the national economy. However, this agro-ecosystem is highly fragile and risk prone due to the adverse effects of degradation mainly due to negative impacts of anthropogenic pressure and climatic adversities and are therefore environmentally disadvantaged.

(**Key words:** *Coastal soils, Land use, Management, Salinity*)

There are projections that demand for foodgrains in India would increase from 192 million tonnes in 2000 to 345 million tonnes in 2030. Hence in the next 20 years, production of food grains needs to be increased at the rate of 5.5 million tonnes annually (ICAR, 2011). In order to meet the targeted food grain production to feed the ever-increasing population the regional imbalances especially in terms of irrigation and resource management are to be removed to the maximum possible extent; together with optimum management of the natural resources and ensuring proper utilization of region specific innovative technologies developed.

The coastal region lagging significantly behind the inland areas, in terms of productivity has a still harder task ahead in lieu of several constraints limiting its productivity and therefore warrants special attention. The present paper analyses the resources, present land use, emerging issues, technological options, impact of present land uses and management on resources and also suggest strategies for sustainable and eco-friendly coastal agriculture.

Coastal soils: Extent and distribution

A knowledge of coastal soils in respect of their extent, distribution, characteristics, problems and potentials is extremely important for optimizing the land use. However, little attention has been given to the judicious use of coastal land, which is subjected to various land degradation problems. Velayutham *et al.*, (1999) presented a comprehensive account on the soil resources and their potentials for different Agro-ecological Sub-regions (AESRs) under coastal ecosystem comprising an area of 10.78 M ha (including islands).

The extent and distribution of Indian coastal areas agro-cological subregion (AESR) wise is furnished in Table 1.

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Table 1. Extent and distribution of Indian coastal areas Agro-cological Subregion (AESR) wise

State/ Area (sq. km)	AESR No.	Brief description of AESRs
West Bengal 14,152	15.1	Bengal Basin and North Bihar Plains/hot moist sub-humid/LGP 210-240 days
	18.5	Gangetic Delta, hot moist subhumid to humid/LGP 240-270 days.
Orissa 7,900	18.4	Utkal Plains and East Godavari Delta, hot dry subhumid/LGP 180-210 days
	18.5	Gangetic Delta, hot moist subhumid to humid/LGP 240-270 days.
Andhra Pradesh 35,500	18.3	Andhra plains/hot dry subhyumid/LGP 150-180 days.
	18.4	Utkal plains east Godavari delta, hot dry subhumid/LGP 180-210 days.
Tamil Nadu 7,424	18.1	South Tamil Nadu plains/hot dry semiarid/LGP 90-120 days.
	18.2	North Tamil Nadu plains/hot moist semiarid/LGP 120-150 days.
Kerala 7,719	19.3	Kerala coastal plains/hot humid to per humid/LGP
Karnataka 7, 424	19.3	Karnataka coastal plains/hot humid to per-humid/LGP 240-270 days.
Maharashtra 10,000	19.1	Konkan coast/hot humid/LGP 210-240 days.
	19.3	Konkan coast plains/hot humid to per-humid LGP 240-270 days.
Goa 220	19.1	North Sahyadris and Kondan coast/hot humid/LGP 210-240 days.
	19.3	Coastal plains/hot humid to per humid/LGP 240-270 days.
Gujarat 17,465	2.2	Kachchh peninsula (Great Rann of Kachchh as inclusion)/hot hyper arid LGP <60 days.
	2.4	South Kachchh and north Kathiawar peninsula/hot arid/LGP 60-90 days.
	5.3	Coastal Kathiawar peninsula/hot moist semiarid/LGP 120-130 days.
Andaman & Nicobar	20.1	Coasts of Islands/hot perhumid LGP >300 days.
Lakshadweep 26	20.2	Coastal Lakshadweep and group of Island/hot humid/LGP 240-270 days.
Puducherry & Karaikal 3	18.4	Coast Puducherry and Karaikal/hot dry subhumid/LGP 180-210 days.

Source: Velayutham *et al.*, (1999). LGP, Length of growing perio

Soil Characteristics

Some of the important soil characteristics of dominant soils of Indian coastal areas are presented in Table 2.

Land Use

The major land use of Indian coastal areas is furnished in Table 3.

Production system constraints

The production system is mainly rice based together with horticulture and plantation crops, agro-forestry, fish and marine products and livestock. The major constraints are discussed below.

Weather- storms and cyclones

Storms and cyclones affect lives and properties of thousands of peoples and alter the dynamics of degradation. The cyclones in the years of 1930, 1940,1943, 1962,1977,1979 and 1990 in the coast of Andhra Pradesh and Tamil Nadu made extensive mark on the landscape. The latest in the series was on May 25th. 2009 [cyclone Aila (a tropical cyclone that developed over the Bay of Bengal)] and hit West Bengal and Bangladesh at a speed of 90-100 km/h and caused major climatic disaster, affecting the lives of millions. The worst affected districts were North and South 24 Parganas, Hooghly, East Mednipur, Howrah, Bardhhaman, and Kolkata, among other places in West Bengal, India. Out of the total crop area affected (2,56,750 ha) in all the districts, the share of North 24 Parganas was 55, 600 ha and that of South 24 Parganas was 69, 150 ha. Almost 60% of the area in the north and south 24-Parganas districts has been rendered uncultivable and not suitable for making seedbed (www.drcsc.org).

Table 2. *Characteristics of dominant soils of Indian coastal areas*

State	Texture (aq)	pH (dSm⁻¹)	ECe	OC (%)	CEC cmol(p⁺)kg⁻¹	BS (%)/ soil classification
West Bengal	sicl-sic	5.5-7.8	-	0.2-0.5	19.4-26.0	70-80 (Vertic Endoaquepts)
	sil-cl	6.5-7.6	-	0.3-0.8	6.6-10.6	74-82 (Typic Fluvaquents)
Orissa	s-sicl c	4.2-7.5 4.5-6.3	5.1-20.2 5.2-16.3	0.1-0.2 Tr-0.2	12.8-13.4 -	75-85 (Aeric Tropaquepts) 49-69 (Vertic Tropaquepts)
Andhra Pradesh	sic-c l-c	8.0-8.4 -	4.6-27.0 -	0.9-1.1 0.9-1.2	4.0-6.6 -	89-100 - (Chromic Haplusterts)
Tamil Nadu	s-sl c	5.1-6.1 -	0.01-0.05 -	0.06-0.1 0.6-1.0	4.2-6.8 -	89-100 (Psamentic Paleustalfs) -
Kerala	c-l	2.4-5.6	8.4-15.8	0.3-19.9	3.9-58.0	37-54 (Typic Sulfaquents)
Karnataka	s-sl	3.9-5.7	-	0.07-1.2	0.7-4.6	28-89 (Aquic Ustifluvents)
Maharashtra	l-c	-	-	0.3-0.6	-	35-42 (Udic Paleustalfs)
	c-l	6.6-7.0	<2.0-2.0	0.4-0.7	20.8-28.0	40-45 (Udic Paleustalfs)
Goa	c-sicl	5.4-5.9	0.06	0.3-0.6	0.5-7.8	48-69 (Fluventic Ustropepts)
	c-l	-	-	0.2-0.6	-	40-50 (Fluventic Ustropepts)
Gujarat	-	8.2-8.4	0.46-3.2	0.13-0.15	-	-
Lakshadweep	-	8.5-9.1	-	0.27-0.54	0.4-1.5	100

Source : Velayutham *et al.*, (1999), Sen *et al.*, (2000)
ECe, Electrical conductivity of saturation extract; OC, Organic Carbon; CEC, Cation Exchange Capacity; BS, Base Saturation

Table 3. *Major land use of Indian coastal areas*

States	Major land use
West Bengal	Rice, wheat, potato, oilseed
Orissa	Rice, mustard, niger, coconut
Andhra Pradesh	Cashew, paddy,
Tamil Nadu	Casurina
Kerala	Coconut, rice, cashew
Karnataka	Rice, groundnut, coconut, cashew, arecanut
Maharashtra	Paddy, millets, horticultural crops (mango, pineapple, cashewnut, arecanut)
Goa	Coconut, rice, cashew, forest
Gujarat	Sorghum, pearlmillet, cotton, pulses (rainfed), paddy, sugarcane, wheat (irrigated)
A & N islands	Paddy, coconut, arecanut, rubber, cashewnut and plantation crops.
Lakshadweep	Coconut, horticultural crops, vegetables.

Table 4. Technologies available for management of the coastal region

Technology	Effects
Drainage Embankments	To control the flooding and silt load
Watershed management	Integrated use of land and water resources for higher productivity and sustainability depending upon local conditions
Rain water conservation	Rain water management dealing with on farm harvest; storage of excess rainwater during monsoon and recycling the same for irrigation in the dry season with the objective to introduce multiple cropping systems in the region.
Improved irrigation methods	Micro irrigation especially in form of drip, is potential irrigation method under the coastal environment.
Conjunctive use of poor quality water	Mixing of poor and good quality water in safe proportion. It may be blending or cyclic strategy mode.
Soil erosion control measures	A suitable blending of forestation and engineering measures to prevent erosion and transport of saline sands to the adjoining land area. Plantations are imperative to protect hills.
Salt leaching	Appropriate methods depending upon the local condition and materials available with the farmers for controlling salinity.
Efficient fertilizer use	Use of organic and inorganic source of nitrogenous fertilizers with suitable technique is to be practiced for enhancing mineralization and reducing the losses through volatilization. Efficient methods of phosphorus and potassium fertilizer application have been evolved for increasing fertilizer use efficiency.
Crop selection and improvement	In adverse condition like coastal region comprehensive strategies have been evolved including bio-technology and hybrid technology to address the multiple problems, occurring simultaneously.
Efficient cropping system	Multi-tier cropping systems involving arable cropping, horticulture and plantation crops as well as agro-forestry have been evolved for better land use, suitable particularly for small holding depending upon problems and potentiality of the area. Various models of agro-silviculture programme have been researched for the coastal region.
Alternate farming system/ multi enterprising	Integrated farming system in coastal region includes crop production and/or sericulture, apiculture, dairy, poultry, aquaculture and forestry. Agroforery, silvi-horticulture, silvi-pastoral system is combined under this programme depending upon location and socio-economic conditions of the local people. The important alternate farming systems are agri-horticultural system, horti-pastoral system, horti-silvicultural system, horti-silvi-pastoral and horti-agri-silvicultural system, home garden agro-forestry.

Drainage congestion

Hydrological and topographical conditions are very adverse in coastal region due to the lower topography. Lack of outlet, presence of flood embankments and inadequately designed sluice gates create further blockage for the speedy disposal of drainage water. The situation is worse in deltaic region of eastern coast occupying comparatively lower topographical position than the marshy lands of Sundarbans. Stagnating water in Sundarban area is a positive reflection of drainage congestion.

High water table/Prolonged water logging

The subsoil water in the coastal region is located very near to the surface. Prolonged water logging is the most common in coastal region, in rice fields, aquaculture farms and marshy lands. Prolonged water logging produces various types of gaseous and non-gaseous toxic products, affecting the ecology of the region adversely.

Soil salinity and related factors

The salt affected soils in the coastal areas in India are spread over 2.52 Mha comprising about

30 percent of the total salt affected soils in the country. Besides, 0.57 Mha area is under mangrove vegetation (Yadav *et al.*, 1983). Most of the areas have problematic soils viz. saline, alkaline, acid sulphate, marshy and waterlogged soils situated in low-lying areas mainly along deltas. Over drafting of ground water, periodic inundation of sea water, lack of internal drainage and saucer shaped topography are the reasons for the salinity in the coastal regions of India.

Severe erosion

Shore line erosion, stream bank erosion, wind erosion are the major threat to coastal region.

Risk of climate change

Coastal zones are particularly vulnerable to climate variability and change. Key concerns include sea level rise, land loss, changes in maritime storms and flooding, responses to sea level rise and implications for water resources. The global climate change caused by the green house effect is estimated and a rise of water level by 0.3 to 2.1 meter is predicted in the sea by the end of 2075A.D. Extensive lowland areas in the large part of the coastal region may be under the deep water. Eastern coast and Southern peninsula are most vulnerable (Sen *et al.*, 2000).

Some important findings based on simulation models are mentioned below (Bhattacharya, 2006)

- Simulation models show an increase in frequencies of tropical cyclones in the Bay of Bengal, particularly intense events are projected during the post-monsoon period.

Sea level rise is projected to displace populations in coastal zones, increase flooding in low-lying coastal areas, loss of crop yields from inundation and salinization.

Technologies available for management of the coastal region

The technologies available for management of the coastal region are presented in Table 4.

Impact of agriculture in coastal area

The impact of agriculture on coastal areas is presented in Table 5.

Knowledge based land use planning – A key to success

Technology evolved to address the specific problems could not fetch the desired results because particular piece of land is affected with more than one problem. Therefore, holistic management consisting of right land use, appropriate technology at the right place is needed. Holistic management consists of comprehensive database and expert system using Remote Sensing and Geographic Information System (GIS).

A framework of comprehensive database is furnished in Table 6.

Conceptual model for mining the database is schematically presented below (Fig.1)

Essence of the model is right technology, right land use and the right place. Success of the soil/ land use model for different conditions will aid in mitigating the impact of degradation, desertification and climate change together with having delicate

Table 5. *Impact of agriculture on coastal areas*

Activity	Environmental and/or social change	Impact of social and or economic concern
Diversion of rivers for irrigation	Increased estuary salinity and decreased estuary circulation	Decreased fish yields
High use of pesticides	Toxic pollution of estuaries and inshore water	Decreased fish yields
High use of fertilizers	Increased amount of nutrients leaching leading to eutrophication of rivers, estuaries and inshore water	Decreased fish yields
Excessive cropping or grazing on watersheds	Watershed erosion, sedimentation of fish habitat in estuaries and inshore water, flood plain deposition and beaches with sediment	Decreased fish yields and silting of channels, increased flood
Withdrawal of ground water at greater rate than natural recharge	Salt water intrusion	Reduction in the water available for use
Extensive nutrient mining	Wide spread outcropping of sulphur rich sediments, high organic carbon deposits are also exposed extensively	Soil fertility imbalance

Table 6. *Framework of comprehensive database*

Module 1	Module 3
Polygon based module ❖ Administration ❖ Soil resource map on 1:250, 000 scale ❖ Soil resource map on 1:50,000 scale ❖ Soil resource map on 1:4 to 10,000 scale ❖ Geology of the state/region ❖ Physiography	Raster based module ❖ Ground and surface water prospects and irrigation potentials ❖ Climatic history punctuated with rainfall pattern and drought frequency ❖ Land use dynamics ❖ Periodic RS data
Module 2	**Module 4**
Point data based module ❖ Grid points collected during SRM ❖ Typifying pedons ❖ Grids and typifying pedons of subsequent surveys ❖ Climatic variant ❖ Ground water status and quality from prominent locations ❖ Land use and yield data ❖ Agro-technology - management and yield of demonstration plots and research farms	Non-spatial data based module ❖ Human and livestock profile ❖ Land use requirement ❖ Market demand and trends

balance between food production and resource conservation.

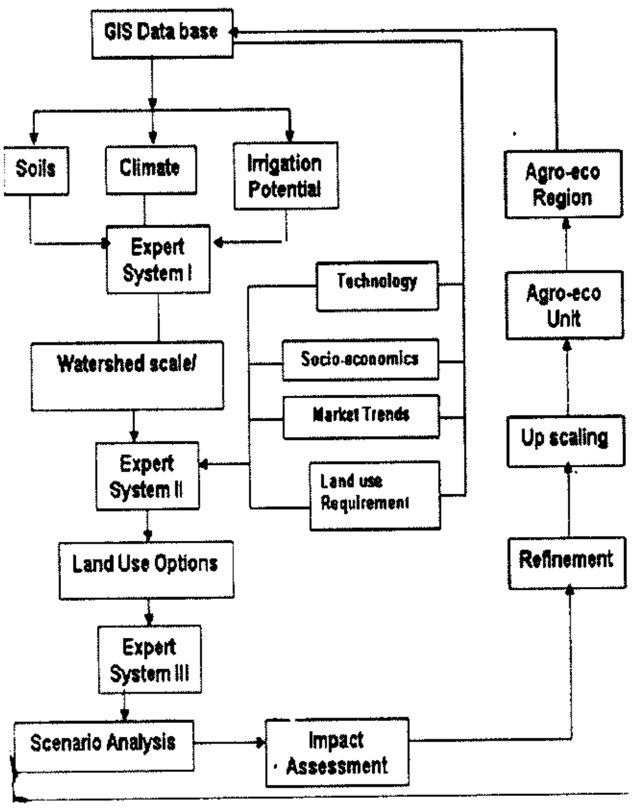

Fig. 1. Model for optimizing land use options

Coastal ecosystem: Agenda of actions/Future options

Some most important future strategies towards development of coastal region are summarized below-

- Comprehensive inventory of soil, water and vegetation using Remote Sensing techniques (RS) and Geographic Information System (GIS).
- Location – specific, eco-positive and low-cost techniques including integrated nutrient, water, pest and watershed management for sustained high productivity.
- Compatible alternate land use planning viz. agri-horticultural system, horti-pastoral, horti-silvicultural, horti-agri-silvicultural system, agro-forestry etc. and diversification of farming systems.
- Marketing infrastructure is to be developed by establishing regulated markets, cold storages which will encourage the farmers to adopt various diversification options.
- Agriculture credit facility needs to be made more accessible to the farmers.
- Transfer of improved and innovative technologies frequently to farmers and user agencies.
- Flood control and suitable design for drainage network.
- Multiple cropping system is to be evolved

- Sweetwater reservoir should be popularized to facilitate rainwater harvesting in farm ponds and also cultivation of cash crops like vegetables on the bank of the ponds.

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Integrated Management of Coastal Saline Soils of Maharashtra

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The coastal saline soils of Maharashtra are spread over two agro-climatic zones. The very high rainfall non-lateritic soil zone (VRN) comprises the whole of Thane district and northern part of Raigad district, where the soils are derived from the basaltic parent material while the very high rainfall lateritic soil zone (VRI) covers the southern part of Raigad and whole of Ratnagiri and Sindhudurg districts. Topographically the coastal area is almost flat and has elevations less than 10 m above mean sea level. The soils in VRN zone had fine texture and moderate hydraulic conductivity. The brackish ground water of coastal saline soils is a constant source of soil salinity. The critical depth of mineralized ground water was found to be 407 ± 15 cm at Panvel. Among various reclamation measures, a strong embankment with one way sluice gate is required to be constructed at least one meter greater that the height of maximum tide to stop the ingress of sea water. Side slope of 2:1 with stone pitching toward creek side and 1:1 toward land side with the grass cover is found to be optimum. In order to remove excess salts by run-off without causing erosion of soil, deep drains of 1.5 m to 2.0 m depth are found effective. Along with the reclamation practices of coastal saline soils, it is necessary to grow the salt tolerant high yielding and multiple resistance varieties of rice during *Kharif* season. Addition of organic material either in the form of FYM, compost or green manure reduces the adverse effects of salinity on rice crop. For *Rabi* cropping the rainwater can be harvested by excavating shallow farm ponds and construction of check dams. Similarly, the results reveal that there is a potential for the fish and prawn species in the fresh/brackish water ponds in coastal saline soils.

(**Key words:** *Coastal saline soil, Maharashtra, Integrated management*)

The Maharashtra State has 720 Km of coastal length with 54 creeks. It comprises the districts of Thane, Raigad, Ratnagiri and Sindhudurg. The coastal saline soils occur in these districts due to periodical inundation of cultivated land by creek/ seawater during high tide. As per the master plan of development of coastal saline soils of Maharashtra the total area estimated to be 65, 465 ha (Anonymous, 1990). The breakup is given in Table No. 1.

Agro-Climatic Zone

The coastal saline soils are spread over two agro-climatic zone of the state. The very high rainfall non-lateritic soil zone (VRN) comprises the whole of Thane district and northern part of Raigad district, where the soils are derived from the basaltic parent material while the very high rainfall lateritic soil zone (VRL) covers the southern part of Raigad and whole of Ratnagiri and Sindhudurg districts. Topographically the coastal area is almost flat and has elevations less than 10 m above mean sea level.

Table 1. *Area under coastal saline soils in the Maharashtra State*

District	No. of creek	Area, ha
Thane	12	20,795
Raigad	07	31,800
Ratnagiri	18	5,770
Sindhudurg	17	7,100
Total	54	65,465

Climate

The rains received from the southwest monsoon are spread over from June to October with peak period between July and August. The total annual rainfall varies from 3000-4000 mm. In spite of such heavy rainfall, occurrence of dry spells of 13, 17 and 31 days in the months of August, September and October, respectively, in 20 years return period coincides with the important physiological growth stages of rice crop, such as maximum tillering, panicle initiation, dough and grain filling stages during which water requirement of rice crop is high (Sahu *et al.*, 1982). The annual maximum daily rainfall received at Panvel found to be 329 mm in 25 years return period (Mahale and Dhane, 2004). The weekly rainfall data indicated that there is scope for rainwater harvesting during 25th -34th MW (Mahale and Dhane, 2003). The data emphasize the need for designing water storage reservoirs to

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harness rainwater for protective irrigation in such soils. The relative humidity ranges between 75-80 percent. Month of May is hottest and has mean temperature of 35.5°C (Sahu *et al.*, 1981).

Physio-Chemical Properties

The physio-chemical properties of some typical coastal salt affected soils in the Konkan region were studied (Joshi, 1985) and showed wide variation in their properties (Table 2). The soils in VRN zone had fine texture and poor hydraulic conductivity while that from VRL zone had coarse texture and moderate hydraulic conductivity.

The concentration of Na+, Mg++ in the surface as well as in the sub surface soils in VRN zone was relatively high. The K+ was within the narrow range. Nacl was dominant salt present in these soils, the order being Na+> Mg++> Ca++ > K+ for cations and CF> SO4 > HCO3- for anions (Joshi and Kadrekar, 1988). The average values of SAR were 28.14 and 20.07 for VRN and VRL zone, respectively.

Soil Fertility

The soil from the VRN zone showed varying content and pattern of distribution of organic carbon through out the soil depth while in the VRL it was in the range of low to very low in the profile. The available P was more in the soil from VRN zone, while the soils from both the zones were well supplied with available K.

The micro nutrient status of the coastal saline soils was studied (Andhalkar, 1984) and it was

Table 2. *Physico-chemical properties of coastal saline soils of Maharashtra*

Sr. No.	Soil Properties	VRN	VRL
I	Physical properties		
	Sand (%)	18.10	51.43
	Silt (%)	38.23	22.91
	Clay (%)	43.67	25.63
	Bulk density (Mg m^{-3})	1.26	1.29
	Hydraulic conductivity	0.25	1.26
	Total porosity (%)	48.48	50.60
	Available moisture (%)	17.93	13.62
II	Chemical properties		
	*p*H	6.80	5.60
	EC_e (ds m^{-1})	25.40	11.90
	Soluble $Ca^{2+}+Mg^{2+}$ (meL^{-1})	145.3	59.40
	Soluble Na^+ (MeL^{-1})	243.30	117.60
	Soluble K^+ (meL^{-1})	2.90	2.0
	Soluble Cl^- (meL^{-1})	319.80	127.2
	Soluble SO_4^{2-} (meL^{-1})	74.50	31.90
	Soluble HCO_3^- (meL^{-1})	12.60	15.70
	SAR	28.14	20.07
	CEC cmol (P+) Kg^{-1}	43.37	26.60
	Exchangeable Na+ cmol (P+) Kg^{-1}	11.15	5.20
	ESP	25.70	25.14
	Organic carbon g kg^{-1}	4.8	7.7
	Available P_2O_5 kg ha^{-1}	75.10	53.97
	Available K_2O kg ha^{-1}	2533.60	1072.83
	$CaCO_3$ (%)	5.0	2.7
	DTPA extractable Zn mg kg^{-1}	1.73	1.75
	DTPA extractable Fe mg kg^{-1}	9.77	28.71
	DTPA extractable Cu mg kg^{-1}	6.80	8.60
	DTPA extractable Mn mg kg^{-1}	35.73	36.94
	DTPA extractable B mg kg^{-1}	1.39	0.98

observed that these soils contain adequate available Mn and Cu. However, deficiency of B, Fe and Zn was found in some soils both in VRN and VRL zones, which is likely to pose the problem in rice cultivation in these soils.

Salinity Variations

The variation in the soil salinity according to the season is a common feature of coastal saline soils. It was observed that the salt content reduced considerably with rainy season, while it increases again in large quantities during dry season (Mehta, 1991a). It was further observed that the salinity of the soil gradually reduced with time after the construction of embankment, which might be due to desalinization by rainwater. It was also observed that during pre monsoon period top soil layer was rich in salt while in reducing soil salinity, it was revealed that it is not the total rainfall but its distribution which matters in reducing soil salinity (Chavan *et al.*, 1984). However, variation in soil salinity does occur during monsoon season if dry spells prevail. The data revealed that the average soil salinity at surface (0-22.5 cm) and sub surface (22.5-45 cm) layer were 9.98 dSm^{-1} and 11.01 dSm^{-1} at Paragon farm for post monsoon season and the average soil salinity at surface and sub surface layer were 16.40 dSm^{-1} and 14.34 dSm^{-1} at Paragon farm for pre monsoon season (Dhane *et al.*, 2000).

Infiltration Rate and Hydraulic Conductivity

The studies regarding infiltration characteristics of these soils were carried out under two covers. The infiltration rate for dry, stirred surface soil without surface cracks was found to be 7.84 cm day^{-1} and for surface cracks but no crop residue was 8.73 cm day^{-1}. In general, the infiltration rate is observed to be very low in heavy textured soil. The value for hydraulic conductivity of soils at Paragon was observed to be 0.62 cm day^{-1} while at Panvel it was 1.05 cm day^{-1} (Sahu *et al.*, 1981).

Ground Water Characteristics

The brackish ground water of coastal saline soils is a constant source of soil salinity. The critical depth of mineralized ground water was found to be 407+ 15 cm at Panvel (Sahu *et al.*, 1982).The ground water table rose to 0.17 m in the month of September and dropped from October onward. The water table depth and its salinity were measured

Table 3. *Rainfall, rainy days and soil salinity at paragon*

Year	Rainfall (mm)	Rainy days	Electrical Conductivity, dSm^{-1}			
			Pre monsoon (May)		Post monsoon (November)	
			0.0-22.5 cm	22.5 to 45.0 m	0.0 to 22.5 cm	22.5 to 45.0 cm
1980	2965.2	109	-	-	-	-
1981	2620.2	106	28.4	19.7	14.9	18.2
1982	2235.7	102	25.1	25.73	11.34	13
1983	3670.0	107	23.73	17.5	11.4	13.31
1984	2882.2	97	19.4	17.96	13.75	16.52
1985	2623.0	103	14.93	14.71	11.57	12.09
1986	2007	85	14.83	15.42	12.16	13.18
1987	2229.40	97	11.85	10.73	9.98	10.29
1988	3169.0	106	9.9	8.96	8.65	8.91
1989	2520.0	103	11.46	11.56	8.84	10.47
1990	[illegible]320.0	124	11.46	11.7	6.06	6.64
1991	2932.40	87	9.68	9.36	7.34	7.99
1992	2414.16	85	11.4	10.91	5.78	6.03
1993	3019.40	105	7.86	7.64	7.13	7.64
1994	3297.8	107	8.61	6.55	8.09	7.62
1995	2080.6	91	13.7	12.6	11.22	10.04
1996	2358.80	102	23.62	19.48	10.4	12.53
1997	2620.0	79	16.31	12.65	12.18	11.2
1998	3052.0	92	26.68	21.4	8.88	10.5
1999	2550	100	22.93	17.85	-	-

Age of rice seedling at transplanting is an important factor in determining yield of rice crop. It was observed (Anonymous, 1990 b) that 25 days old seedling of Panvel-1 rice variety with four seedling per hill and 100 kg N ha^{-1} gave the optimum yield (36.45 q ha^{-1}). Spacing of 15 x 20cm for Panvel-1 variety and 15 x 15cm for panvel-2 variety were found to be optimum (Anonymous, 1986).

Nutrition Management

Addition of organic material either in the form of FYM, compost or green manure reduces the adverse effects of salinity on rice crop. Dhanincha (*Sesbania cannabina*), Shevari (*Sesbania aegyptica*) and leaves of Bhend (*Thespesia populanea*) are found to be useful in increasing the yield of rice in coastal saline soils (Kadrekar *et al.*, 1981). Liner response was observed with increasing doses of FYM up to 15 t ha^{-1} along with the recommended doses of fertilizers (Chavan *et al.*, 1990). The fertilizers like ammonium sulphate, calcium ammonium nitrate and ammonium sulphate nitrate were found equally effective in rice crop (Kadrekar *et al.*, 1981). The response of rice varieties to nitrogen was found to be quadratic (Rajput and Mehta, 1990). Similarly the practice of deep point placement of urea briquettes (UB) containing diammonium phosphate (DAP) fertilizer in coastal saline soil for transplanted rice is agronomically more efficient than conventional application of prilled urea and phosphate (Dhane *et al.*, 2002).

Rabi Cropping

There is no source of good quality irrigation water during *Rabi* season in the coastal saline belt of Maharashtra. The under ground water is brackish and not suitable for irrigation. However, this area receives very high rainfall. The rainwater can be harvested by excavating shallow farm ponds and construction of check dams (Sahu *et al.*, 1981). This stored water can be used for growing certain crops with protective irrigation. The chemical properties of pond water are presented in Table 5. The salinity of 0.20 ha surface dugout pond at Panvel has started decreasing after the construction of pond (Table 6) and can be used for growing vegetables and fishes as a low cost technology for integrated farming in Kharland (Dhane *et al.*, 2002).

Many pulse, oilseed and vegetable crops and their varieties were screened for salt tolerance at Panvel locations. The following crops (Table 7) performed satisfactorily (Anonymous, 1986).

Table 5. *Chemical properties of pond water*

Pond No.	Depth of Pond	Month	pH (1:2)	EC dSm^{-1}	Ca^{++} mel^{-1}	Ca^{++}+ Mg^{++} mel^{-1}	Cl mel^{-1}	HCO_3^- mel^{-1}	SO_4^- mel^{-1}
1.	2.75	Dec.	7.4	0.68	1.58	2.25	5.0	1.6	1.2
		Jan.	7.4	0.72	1.60	2.30	6.0	1.8	1.4
		Feb.	7.7	0.86	1.25	1.80	8.0	2.0	1.5
		Mar.	7.5	0.86	0.40	1.20	7.0	4.0	1.7
		Apr.	7.9	1.35	0.60	1.60	10.0	6.0	1.6
		May.	8.0	1.60	0.80	2.80	16.0	8.0	1.8
2.	2.00	Dec.	7.4	0.93	0.92	2.65	9.0	1.7	1.8
		Jan.	7.3	0.98	1.00	2.85	10.0	1.8	2.0
		Feb.	7.5	1.02	0.86	2.10	12.0	4.0	2.0
		Mar.	7.7	1.07	0.65	1.20	16.0	4.0	2.1
		Apr.	7.6	1.63	0.80	1.40	17.0	4.0	1.9
		May.	7.8	2.34	1.10	2.70	18.0	6.0	2.2
3.	3.00	Dec.	7.4	8.20	6.50	18.00	170.0	1.7	2.1
		Jan.	7.3	9.10	7.40	20.00	180.0	1.8	2.3
		Feb.	7.7	9.88	7.40	30.00	222.0	6.0	2.4
		Mar.	7.4	13.72	9.00	36.60	282.0	6.0	2.2
		Apr.	7.6	16.64	10.00	62.00	406.0	6.0	2.5
		May	7.3	34.84	11.90	125.0	776.0	9.8	2.9

Table 6. Water salinity of 0.20 ha pond (1.5 m depth) at Panvel

Year	Salinity, ppt, in the month of April
1993-94	14.5
1994-95	9.2
1995-96	6.5
1996-97	6.2
1997-98	4.5
1998-99	2.5
1999-2000	1.0

Fish farming

Use of coastal saline area for agriculture alone has certain limitations. It has been estimated that out of 65,465 ha about 14,655 ha area can be utilized for fish and prawn culture. The marine fishing in Maharashtra has stabilized around 3.5 to 4 lakh tones for the last several years. It is, therefore, essential to concentrate efforts on brackish water as well as rice cum fish farming.

Rice cum fish farming

In the simultaneous farming of rice and fish *Cyprinus carpio* yielded 500 kg ha^{-1} under intensive culture in 90 days and 149.1 kg ha^{-1} under extensive culture in 90 days (Shingare *et al.*, 1996).

Fish/prawn culture in brackish water/fresh water ponds

Jitada (*Lates calcarifer*) culture is fairly wide spread in the coastal area of the state and ranked second after Indian major carps in culture fisheries. When Jitada was used as forage fish an average growth of 780 g of Jitada in eight months was observed. Under the combination of Jitada, Indian major carps and Tilapia, the production was 1475 kg ha^{-1} in seven months culture period (Shingare *et al.*, 1995).

With the identical technique of phased fertilization, the fresh water prawn *Macrobrachium rosenbergii* grew to an average weight of 60 g in 15 weeks while the tiger prawn *Penaeus monodon* grew to an average weight of 43 g in 25 weeks (Shirgur, 1986). In nursery ponds at Paragon post larvae of *M. rosenbergii* were reared by administering, different combinations of oil cake, rice bran and fish meal, when maximum growth/survival was observed with 80 per cent oil cake + 10 per cent rice bran + 10 per cent fish meal (Shirgur *et al.*, 1990). These results reveal that there is a potential for the above fish and prawn species in the fresh/brackish water ponds in coastal saline soils.

Suggested solutions

Ingress control

- Embankment and sluice gate construction maintenance.

Soil management

- Reclamation of soil by physical, biological or chemical means.
- Land shaping and drainage.
- Irrigation and water management.

Crop management

- Use of suitable varieties tolerant to stress situation
- Appropriate agronomic / cultural management practices.
- Appropriate fertilizer management practices with emphasis on biological nitrogen fixation.
- Suitable alternate land use of other unproductive (marginal) lands.
- Integrated farming system for agriculture, fisheries and forestry.

Forestry

- Adequate plantation of Mangrove and other suitable identified species.
- Adequate expansion of programme under agro-forestry with suitable tree species preferably with multiple objectives for their beneficial roles on nutrient and soil fertility, nutrient recycling, soil conservation, soil physical properties and ecosystem stability.

Table 7. Crops suitable for Rabi cultivation in coastal saline soils

Sr. No.	Crop/Variety	Duration, days	No. of protective irrigation	Salinity range, EC2, dS m^{-1}	Yield, q ha^{-1}
1.	Radish (Pusa Reshmi)	55-60	5 to 6	4 to 7	190 to 200
2.	Spinach (All Green)	80-90	6 to 7	3 to 5	140 to 150
3.	Tomato (Pusa Rabi)	130-150	8 to 10	3 to 7	180 to 190
4.	Mustard (Pusa Bold)	110-120	3	2 to 7	2.5 to 3.0
5.	Linseed (AKL-10)	110-120	3	3 to 5	3.0 to 3.5

Thus, the complexity of biotic system and their inter-relation as essential components of the whole system must borne in mind in future planning of coastal land development. No piecemeal management of single or isolated component (s) will possibly succeed. Hence, it is suggested that each coastal saline land watershed should be studied individually from point of view of productivity of the eco system before undertaking development of these lands.

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Physico-chemical Properties and Major Nutrient Status in Some Soils of Krishna Western Delta, Andhra Pradesh

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A reconnaissance survey was conducted to study the physico-chemcial properties and available nutrient status of some of the soils of Krishna Western Delta, Andhra Pradesh. The soil samples were collected from representative areas in the delta and analyzed for soil reaction, electrical conductivity, organic carbon and major nutrients. The results revealed that texture of the soils varied from sandy loam to clayey. Majority of the soils have neutral pH and normal electrical conductivity. About 48% of soils have low organic carbon content while rests of them were in medium status. The available nitrogen in the soils was low to medium while the phosphorus and potassium were medium to high in status. Significant positive correlations were found to exist between organic carbon and available N, P and K status of the soil under study. The electrical conductivity of saturation extract of the soils of Villages Kovelamudi, Mutluru and Pathareddypalem were found to be saline and need proper reclamation measures during monsoon season for growing a good crop.

(**Key words:** *Physico-chemical properties, Krishna Western Delta, Major nutrients*)

The rapid development of irrigation has contributed significantly in enhancing food grains production in Andhra Pradesh. The Krishna western delta comprises Guntur district and part of Prakasam district and covers an area of 2,40,000 ha. The predominant crops in the delta area are paddy and the other is sugarcane, cotton, chillies, maize, turmeric, pulses and horticultural crops. The major part of the Krishna delta is flat with gentle slope towards Bay of Bengal. It has some undulations in the middle present in the form of deltaic lobes, beach ridges and flood plains. It lies mostly on granites and basalts with limited groundwater potential, with some deep alluvium in the delta with high groundwater potential. The general climatic conditions of the delta are with hot summer and cold winter. The delta area receives precipitation from Southwest monsoon and Northeast monsoon, of which the Southwest contributes 89% of the rainfall, remaining is from Northeast monsoon. This paper will examine the physico-chemical properties and nutrient status of some of the soils of Krishna Western Delta and assess their suitability for growing a better crop during the monsoon period.

MATERIALS AND METHODS

The study area covers a part of Krishna Western Delta in Guntur district, Andhra Pradesh which includes major cropping areas with different soils types. Twenty-six soil samples representing fourteen villages were selected for the study. Soil samples from Twenty-six villages (3 representative soil samples from each village) were selected and the composite soil samples (0-15 cm) were prepared to determine the status of available N, P and K. Organic carbon was estimated by Walkley and Black (1934) method. Available nitrogen was determined by alkaline permanganate method (Subbaiah and Asija, 1956). Available phosphorus was extracted by Olsen's method (Olsen *et al.*, 1954). Available potassium (neutral normal ammonium acetate extractable) was determined by Flame photometer method. The simple correlation analysis of data was computed in relation to available nutrient contents with different physico-chemical properties of the experimental soils. The determination of water soluble salts in soils is important in irrigated areas to know the salt content of soils because these salts are in danger of becoming saline or alkali. The water-soluble salts are present in ionic form in aqueous solutions and are determined in saturation extract. The saturation extract determination considered being more reliable because it is directly related to field moisture range.

RESULTS AND DISCUSSION

Physico-chemical properties of the soils of Krishna Western Delta

Soil pH and EC

Soil pH varied from 7.02 to 7.75 with an average of 7.40 (Table 1). According to classification of soil

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Table 1. *Physico-chemcial properties of soil samples in Krishna Western Delta*

S. No	Village*	PH (1:2)	EC (dSm-1)	O.C. (%)	Soil Texture	Sand (%)	Silt (%)	Clay (%)	CEC (m.eq 100g-1)	Exchangeable Cations m.e. 100 g-1 soil				ESP (%)
										Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	
1	Pedamatlapudi	7.05	0.46	0.27	Sandy Clay loam	66.3	9	24.7	11.6	3.0	4.5	1.24	0.48	10.70
2	Chinamatlapudi	7.54	0.43	0.29	Sandy Clay loam	69.2	8	22.8	11.9	4.0	5.0	1.19	0.41	10.00
3	Mollagunta	7.68	5.17	0.54	Clayey	36.8	14	49.2	32.3	10.5	13.0	4.53	1.38	14.02
4	Velaturu	7.75	3.73	0.55	Clayey	37.7	12	50.3	34.9	14.0	10.5	4.32	1.32	12.38
5	Tativakapalem	7.10	0.74	0.51	Clayey	37.3	16	45.7	38.8	14.0	15.5	4.75	0.97	12.24
6	Pullameraka	7.41	0.56	0.49	Clayey	38.5	16	45.5	36.2	14.0	15.5	4.61	1.00	12.73
7	Jonnavaripalem	7.72	11.80	0.59	Clayey	31.5	14	54.5	46.4	16.5	18.5	6.3	1.44	13.58
8	Atchuyutapuram	7.72	10.20	0.56	Clayey	37.2	14	48.8	47.4	18.5	19.0	6.36	1.51	13.46
9	Chavali	7.12	1.30	0.55	Clayey	30.8	19	50.2	45.7	16.0	14.5	6.15	0.84	13.46
10	Peravali	7.04	2.30	0.54	Clayey	33.9	16	50.1	46.4	16.0	18.0	6.28	1.03	13.53
11	Peravalipalem	7.28	1.20	0.58	Clayey	37.4	12	50.6	44.5	15.5	16.5	5.65	1.06	12.70
12	Yazali	7.30	1.24	0.42	Sandy Clay loam	49.3	12	38.7	24.3	8.0	9.0	2.62	1.03	10.78
13	Kazipalem	7.32	0.99	0.43	Sandy Clay loam	52.9	8	39.1	26.2	8.5	9.0	3.02	0.97	11.53
14	Dommavaripalem	7.58	1.20	0.38	Sandy Clay loam	59.4	8	32.6	22.7	8.5	7.5	2.81	0.97	12.38
15	Mantrivaripalem	7.64	0.72	0.62	Clayey	37.1	18	44.9	34.3	20.0	10.0	5.43	0.89	12.26
16	Pudivada	7.02	5.56	0.47	Clayey	42.4	14	43.6	30.8	10.5	12.5	4.2	1.03	13.64
17	Srirampuram	7.05	1.50	0.61	Clayey	32.5	13	54.5	42.6	16.5	14.5	5.26	1.17	12.35
18	Yadlanka	7.50	10.35	0.55	Clayey	35.4	14	50.6	41.3	15.5	14.0	5.07	1.22	12.28
19	Kothareddipalem	7.62	1.21	0.47	Clayey	44.8	12	43.2	36.4	12.5	13.5	4.71	0.81	12.94
20	Chebrolu	7.46	2.50	0.43	Clay Loam	41.4	19	39.6	28.5	11.0	10.0	4.49	0.82	15.75
21	Chilapalem	7.61	7.01	0.51	Clayey	42.8	10	47.2	38.2	11.5	12.0	4.86	0.84	12.72
22	Cherukupalli	7.35	5.30	0.43	Clay Loam	40.4	20	39.6	32.8	10.0	14.5	4.17	1.03	12.71
23	Karampudi	7.25	11.0	0.54	Clayey	39.4	11	49.6	37.5	14.0	15.5	4.52	0.94	12.05
24	Kovelamudi	7.10	26.30	0.46	Clayey	43.8	14	42.2	31.6	12.0	10.0	4.5	0.84	14.24
25	Mutlooru	7.65	15.4	0.48	Clayey	36.4	19.2	44.4	30.4	11.0	12.0	4.16	0.81	13.68
26	Pathareddipalem	7.42	13.6	0.46	Clayey	38.4	18.9	42.7	33.8	13.5	12.5	4.07	0.82	12.04
	Mean	**7.40**	**5.45**	**0.49**		**41.7**	**13.9**	**45.0**	**34.1**	**12.5**	**12.6**	**4.43**	**0.99**	**12.7**

* Three representative soil samples from each village was taken

Table 2. *Status of available major nutrients in soils of Krishna Western Delta*

S. No.	Village*	Available major nutrients (kg ha^{-1})		
		N	P_2O_5	K_2O
1	Pedamatlapudi	296	30.6	275
2	Chinamatlapudi	244	34.5	295
3	Mollagunta	352	40.9	325
4	Velaturu	380	42.4	315
5	Tatlvakapalem	406	66.4	325
6	Pullameraka	298	55.3	295
7	Jonnavaripalem	386	48.3	580
8	Atchuyutapuram	272	50.3	514
9	Chavali	358	62.2	590
10	Peravali	298	60.5	304
11	Peravalipalem	374	62.5	548
12	Yazali	272	38.5	510
13	Kazipalem	272	33.4	445
14	Dommavaripalem	294	38.3	238
15	Mantrivaripalem	298	52.3	514
16	Pudivada	272	55.3	510
17	Srirampuram	352	69.4	546
18	Yadlanka	332	52.2	490
19	Kothareddipalem	272	45.2	288
20	Chebrolu	326	46.3	345
21	Chilapalem	374	47.2	350
22	Cherukupalli	244	41.7	317
23	Karampudi	244	43.6	233
24	Kovelamudi	380	53.2	568
25	Mutlooru	352	43.5	347
26	Pathareddipalem	326	40.35	293
	Mean	**318**	**48.2**	**398**

* Three representative soil samples from each village was taken

Table 3. *Correlation coefficient (r) values of pH, organic carbon and clay content with available nutrients*

Soil properties	Available nutrients		
	N	P_2O_5	K_2O
PH	0.038	-0.408	0.477*
Organic carbon	0.444*	0.686*	0.480*
Clay	0.495*	0.667*	0.425*

*Significant at 5% level

reaction, 11 soil samples were with neutral pH (6.6 to 7.3) and 15 samples were slightly alkaline pH (7.4-7.8). The minimum pH was observed in Pudivada and Pedamatlapudi villages where as maximum values was noticed in Velaturu, Atchuyutapuram and Jonnavaripalem. The relative pH of the soils might be due to the high amount of base saturation. The electrical conductivity (EC) of the soils ranged from 0.43 to 26.3 with a mean of 5.45 dSm^{-1}. Majority of the soils have EC less than 4 dSm^{-1}. However, the sampling sites of Mollagunta, Jonnavaripalem, Atchuyutapuram, Pudivada, Yedlanka, Chilapalem, Cherukupalli, Karampudi, Kovelamudi Mutloor and Pathareddipalem have EC more than 5 dSm^{-1}.

Organic carbon (%)

The organic carbon content of the soils varied from 0.27 to 0.62 with an average percent of 0.49. The organic carbon was low (<0.5%) in soils of 11 villages (42% soils) while the samples from 15 village (48% soils) were in medium status (0.5-.75%). Soil in low organic carbon is possibly because of high temperature and good aeration in the soil, which increase the rate of oxidation of organic matter.

Table 4. *Saturation Extract of the soil samples of Krishna Western Delta*

S. No	Village*	pH	ECe (dSm^{-1})	Na^+ m.eq l^{-1}	Ca^{++} m.eq l^{-1}	Mg^{+2} m.eq l^{-1}	K m.eq l^{-1}	HCO_3 m.eq l^{-1}	Cl^- m.eq l^{-1}	SO_4^{-2} (m.eq l^{-1})	SAR $(mmol\ l^{-1})^{1/2}$
1	Pedamatlapudi	8.09	1.8	11.7	4.0	3.2	0.48	4.0	14	0.64	5.14
2	Chinamatlapudi	8.18	1.7	13.0	2.0	1.4	0.41	3.0	13	0.31	8.42
3	Mollagunta	8.29	11.3	74.1	6.0	45.4	1.38	6.1	110	1.63	10.65
4	Velaturu	8.16	8.4	52.3	5.4	26.6	1.32	4.4	92	1.19	9.66
5	Tativakapalem	8.21	1.9	10.1	2.6	5.2	0.97	5.0	16	0.56	3.96
6	Pullameraka	7.82	1.0	7.8	2.4	2.0	1.00	3.0	5	3.45	4.38
7	Jonnavaripalem	6.58	30.5	204.3	39.6	93.4	1.44	2.2	330	2.79	19.20
8	Atchuyutapuram	7.29	21.7	124.0	25.6	62.6	1.51	3.0	220	1.29	14.28
9	Chavali	7.49	2.4	17.8	5.2	1.4	0.84	3.4	24	1.05	8.92
10	Peravali	7.38	3.7	30.4	6.2	6.0	1.03	3.6	34	1.37	10.09
11	Peravalipalem	7.67	1.9	14.8	4.6	3.6	1.06	1.8	18	0.82	6.08
12	Yazali	7.05	3.0	25.7	3.4	4.2	1.03	2.8	30	0.73	10.56
13	Kazipalem	7.27	1.9	17.0	4.2	2.0	0.97	2.4	19	0.63	8.38
14	Dommavaripalem	6.82	2.4	17.2	5.6	4.2	0.97	2.0	24	0.46	6.50
15	Mantrivaripalem	6.96	1.3	11.7	2.2	1.2	0.89	3.2	10	0.49	7.74
16	Pudivada	6.40	15.8	90.0	36.0	26.0	1.03	1.6	174	1.05	13.57
17	Srirampuram	7.04	3.2	21.1	6.2	6.2	1.17	2.4	33	0.74	6.92
18	Yadlanka	6.49	24.9	116.2	55.0	114.0	1.22	2.0	272	1.58	9.77
19	Kothareddipalem	6.55	4.0	26.5	12.0	8.4	0.81	3.4	41	0.45	6.98
20	Chebrolu	7.14	9.5	42.1	32.8	25.6	0.82	2.0	100	0.86	6.50
21	Chilapalem	6.78	31.5	186.9	74.2	94.2	0.84	2.4	332	1.76	16.31
22	Cherukupalli	7.21	14.0	80.4	33.0	40.8	1.03	2.2	152	1.37	10.63
23	Karampudi	7.13	27.5	107.6	81.0	118.0	0.94	2.2	280	1.37	8.55
24	Kovelamudi	7.20	93.0	659.7	105.0	195.0	0.84	3.8	1072	2.24	45.26
25	Mutlooru	7.27	59.0	384.1	81.6	190.0	0.81	3.2	560	2.99	25.28
26	Pathareddipalem	6.71	52.1	291.0	110.0	194.0	0.82	2.6	512	1.42	18.44
	Mean	**7.28**	**16.5**	**101.00**	**28.68**	**49.02**	**0.99**	**2.99**	**173.00**	**1.28**	**11.62**

*Three representative soil samples from each village was taken

Soil Texture and Exchangeable Sodium Percentage (ESP)

The texture of the soils ranged from Sandy clay loam to Clay loam and Clayey and the ESP values were low in all soil samples under study (Table 1).

Cation Exchange Capacity (CEC)

The CEC of the soil ranged from 1.65 to 47.4 with an average of 34.5 C mol (+)/kg. Soils with clayey contained higher amounts CEC compared to the soils with clay loam and sandy clay loam.

Available N

The available N in soil samples ranged from 244 to 406 kg ha^{-1} with an average 8 soil samples were in low category (< 280 kg ha^{-1}) and 18 were in medium category (280-560 kg ha^{-1}). A significant and positive correlation (r=0.444*) was found between organic carbon and available nitrogen (Table 4), since most of the soil nitrogen is in the organic form. Similar results were also reported by Verma *et al.*, (1980).

Available P_2O_5

The available P_2O_5 in the soil samples ranged from 30.6 to 69.4 with an average of 48.2 kg ha^{-1}. On the basis of ratings suggested by Muhur *et al.*, (1963), about 15 soil samples were in medium category (20-50 kg ha^{-1}) and 10 samples were in high status (above 50 kg ha^{-1}). A significant positive correlation (r=0.686*) was observed between the available phosphorus and organic carbon. This indicates that presence of organic matter increases the availability of phosphorus in soil. According to Tisdale *et al.*, (1997) about 50% of phosphorus is in the organic form and decomposition of organic matter produces humus which forms complex with Al and Fe and protects the P fixation by reducing adsorption/ phosphate fixation. Available phosphorus and clay content were found positively correlated (r=0.667*).

Available K_2O

The available K_2O in the soil samples ranged from 233 to 590 with an average of 398 kg ha^{-1}. According to Mohur *et al.*, (1963), about 7 soil samples were in medium category (125-300 kg ha^{-1}) and 19 samples were in high status (above 300 kg ha^{-1}). A positive correlation (r=0.480*) was observed between organic carbon and available K content of soils (Table 3). This might be due to the creation of favourable soil environment with presence of high organic matter.

Water-soluble salts in aqueous extracts

The determination of water soluble salts in soils is important in irrigated areas to know the salt content of soils which leads to becoming saline or alkali. The water-soluble salts are present in ionic form in aqueous solutions and are determined in saturation extract. The saturation extract determination considered being more reliable because it is directly related to field moisture range.

The saturation extract of some of the soil samples of Krishna Western Delta were analyzed for pH, ECe, Cations and Anions (Table 4). The values of pH varied from 6.55 to 8.29 with an average value of 7.28. The ECe varied from 1.0 to 93.0 with a mean of 16.52 dSm^{-1} while the values of SAR ranged from 3.96 to 45.26 with an average value 12.70 (mmol $l^{-1})^{1/2}$. Based on the ratings of Richards (1954), it was found that about 15 samples (57%) were in safe limits (< 10), 8 samples (31%) were moderately safe (10-18), while 3 samples were unsafe (above 26). The highest SAR was found in the soil samples of Kovelamudi and Mutloor indicated that these soils are saline and need proper reclamation measures during monsoon for growing a good crop.

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Impact and Assessment of Soil and Water Conservation Measures on Ground Water Recharge

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Water is critical input to the agricultural production and human needs. But due to increasing demand, its quantity and quality is reducing at alarming rate. Therefore, it is needed to conserve the soil and water resources on watershed basis. By considering the above fact, the College of Agril Engg and Tech, Dr., BSKKV, Dapoli has undertaken to develop 'Priyadarshini 'Watershed as a model watershed for hilly Konkan ecosystem. Under this different soil and water conservation measures viz. terracing, continuous contour trenches (CCT), recharge pits, online recharge ponds, off line recharge ponds, waters harvesting lined ponds, underground diaphragm, konkan vijay bandhara, cement nala bandh, etc were constructed as per the development plan of watershed. The impact of these works was analyzed in the present study by observing water levels of four wells located in influenced area (W1, W2, W3, and W4) and five wells located in uninfluenced area (W5, W6, W7, W8, and W9). It is observed that, wells located in uninfluenced area have average water level drop by 2.27m compare the wells in influenced area. It is also observed that, well located in influenced area have water availability for longer duration whereas wells located in uninfluenced were dried early. The horizontal influence of Priyadarshini online recharge pond and conservation measures form its sources of recharge found to be up to 800m in downstream side. Hence, the work of soil and water conservation measures have significant impact on ground water recharge and increasing the ground water level of the watershed.

(***Key words:*** *Groundwater recharge, Watershed, Soil and Cater conservation measures, Influence area and uninfluenced area)*

The Konkan region is long narrow strip on western side of Sahyadri with 720 km coastline spread between 15°6′N and 20°22′N latitude and 72°30′E and 73°48′E longitude covering a geographical area of 3.08 Mha. Konkan region receives heavy rainfall (Annual rain fall 3000-4000 mm) in monsoon season. The region is having 10 per cent of total geographical area of Maharashtra state and receives 46 per cent of the rainfall of the state. Though, this region receives heavy rainfall, but scarcity of the drinking water in summer season is a reality. This is due to hilly topography of the region coupled with low water holding capacity of the soil. During rainy season, major portion of rainfall makes its way as runoff towards Arabian Sea. Under such situation conservation of soil and water recourses on watershed basis are essential. Soil and water conservation works includes water harvesting ponds (lined and unlined), loose boulders dams, Konkan Vijay Bandhara, CCT/SCT, terracing, cement nala bandh, earthen nala bandh, crop management practices etc adopted in hilly area. These works helped to reduce soil erosion and augment the ground water recharge (Kumar and Wabsi, 1998; Phadanvis *et al.*, 1998; Pandey *et al.*, 1999 and Kumars and Seethapathi, 2000). The water conservation measures were found more effective for rising of water tables in observation wells located in the middle and lower reaches of the watershed (Gitte *et al.*, 2002).

Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli has developed "Priyadarshini Watershed" as a model watershed by adopting different soil and water conservation measures suitable for the Konkan ecosystem. The impact of these works for ground water recharge in the watershed is assessed and presented in this study.

MATERIALS AND METHODS

Study area

The Priyadarshini watershed is developed by Dr. B S Konkan Krishi Vidyapeeth, Dapoli as model watershed representing special topography and geographical features of the region with an area of 38.72 ha. Its topography is hilly, undulating with shallow and stony laterite soil (sandy loan in nature). The soil depth varies from 20 cm to 90 cm and average soil depth of the watershed is 45 cm. The land slope of the watershed is ranging from 33

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per cent to 6 per cent. It is steeper at upper ridge and started reducing towards the lower reaches. Geographically, it is situated at 17°45'N latitude and 73°26'E longitude. Its elevation is 250 above MSL. The climate of the region is warm, humid with an average annual precipitation of 3000 mm and most of the rains received during monsoon i.e June to September only.

Soil and water conservation works

The different soil and water conservation measurers were adopted as per the land capability and presented in Table 1. In the watershed, terracing, continuous contour trenches, recharge pits, online recharge ponds, off line recharge ponds, waters harvesting lined ponds, underground diaphragm, konkan vijay bandhara, cement nala bandh, etc were undertaken from year 2003 to 2010. The works were undertaken with spatial topographical needs of the area to conserve the soil and water. Out of total 38.72 ha area, 25 ha area of the watershed under orchard (mango-variety, alphanso, cashew, konkum etc.) 5.32 ha under permanent pasture and 5 ha under building and roads etc. and 1 ha land under seasonal cropping and 2.40 ha were utilized for different water harvesting structures.

In the watershed one Priyadarshini pond having capacity 27,370 cum capacity was constructed as farm pond by excavating up to 4.25/m depths and it serves as major source of ground water recharge to the wells in downstream side. It holds the water maximum upto last weeks of the March and then after it become the dry but effect of recharging shown by the wells in the influenced and uninfluenced area.

Two rectangular and one circular recharge ponds were contracted. The water from catchments was diverted to both rectangular recharge ponds having the capacity of 4,156 m^3 each and circular pond having capacity of 113.03 m^3. As drainage line treatments works, 14 Konkan vijay bandhara (KVB) were constructed on the stream passing through the center of the watershed and these KVB harvested 119 m^3 of water. The Konkan vijay bandhara are same as loose boulders but become imperious by laying plastic on upstream side after recession of monsoon i.e. in the month of September.

Ground water monitoring

The four wells (W1, W2, W3, and W4) from influenced area and five wells (W5, W6, W7, W8, and W9) located in the uninfluenced area of watershed were selected for recording observation. The weekly water levels of all the selected wells were recorded from year 2005 to year 2010. The water table hydrograph and contour map of Priyadarshini watershed was prepared. The natural recession curves of wells for influenced and uninfluenced area of the watershed were prepared to study the influence of ground water recharge. The data were also analyzed to assess the significance on ground water recharge of Priyadarshini ponds and due to soil and water conservation works.

RESULTS AND DISCUSSION

Water level fluctuations of wells

Weekly water table of four wells from influenced area and five wells from uninfluenced area of watershed were monitored during October 2005 to February 2010.

Table 1. *Soil and water conservation work adopted in the watershed*

Sl. No.	Conservation Work	No. of structures constructed	Capacity of runoff storage (cum)	Area under utilization (ha)
1	Priyadarshini dugout type online pond	1	27370	0.80
2	Cement nala bandh (RCC, cement, & Laterite)	3	979.87	0.11
3	Dugout type offline recharge pond (Rectangular and circular)	3	4156	-
4	Dugout type 250 GSMUV stabilize line rainwater harvesting ponds	2	4563	0.3
5	Konka Vijay band	14	1191.43	0.2
6	Continuous contour trenches, Staggered contour trenches	-	-	5.0
7	Terracing	-	-	12.5
8	Under ground diaphragm (4 m deep X 200 m length x 0. 3 m wide)	1		-

W1 is situated near Priyadarshini pond. Hence, it shows maximum beneficial influence on ground water. The average water table drop was 2.94 m during October to April. Average water table of this well was 99.1 m throughout the year, which was much higher than average water table of other influenced and uninfluenced area wells. This is because of the ground water recharge received by this well from Priyadarshini pond. Average water depletion rate was 1.35 cm d^{-1}. It remained constant for most of the period.

W2 is located about 700 m downstream to the Priyadarshini pond and near the main stream showed higher water table as compared to the well situated in the uninfluenced area of watershed. The average water table drop from October to April was 5.96 m. Average water table of this well for study period was 90.32 m. Water depletion was higher in initial period. Average water depletion rate was 2.75 cm d^{-1}.

W3 is situated at downstream side of the Priyadarshini pond at 850 m, situated at new building of CAET Dapoli campus; the water from well was used for irrigation as well as domestic purpose. The average water table drop from October to April was 5.78 m. The result showed that rapid depletion of water table throughout the year. Average water depletion rate was 2.65 cm d^{-1}.

W4 is situated beyond the area of watershed but it is at downstream side of watershed considered in the influenced area and it is at 870 m southern side of Priyadarshini pond. The water from this well was utilized for irrigation purpose in Hi-tech project. The average water table drop from October to April was 6.06 m. Average water depletion rate was found to be 2.79 cm d^{-1}.

W5 is located about 800 m south of watershed adjacent to the road from university main gate to university library. The water from this well was used for domestic purpose. Average water depletion rate was found to be 3.11 cm d^{-1}.

W6 is near to W5 (800m), still southern side towards the university library. The water from this well was used for domestic purpose throughout the year. It showed more fluctuation, but later it showed almost constant depletion rate. Average water depletion rate was found to be 3.6 cm d^{-1}.

W7 is situated in northwestern side of Priyadarshini pond Water from this well was frequently pumped for hostel. Well-showed uneven pattern of depletion. Average water depletion rate was found to be 3.84 cm d^{-1}.

W8 is situated near the Kisan Bhavan at northeastern side of the Priyadarshini pond 890 m away. The water from this well was utilized for Kisan-Bhavan as well as for irrigation to cashew and mango orchards in Kisan watershed. Because of frequently pumping of water from well it showed tremendous water table fluctuation. Average water depletion rate was found to be 3.35 cm d^{-1}.

W9 is situated at northern side of Priyadarshini pond (Sable quarter) private owned well located outside of the watershed. Water was daily lifted for domestic purpose and showed more water depletion as compared to well situated from the influenced area of watershed. Average water depletion rate was found to be 3.28 cm d^{-1}.

Table 2. *Water level of wells located in the influenced and uninfluenced area from year 2005-2010*

Wells No.	Reduced level of wells (m)	Average water table drop (m)	Water table depletion rate (cm day^{-1})
Wells in influenced area			
W1	104.40	2.94	1.35
W2	100.03	5.96	2.75
W3	100.27	5.78	2.65
W4	98.74	6.06	2.79
Wells in uninfluenced area			
W5	100.85	11.10	3.11
W6	100.58	13.10	3.6
W7	101.94	9.11	3.84
W8	100.89	13.5	3.35
W9	100.00	14.03	3.28

Average water depletion of wells located in influenced and uninfluenced area

The hydrograph of ground water levels of well located in influenced area and uninfluenced area were drawn and shown in Fig 1. It is observed that, the natural recession curve for well located in influenced area and uninfluenced area is logarithmic in nature. It also shows depletion of ground water levels in wells located in uninfluenced area are faster as compared to the well located in influence area. The recession curves have coefficient of regression at 1 % level of confidence are 0.96 and 0.93 for well located in influenced area and uninfluenced area, respectively. Hence, the well in influenced area have low rate of depletion due to the effect of ground water recharge of the Priyadarshini pond and different soil and water conservation work executed in the watershed.

Comparison of ground water table in influenced and uninfluenced area

It was observed that, the wells in influenced area of watershed has average drop 5.18 m with average depletion rate 2.39 cm d^{-1} and it also observed that, the wells in uninfluenced area of watershed has average drop 7.45 m with average depletion rate 3.43 cm d^{-1}, which is much higher as compared to the influenced area (Fig. 1). Hence, the well within the influenced area has less depletion rate and due to recharge from the Priyadarshini pond.

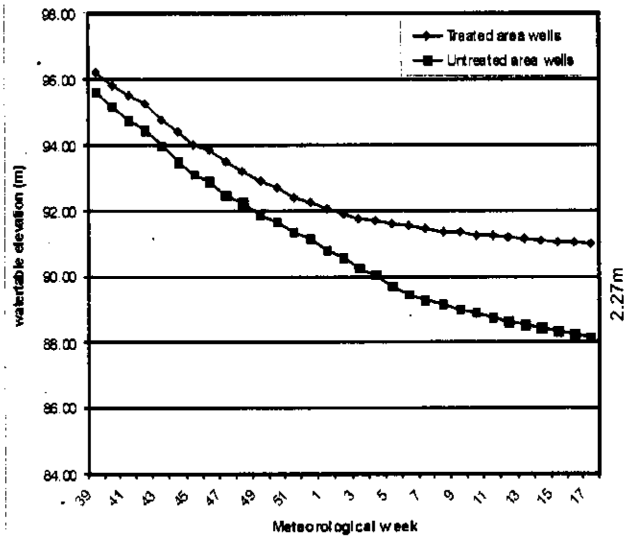

Fig. 1. Average water table elevation in influenced and uninfluenced area from 2005 to 2010

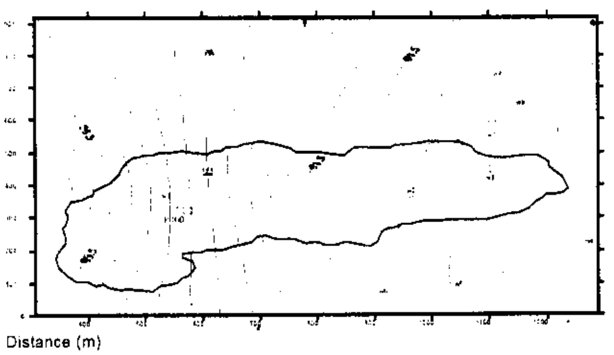

Fig. 2. Isobaths map of Priyadarshini map of year 2005-10

It is observed from Fig. 1 that, there was build up in water table in the influenced area of watershed during the year 2005-10. The average waterfall in the influenced area of the watershed was recorded as 5.18 m while it was recorded as 7.45 m in the uninfluenced area of watershed during year 2005-10. It was observed that, the water table of the influenced area was 2.27 m higher than the water table of uninfluenced area.

Isobaths map of Priyadarshini Watershed for the year 2005-10 is presented in Fig. 2. From the isobaths map, it is observed that, well near Priyadarshini pond has high water table exists. It is clear that, there was flow of water from Priyadarshini pond towards the downstream side. As a result of this, water table of the well situated on downstream side of this pond was high as compared to other wells situated in uninfluenced area of the watershed.

On stream pond has storage volume of 27,470 m^3, after rainy season water in pond-started depletion. Water was available in the pond up to last week of February. But this pond proved to be source of groundwater at downstream side. Analysis of average water level of wells in influenced area and uninfluenced area shows the impact of on stream pond on groundwater recharge. It is observed that ground water level increased in influenced zone more prominently upto the 800 m from the source of the recharge (Priyadarshini pond) and same trend is also observed in the Isobaths map of Priyadarshini watershed given in Fig. 2.

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Rainwater Harvesting Through Lined Farm Pond for Sustainable Development of Konkan Region

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Two dugout type 250 GSM Silpaulin lined farm pond of 18.90 lakh liters and 26.72 lakh liters capacities were constructed at Instructional farm, College of Agriculture Enginering and Tech., Dr. BSKKV, Dapoli in the year 2004-05. The total cost involved in construction and lining of ponds was Rs 2, 16,515/-. The cost of harvested rainwater was observed to be Rs 0.97 per liter. The harvested rainwater was utilized for irrigation of different crops such as banana, watermelon, brinjal, chilli, cabage, cashew, leafy vegetables *etc.*, on area of one hectare during the years 2005-10. The aquaculture was practiced in the year 2005-06 and 2006-07. The amount of harvested rainwater used for irrigating different crops was 32.31 lakh liter (70.80 per cent) and 13.32 lakh liter (29.2 per cent) lost as evaporation. The net income obtained from the production of different crops for entire duration of year 2005-10 was Rs 4,15,885/-. Hence, the average BC ratio for the life span of lining material of was 1:1.97. The average net benefit (Rs per sq m) for watermelon, cabbage, brinjal, chilly and leafy vegetable were observed to be 18.42, 8.05, 8.88, 8.05 and 9.10, respectively. The watermelon gave largest returns per unit area as compared to other crops.

*(**Key words:** Rain water harvesting, lining, silpaulin, dugout type ponds, agriculture, irrigation)*

The Konkan region is coastal parts of the Maharashtra state situated between 15°6′ N and 20°22′ N latitude and 72°30′ E and 73°48′ E longitude covering total geographical area of 30.9 lakh ha. The total cultivable area is 8.6 lakh ha which is 28.25 per cent of total geographical area of the Konkan region, The region constituts 10% of total area and receives 46 per cent of total precipitation of the of Maharashtra state. The average annual rainfall of the region is 3000 mm. Though, the region falls under humid zone, irrigation potential is created to the tune of 4.92 per cent and actual area under irrigation is less than 1.5 per cent. This region also faces the problem of water crisis in the summer. The heavy rains received during monsoon can be utilized for cropping in non-monsoon period. The limitation for storing the harvested rainwater in the farm pond in the region is percolation through the bottom and seepage from sides of the ponds. The seepage losses can be reduced by providing the lining to the ponds.

The various rainwater harvesting techniques have been demonstrated to the farmers by various developmental agencies of the state but it has failed to achieve its desired level. Verma (1981) stated that, rainwater harvested in small check dams could be used for providing life saving irrigation to rainfed crops in submontane region of Punjab. Srivastva (1988) advocated the use of 250 micro black-colored LDPE sheet lining with round smooth stones for construction of water harvesting tanks in hilly areas. Saha *et al.*, (2007) recommended the use of Jalkund made up of clay and cow dung plastering followed by 3.5 cm cushioning with dry pine leaf, laying down of 250 micro meter LDPE black agrifilm covered with 5.8 cm bamboo for storage of rainwater (600-30000 liter capacity) for north eastern hilly region. Since, the LPDE sheet is available in 6 m width; it required joints in large tanks. These joints become weaker with passage of time and store water seeps down. Rana *et al.*, (2009) reported that, Silpaulin lined farm pond are more economical than LDPE line and cement lined farm ponds.

The Silpaulin film (250 GSM) provided to be best lining material for the farm ponds in the Konkan region to control seepage through bottom and side of farm pond (Kale *et al.*, 2002). The study was conducted to find out the best crop combination suitable for the Konkan region. An attempt was also made to study the possibility rearing the fishes (IMC) in the harvested rain water as a concept of integrated farming for the region.

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Table 2. *Crop grown, water utilization and its benefits for year 2005-2006*

Sr No.	Crop grown	Area, m^2	Crop duration, Days	Water utilized (through micro irrigation system), lit.	Balance water in pond	Yield, kg	Cost of production, (Cultivation, labor, seed, fertilizer, pesticides etc)	Income, Rs	Profit, Rs	BC Ratio
1	2	3	4	5	6	7	8	9	10	11
1	Watermelon (Variety-F1, Namdari 295)	1200	November to March (120 days)	3,16,800	42,45,200	3500	3450	17500	14050	
2	Cabbage (Golden acre) (Drip and micro Sprinkler)	900	December to February (90 days)	3,83,377	38,61,823	1562	3800	12496	8696	
3	Leafy vegetables (Spinach, Coriander, etc)	300	November to February (4X4)	1,00,520	37,61,303	1500 bunches	500	3000	2500	
4	Brinjal (E-395, Local)	800	December to March	1,80,000	35,81,303	1230	2500	9840	7340	1.31
5	Fish (Katla, Rohu)	2248	July to March	-	35,81,303	536	4500	21440	16940	
6	Prawns (*M rossenbergii.*)	2248	July to March	-	35,81,303	24.75	450	7425	6975	
7	Cashew and gardening	6615	January to May	10,26,250	25,55,053	-	Cashew was two year old therefore no production observed			
8	Evaporation loss			13,22,770	12,32,283					
9	Balance water used for fish cultivation upto last week of May				**12,32,283**	**Total**	**15200**	**71701**	**56501**	

Table 3. *Crop grown, water utilization and its benefits for year 2006-07*

Sr No.	Crop grown	Area, m^2	Crop duration, Days	Water utilized (through micro irrigation system), lit.	Balance water in pond	Yield, kg	Cost of production, (Cultivation, labor, seed, fertilizer, pesticides etc)	Income, Rs	Profit, Rs	BC Ratio
1	2	3	4	5	6	7	8	9	10	11
1	Banana (Supplementary irrigation)	2800	Planted in September 2006	15,09,900	30,52,100	-	-	-	-	
2	Watermelon (Variety-F1, Namdari 295)	1200	November to March (120 days)	3,16,800	27,35,300	3160	3200	25280	22080	
3	Cabbage (Golden acre) (Drip and micro Sprinkler)	1050	December to February (90 days)	4,15,000	23,20,300	1650	3800	13200	9400	
4	Brinjal (E-395 local)	800	Dec to May	3,50,400	19,69,900	1350	2580	9450	6870	1.34
5	Chili (Jwala)	800	Dec to May	3,50,400	16,19,500	750	2560	9000	6440	
6	Leafy vegetables (Spinach, Coriander, etc)	300	November to February (4X4)	1,00,520	15,18,980	1600 bunches	600	3200	2600	
7	Fish (Katla, Rohu)	2248	July to March	-	15,18,980	350	3500	14,000	10,500	
8	Cashew and gardening	6615	January to May	1,90,200	13,28,780	-	Cashew was Three year old therefore no production observed			
9	Evaporation loss			13,14,430	14,350					
10				**Balance**	**14,350**	**Total**	**16,240**	**74,130**	**57,890**	

Table 4. *Crop grown, water utilization and its benefits for year 2007-2008*

Sr No.	Crop grown	Area, m^2	Crop duration. Days	Water utilized (through micro irrigation system), lit.	Balance water in pond	Yield, kg	Cost of production, (Cultivation, labor, seed, fertilizer, pesticides etc)	Income, Rs	Profit, Rs	BC Ratio
1	2	3	4	5	6	7	8	9	10	11
1	Banana (Supplementary irrigation)	2800	Planted in September 2006	17,72,400	27,89,600	1780.2	25750	85650	59900	
2	Watermelon (Variety-F1, Namdari 295)	1200	November to March (120 days)	3,16,800	24,72,800	3560	3500	28488	24988	
3	Cabbage (Golden acre) (Drip and micro Sprinkler)	1050	December to February (90 days)	4,15,000	20,57,800	1050	4200	10500	6300	2.27
4	Leafy vegetables (Spinach, Coriander, etc)	300	November to February (4X4)	1,00,520	19,57,280	1600 bunches	600	3200	2600	
5	Cashew and gardening	6615	January to May	2,08,760	17,48,520	130		4550	4550	
6	Evaporation loss			13,20,530	4,27,990					
7				**Balance**	**4,27,990**	**Total**	**34,050**	**1,32,388**	**98,338**	

Table 5. *Crop grown, water utilization and its benefits for year 2008-2009*

Sr No.	Crop grown	Area, m^2	Crop duration, Days	Water utilized (through micro irrigation system), lit.	Balance water in pond	Yield, kg	Cost of production, (Cultivation, labor, seed, fertilizer, pesticides etc)	Income, Rs	Profit, Rs	BC Ratio
1	2	3	4	5	6	7	8	9	10	11
1	Banana (Supplementary irrigation)	2800	Planted in September 2006	17,72,400	27,89,600	1780.2	10 000	72550	62,550	
2	Watermelon (Variety-F1, Namdari 295)	1200	November to March (120 days)	3,16,800	24,72,800	3136	3500	25088	21,588	
3	Cabbage (Golden acre) (Drip and micro Sprinkler)	1050	December to February (90 days)	4,15,000	20,57,800	1256	3950	12560	8,610	2.79
4	Leafy vegetables (Spinach, Coriander, etc)	300	November to February (4X4)	1,00,520	19,57,280	1520 bunches	600	3040	2440	
5	Cashew and gardening	6615	January to May	2,08,760	17,48,520	190		7875	7875	
6	Evaporation loss			13,21,710	4,26,810					
7				**Balance**	**4,26,810**	**Total**	**18,050**	**1,21,113**	**1,03,063**	

Table 6. *Crop grown, water utilization and its benefits for year 2009-2010*

Sr No.	Crop grown	Area, m^2	Crop duration, Days	Water utilized (through micro irrigation system), lit.	Balance water in pond	Yield, kg	Cost of production, (Cultivation, labor, seed, fertilizer, pesticides etc)	Income, Rs	Profit, Rs	BC Ratio
1	2	3	4	5	6	7	8	9	10	11
1	Banana (Supplementary irrigation)	2800	Planted in September 2006	17,72,400	27,89,600	1300.6	10,169	60,260	50,099	2.31
2	Watermelon (Variety-F1, Namdari 295)	1200	November to March (120 days)	3,16,800	24,72,800	3914.12	3500	31,313	27,813	
3	Cabbage (Golden acre) (Drip and micro Sprinkler)	1050	December to February (90 days)	4,15,000	20,57,800	1307.46	4050	13,074	9,024	
4	Leafy vegetables (Spinach, Coriander, etc)	300	November to February (4X4)	1,00,520	19,57,280	1388.3 bunches	600	4,165	3,565	
5	Cashew and gardening	6615	January to May	2,08,760	17,48,520	200		9,600	9,600	
6	Evaporation loss			13,21,710	4,26,810					
7				**Balance**	**4,26,810**	**Total**	**18,319**	**1,18,412**	**1,00,093**	

The Average B: C ratio for year 2005 to 2009 is 1:1.97

Table 6. *Crop grown, water utilization and its benefits for year 2009-2010*

Sr No.	Crop grown	Area, m^2	Crop duration, Days	Water utilized (through micro irrigation system), lit.	Balance water in pond	Yield, kg	Cost of production, (Cultivation, labor, seed, fertilizer, pesticides etc)	Income, Rs	Profit, Rs	BC Ratio
1	2	3	4	5	6	7	8	9	10	11
1	Banana (Supplementary irrigation)	2800	Planted in September 2006	17,72,400	27,89,600	1300.6	10,169	60,260	50,099	2.31
2	Watermelon (Variety-F1, Namdari 295)	1200	November to March (120 days)	3,16,800	24,72,800	3914.12	3500	31,313	27,813	
3	Cabbage (Golden acre) (Drip and micro Sprinkler)	1050	December to February (90 days)	4,15,000	20,57,800	1307.46	4050	13,074	9,024	
4	Leafy vegetables (Spinach, Coriander, etc)	300	November to February (4X4)	1,00,520	19,57,280	1388.3 bunches	600	4,165	3,565	
5	Cashew and gardening	6615	January to May	2,08,760	17,48,520	200		9,600	9,600	
6	Evaporation loss			13,21,710	4,26,810					
7				**Balance**	**4,26,810**	**Total**	**18,319**	**1,18,412**	**1,00,093**	

The Average B: C ratio for year 2005 to 2009 is 1:1.97

Cultivation of agricultural crops and its benefits

In the year 2005-06, the water was utilized for irrigation through micro irrigation system to watermelon (Namdhari, F1), cabbage (Golden acre), leafy vegetable, brinjal (E-395), chili (Jwala) and supplemental irrigation to cashew garden (Table 2) during the period of November to May. The actual evaporation loss measured at site was found 13.23 lakh liters, which was 29 per cent of total harvested rainwater. Out of total 45.65 lakh liter harvested rain water 43.96 per cent (20.07lakh liters) water utilized for above crops for irrigation to one ha area. Remaining water of 12.32 lakh liter water was utilized for aquaculture (IMC) upto June 2006. Micro irrigation systems (Drip and micro sprinklers) were installed on the farm and water was lifted with 3 hp electrical motor pump. Cost of lifting water was included in the cost of cultivation. Water requirement was estimated with evaporation data available at agro meteorological station, Dapoli. The total income generated due to selling of the farm produce during 2005-06 by considering local market prices was Rs 71,701/- and cost of production obtained which included (cultivation, labours, seeds, fertilizers, pesticides, electrical charges, etc) was Rs 15,200/- for all crops cultivated during year 2005-06. Hence, net income for the year 2005-06 was Rs. 56,501/-. The cost benefit (BC) ratio of harvested rainwater for year 2005-06 was 1:1.31. Though, the BC ratio for year 2005-06 is less but by considering long life of ponds benefit can be increase by altering the cropping system.

The same cropping pattern was followed for year 2006-07 of previous year (2005-06) in addition to that, perennial crop banana (G-nine) was cultivated on 2800 sq m area in the month of September 2009. The experiment for different density of 1.25 m x 1.25 m, 1.5m x 1.5m and 1.75m x 1.75 m on drip irrigation system with different level of water application rate and different fertigation levels was operated. The 15.09 lakh liter was supplied to banana as supplemental irrigation. The total water utilized for irrigating to all crops is given in Table 3 was 32.30 lakh liters and only 14,350 liter was remaining balance in the ponds meeting the evaporation losses at end of May 2007. The production cost for year 2006-07 was Rs 16,240/- and total gross income generated was Rs 74,130/-. The net income was Rs 57,890/-. The BC ratio for year 2006-07 obtained was 1:1.34.

The banana, watermelon, vegetable crops and cabage were cultivated on an area of 5350 sq m. The details of cost involved and benefit from different crops grown in year 2007-08 is in given Table 4. The total gross income for year 2007-08 was Rs 1,32,388/-and production cost was Rs 34,050/-. Hence, net income was Rs 98,338/-. The BC ratio for year 2007-08 was 1:2.27. As the banana started the yielding, the BC ratio of this year is prominently increased as compared to the year 2005-06 and 2006-07.

In the year 2008-09 (Table 5), same crops were repeated as year 2007-08. Water supplied for the crops was also same and production is found nearly same. But production cost is found less compared to the year 2007-08. The production cost for year 2008-09 was Rs 18,050/- which half of year 2007-08 and net income is Rs 1,03,063/-. The BC ratio for year 2008-09 is 2.38. It is much high as compared to the year 2007-08. In addition that cashew was cultivated in year 2003-04.

The water harvested and crop cultivated, income generated during period of 2009-10 are shown in Table 6. The same quantity of water was utilized for the cultivation of banana, cabbage, watermelon and leafy vegetables etc. Total cost of production was found to be Rs 18,319/- and gross income is Rs 1,18,412/-. The net income is Rs 1,00,093/-. But this year production of banana drastically decreased due to third raton of Banana and crop suffered due to Fyan cyclone in the month of November 2009.

Aqua culture in the ponds

The fresh water aquaculture (IMC) were cultivated in the harvested rain water in both ponds during year 2005-06 and 2006-07. Total number of 3500 seedlings of Katala and Rohu and 1500 seedling of M. Rossenbergii were released in the month of June 2005 in both ponds. It was harvested in the month of April and May in respective years. The fishes were fed as per the feeding schedule. The quality of water i.e. pH, EC was checked at regular interval. The provision was made to aerate the water by aerator to increasing the dissolved oxygen in the water. Total production of 536 kg and 350 kg in the year 2005-06 and 2006-7 were obtained respectively. That gives to total benefit by selling the fishes of Rs 16,940/- for year 2005-06 and Rs 10,500/- for year 2006-07 and Prawn production was obtained 24 kg gave total benefit of Rs 6975/- for year 2005-06. But, growth of the both fishes and Prawn was not found satisfactory in the pods. It may be due to, was lined pond give no proper growth of algae in the harvested water.

Table 7. *Projected area that can be brought under irrigation on harvested water through lined pond*

Sr. No.	Crop grown	Area, m^2	Average water supplied to the crops, liter	Water supplied by the crops, liter / m^2	Projected area that can be brought under each crop on harvested rain water, ha.
1	Watermelon, (Namdari)	1200	316800	264	1.73
2	Cabage, (Golden acre)	1050	415000	395	1.15
3	Brinjal, (local) 800	350400	438	1.04	
4	Chili, (Jwala) 800	350400	438	1.04	
5	Leafy vegetables (Math, spinach, coriander, etc.)	300	100520	335	1.36

Cost benefit ratio of harvested rainwater

In both ponds in the 5 year life tenure of Silpaulin from 2005-10 total of 228.1 lakh liter water was harvested. The total cost involved for construction and lining of ponds was Rs 2,16,515/- (Table 1). The cost of harvested water was observed to be Rs 0.97 per liter. On an average total 166.0 lakh liter water utilized for different crop viz banana, watermelon, cabages, brinjal, chilli, leafy vegetable and to cashew irrigation excluding evaporation losses. The net income obtained from the production of different crops for duration of year 2005-10 was Rs 4,15,887/-. Hence, the average BC ratio for the life span of lining material was 1:1.97.

The projected utilization of harvested water for different crops suitable for the region estimated on the basis of five years study is shown in Table: 7. It is observed form Table 7 that, harvested rainwater (45.66 lakh liters) could irrigate single crops of watermelon on 1.73 ha area and it followed by cabage, leafy vegetable, brinjal and chili of 1.15, 1.36 and 1.04 ha. respectively. It is observed that, watermelon crop has given more returns of Rs 18.42/m^2. Hence, paddy followed by watermelon is suitable for South Konkan region. The average net benefit Rs per sq m observed for cabbage, brinjal, chilly and leafy vegetable were Rs. 8.05, 8.88, 8.05 and 9.10, respectively. Hence, this water harvesting pond technology with lining is found suitable for harvesting rainwater and bringing more area under irrigation of the region. Thus, it may helps in enhancing the employment generation in the rural area. Therefore, this technology is appropriate for sustainable development of the Konkan region.

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Assessment of System of Rice Intensification (SRI) during *Rabi* Season in Coastal Salt-Affected Soils

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The coastal agricultural system in India is predominated by rice crop. During *Kharif* season due to availability of rainwater, the salinity problem of the coastal soil usually remains manageable level and thus the rice cultivation is prevalent among the farmers. But as the monsoon recedes the availability of freshwater declines, soil starts drying and the soil salinity builds up gradually. Therefore, the cultivation of rice during this *Rabi* season is more challenging and requires good management practices, particularly water. System of rice intensification (SRI) is one of the options for rice cultivation, which requires less water and may be suitable under such conditions. It involves single and young seedlings (8-12 d) transplantation with care instead of conventional method of multiple and mature seedlings. SRI spaces rice plants more widely (25 cm × 25 cm) and does not depend on continuous flooding of rice fields. It uses lesser seed, chemical inputs, irrigation water and promotes soil biotic activities in and around plant roots enhanced through application of compost and weeding with a rotating hoe that aerates the soil. However, entire set of management practices of SRI as evolved in other rice production environments are not suitable under coastal salt affected areas. Under the salinity stress condition the seedling stage of rice is very sensitive, therefore very young seedling as suggested may not sustain this stress, similarly the problem of mortality of single seedling transplanting per hill needs to be addressed. Relatively older seedling (15-18 days old) instead of 8-12 days old seedling transplanting and gap filling in case of mortality may be done at appropriate stage to fill the hills, which remain open due to mortality of seedlings. The organic manure requirements in SRI can be met during *Rabi* season by cultivation of Azolla along with rice in the initial stage of rice crop and incorporating the same at the latter stage augmented with seed treatment with *Azospirillum*, Phosphate Solubilizing Bacteria and Trichoderma.

(***Key words:*** *Assessment, System of Rice Intensification, Saline soils, Modifications, Rabi season*)

In the coming decades, the farm families of India need to produce more food grains and other agricultural ·ommodities under conditions of shrinking per capita land and water resources and expanding biotic and abiotic stresses. India needs to increase its rice production at the rate of 2.0 million tonnes per year until 2050 to meet its food security. By 2025, 15 out of 75 million hectare of Asia's paddy rice will experience water shortage (Tuong and Boumann, 2003). To meet the increasing food demand due to the burgeoning population, more foods have to be produced per unit of cultivated area through manifold increase in the land and water resource use efficiency. To make the agricultural production sustainable, technologies that conserve the resources (land, water, seeds, etc.) and reduce the cost of cultivation are to be developed and adopted. Since rice is the staple food of the majority of the population of India in general and coastal region in particular, increase in the productivity of this crop could help to achieve food security. In the present paper the suitability of the System of Rice Intensification (SRI) in increasing productivity and conserving resources for the coastal salt affected soils have been studied.

MATERIALS AND METHODS

A field trial was conducted during the Rabi season of 2010-2011 at Central Soil Salinity Research Institute, Regional Research Station, Canning Town (latitude: 22°15′ N, longitude: 88°40′ E and altitude: 3.0 Meters from AMSL) to assess the SRI method for the coastal salt affected soils. The climate of the experimental site is sub-humid with Aquic moisture and Hyperthermic soil temperature regimes. The average annual rainfall is 1802 mm, out of which about 80% occurs during monsoon (June – October) and only very limited rain during rest of the period of year. The experimental soil is silty clay in texture, almost neutral pH (7.28), and having 0.61% organic carbon, 0.049% total N, and 192, 22.4 and 468 kg ha^{-1} of available N, P and K, respectively. The soil is saline with ECe of 6.68 dSm^{-1} during the land preparation (December) for

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Table 1. *Suggested package of practices for SRI in coastal salt affected soils as compare to normal soils*

Particulars	Normal transplanting	Normal SRI	SRI in Salt affected soils
Variety	HYV	Same as normal transplanting	Salt tolerant varieties
Nursery preparation	Wet beds with less FYM and NPK as recommended (1:0.5:0.5 kg NPK 100 m^{-2} area)	Nursery on raised beds with old gunny bag at the bottom and manured heavily without NPK	Nursery in raised beds, with irrigation facility to wash out salts, optimum FYM application
Seeding density	Seeds are sown thickly @60 g m^{-2} in 1000 m^2 nursery area (60 kg seed ha^{-1}) for one hectare of transplanted area	Seeds are sown thinly @50 g m^{-2} in 100 m^2 nursery area (5 kg seed ha^{-1}) for hectare of transplanted area	Seeds are sown thinly @50 g m^{-2} in 120 m^2 nursery area (6 kg seed ha^{-1}) for one hectare of transplanted area. Seedling from 100 m^2 nursery area is used for transplanting and from rest 20 m^2 nursery area for gap filling
Seedling	Roots are washed in water and transplanted at 4-5 leaf stage	Roots are not washed in water and transplanted along with soil at 2.5 leaf stage immediately	Roots are not washed in water and transplanted along with soil at 3-4 leaf stage
Transplanting	Transplanted after 12 - 24 hours after uprooting	Transplanted immediately after pulling the nursery	Transplanted immediately after pulling the nursery
Spacing	Shallow to deep planting with a spacing of 15 X 15 cm	Only shallow planting with a spacing of 25 X 25 cm	Only shallow planting with a spacing of 25 X 25 cm
Age of seedling	Transplanted after 30 days with 3 - 4 seedlings $hill^{-1}$	Transplanted at 12 days with single seedling $hill^{-1}$	Transplanted within 15-18 days with single seedling $hill^{-1}$
Gap filling	Gap filling done at 10^{th} day after transplanting. Transplanting shock is observed	Gap filling is not compulsory and transplanting shock is not observed	Gap filling is to be done 10^{th} day after transplanting in the hills where mortality is observed due to salinity
Weeding	Manual weeding twice (30 and 45 DAT)	Use of cono weeder in both the directions (3 times) to control weeds and uprooted weeds are incorporated	Use of cono weeder in both the directions (3 times) to control weeds and weeds are incorporated
Water management	Submergence of 2-3 cm is maintained throughout crop growth	Saturation is maintained up to PI stage and later thin film of water (2 cm)	Extra water is used for washing out the salts from the root zone
Nutrient management	Recommended dose of fertilizer	Recommended dose of fertilizer	FYM along with fertilizer. cultivation of Azolla along with rice, use of *Azospirillum*, Phosphate Solubilizing Bacteria and *Trichoderma*

the experiment. Salinity builds up due to gradual drying up of lands after monsoon season and attains maximum in the month of April-May, it builds up in the soil due to upward capillary movement of saline groundwater present at shallow depth.

The six treament combinations consited of two varieties (Canning 7 and CSR 4) and three management practices (Table 1): normal transplanting (NT), normal SRI (NSRI) and SRI in Salt affected soils (SRI SALT). The experiment was conducted in a Randomized Block Design with three replication. Plant height (cm) was measured from the base of stem up to the apex of the plant (tip of the longest leaf or the panicle if longer). The average height was calculated from the observations taken on 12 hills in each plot. Numbers of tillers $hill^{-1}$ under each treatment was noted on 12 random hills by visual counting. The leaf length and breadth were measured by the use of Leaf Area Meter (Model: CI-202). The whole root system of 12 randomly selected hills from each treatment was separated carefully by washing under water. The entire root system along with adhered soil was transferred onto a fine wire mesh and adhering soil was removed by applying a fine jet of water on to the root system. Precautions were taken to prevent any loss of roots. The root parameters were measured for each treatment. Grains were harvested, dried and weighed, and grain weight is adjusted to a moisture content of 0.14 g H_2O g^{-1} fresh weight. Grain yield was determined from each plot and converted to t ha^{-1} by multiplying suitable factor.

RESULTS AND DISCUSSION

Options for increasing rice productivity

Out of the several options like hybrid seeds, biotechnologies and SRI; SRI is comparatively better as the former technologies are heavily dependent on high-cost modern inputs and also have the associated problems of soil and environmental degradation. The System of Rice Intensification (SRI) developed in Madagascar by Father Henri de Lau Lanie in association with Non-Governmental Organization – Association Tefy Saina (ATS) and many small farmers in the 1980's (Stoop *et al.*, 2002; Uphoff *et al.*, 2002) offers opportunities to researchers and farmers to expand their understanding of potentials already existing in the rice genome. It involves careful transplanting of single young seedlings (8-12 d) instead of conventional method of multiple and mature seedlings. SRI spaces rice plants more widely (25 cm × 25 cm) and does not depend on continuous flooding of rice fields. It uses lesser seed, chemical inputs and promotes soil biotic activities in and around plant roots, enhanced through application of compost and weeding with a rotating hoe that aerates the soil. SRI reduces the need for irrigation water by half and also reduces the requirement for capital and seed (Uphoff, 2003). It has been reported that there is saving of seeds by 80%, irrigation water by 50% (Bisht *et al.*, 2007) and increase in yield by 25-30% (Uprety, 2006 and Chellamuthu and Sridevi, 2006). Dobermann (2004) opined that SRI approach may serve the important needs of resource-poor farmers in areas with poor soils, but are likely to have little potential for improving rice production in intensive irrigated systems on more favorable soils, where high yields can be achieved through implementation of more cost-efficient management practices.

Coastal rice growing environment

The coastal agricultural system in India is predominated by rice crop. During *Kharif* season due to availabilty of rainwater, the salinity problem of the coastal soils usually remains managable and thus the rice cultivation is prevalent among the farmers. But as the monsoon receedes the availability of freshwater declines, soil start drying up and the soil salinity builds up gradually. Therefore, the cultivation of rice during the *Rabi* season is more challenging and requires good management practices, particulalrly water. SRI is one of the options for rice cultivation which requires less water, thus may prove suitable under these conditions. In *Rabi* season also, rice occupies major share of cultivable area in coastal salt-affected soils. The cost of cultivation of rice is higher during this season due to the scarcity of irrigation water, heavy incidence of insect pests and diseases *etc.* Reports suggest that SRI has the potential to become profitable through reallocation of resources, especially labour, capital and irrigation (Reddy *et al.*, 2005). Salinity is a major yield-reducing factor in coastal rice production systems during *Rabi* season. Irrigated rice is a well-suited crop in controlling and even reducing soil salinity, but it is a salt-susceptible crop and yield losses due to salinity can be substantial. Therefore, while practicing the SRI, the recommended normal package of practices may not be suitable and a set of modified practices as suggested (Table 1) may be followed. Adjustments and specific recommendations are to be followed under coastal salt affected environment. Under the salinity stress condtion the seedling stage of rice is very sensitive, therefore very young seedling may not sustain the stress, similarly the problem of mortality of single seedling transplanted per hill needs to be addressed. To overcome these problems modifications need to be done to maintain optimum uniform plant population in the entire field. Relatively older seedling (15-18 days old) instead of 8-12 days old seedling transplanting and gap filling in case of mortality may be done at appropriate stage to fill the hills which fall open due to mortality of seedlings.

Benefits from SRI

Saving of Seed: The seed rate is only 6 kg ha^{-1} as compared to 60 kg ha^{-1} under normal transplanting. This is a great benefit particularly for small and marginal farmers for whom seed cost is a barrier for adoption of improved varieties.

Increased tillering: The number of tiller per hill increased from 23 under normal transplanting to 37 following package of practices for SRI in salt affected soils (Table 2). This is the most obvious and significant result obtained under SRI method.

Table 2. *Performance of salt tolerant rice varieties under normal transplanting, normal SRI and SRI in salt affected soils*

Treatments	Plant height (cm)	Tillers hill^{-1}	Leaf length (cm)	Leaf breadth (cm)	Grain yield (t ha^{-1})
V1NT	102.8	23	35.5	1.10	4.93
V1NSRI	101.7	35	37.8	1.40	4.76
V1SRI SALT	101.5	37	38.8	1.40	6.34
V2NT	99.0	22	34.5	1.07	4.37
V2NSRI	98.5	33	35.6	1.30	4.61
V2SRI SALT	97.3	36	35.9	1.30	6.25
CD (0.05)	4.4	3.0	3.1	0.20	1.37

V1: Canning 7, V2: CSR 4
NT: Normal Transplanting, NSRI: Normal SRI, SRI SALT: SRI in Salt affected soils

Table 3. *Root characteristics of salt tolerant rice varieties under normal transplanting, normal SRI and SRI in salt affected soils*

Treatments	Root length (cm)	Root volume (c.c. hill^{-1})	Root dry weight (g hill^{-1})
V1NT	19.74	50.64	8.25
V1NSRI	22.40	57.23	9.47
V1SRI SALT	22.74	59.72	9.88
V2NT	20.11	50.12	7.93
V2NSRI	23.43	58.45	9.51
V2SRI SALT	24.27	59.33	9.67
CD (0.05)	2.22	5.13	1.21

V1: Canning 7. V2: CSR 4
NT: Normal Transplanting, NSRI: Normal SRI, SRI SALT: SRI in Salt affected soils

Greater root growth: The higher root growth in terms of root length, volume and weight was observed with SRI compared to normal transplanting (Table 3). The root length increased from 19.74 cm to 22.74 cm in case of variety Canning 7 and the same increased from 20.11 cm to 24.27 cm in case of variety CSR 4 due to adoption of package of practices of SRI for salt affected soils. Similarly the increase in root volume and weight were18 and 21%, respectively, in plants grown with SRI for salt affected soils over normal transplanting.

Water savings: Water requirements with SRI are usually reduced by about half since paddies are not kept flooded during the entire crop cycle. Water is much reduced during the vegetative growth phase, and only a minimum of water is kept on the field during the reproductive phase. This will become increasingly important in the agricultural sector. However, under saline situation extra amount of water is needed to washout the salts from the soil to avoid damage to the crop plants due to salinity under dry situation during Rabi season. The amount of irrigation water applied were 1450, 730 and 890 mm for NT, NSRI and SRISALT methods of cultivation, respectively. Averaged over varieties, the corresponding water use efficiency (WUE) values were 3.27, 6.41 and 7.63 kg ha^{-1} mm^{-1}, respectively. Thus there is increase in WUE as well as saving of significant amount of precious irrigation water, which could be used for growing other crops.

Less lodging: Because of stronger tillers and larger root systems, SRI plots withstood the force of wind and rain. The plants were sturdy, uniform in height and the growth of tillers in a hill was compact resulting in cushioning the effect of storm, hence less lodging.

Applicable to all varieties: Farmers can use whatever varieties they are already planting since SRI methods enhance yield for traditional as well as improved cultivars. However, under salinity stress condition the recommended salt tolerant varieties are to be grown for getting higher yield.

Less use of chemical fertilizers: While fertilizer increase yield with SRI methods, compost or any decomposed biomass usually gives even better results. Compost requires more labor but saves cash and avoids the need to borrow money, which is important for poorer farmers. Seed treatment with Trichoderma, seedling root dip for 8 to 10 hours in a solution of *Azospirillum* + Phosphotika at 5 kg ha^{-1} as well as growing of Azolla as dual crop with rice during the initial vegetative growth period and incorporating the same at later stage when it covered the entire field added organic matter to the soil and provided nutrients to the rice crop.

Reduction in cost of production and increase in yield: With external input requirements reduced, farmers can save substantial expenditure at the same time the yields are increased. The grain yield was significantly highest in the treatment with SRI in salt affected soils, irrespective of variety (Table 2). Reduction in yield by following normal SRI in salt affected soils may be due to the mortality of seedlings under salt stress condition.

Limitations of SRI

The main limitations for SRI are control over irrigation water i.e. to apply it when it is needed. The uprooting and transplanting of young seedling needs expertise and utmost care. When the fields are not kept flooded, there will be opportunity for more weed growth. Initially, SRI methods require more labor, as they need to be learned and mastered. In fact, this requirement is reduced in subsequent seasons, and SRI labor demand eventually becomes less than with conventional cultivation. The major requirement for SRI is motivation and skill. Farmers need to become more conscientious and knowledgeable managers of their plants, soil, water and nutrients. This is a cast at the outset, since time and effort are needed to disseminate SRI techniques correctly to farmers who may not have much confidence in them.

A set of modified holistic management practices are imperative to make SRI cultivation a success on coastal salt affected soils. This will save irrigation water and this saved water can be used for growing other high value crops in the unutilized land, thus crop diversification and risk minimization can also be achieved. Above all, planned effort and support to train as well as demonstrate farmers/farm women the basics and benefits of SRI is required in the salt affected area to realize the fruits of such technologies which can improve the livelihood of farmers in these disadvantaged areas.

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Computation of Reference Evaportranspiration for Humid Climate of Maharashtra State

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An attempt was made to estimate the reference evapotranspiration by PM-56 and Epan models for Dapoli station of Maharashtra. The six years (2000-2005) data was analyzed. The results showed that the daily reference evapotranspiration by Epan and PM-56 model was 3.28 mmday^{-1} and 3.88 mm day^{-1} respectively. The maximum reference evapotranspiration by Epan observed in the month of April while for PM-56 model in the month of May. The daily and monthly reference evapotranspiration estimated by PM-56 gave higher values i.e. 18.29 per cent more than Epan model. The data was also analyzed seasonally and found less error in winter season (0.11 mm day^{-1}) and maximum in summer (0.30 mm day^{-1}). The overall correlation coefficients for daily, metrological weekly, monthly and seasonal was more than 0.8 which indicated good correlation between Epan and PM-56 model. The developed linear relationship equations for different periods facilitate easy and quick estimation of reference evapotranspiration from Epan model to PM-56 model.

(***Key Words:*** *Reference Evapotranspiration, Penman-Monteith model, evaporation, correlation coefficient)*

The crop water requirement varies with crop characteristics and local condition. The crop water requirement is predicted using different approaches such as energy balance, empirical relationship and field study methods. The empirical relationships need many climatological variables for prediction of reference evapotranspiration. The availability of climate variables is limited in many locations of the country (Ali *et al.*, 2009). Many scientists had studied the different empirical methods at different locations of the country. Karla (1996) tested different empirical reference evapotranspiration estimation model and least square regression model for semi arid region (Chandigarh) and claimed that Penman model found suitable. Tomar and Ranade (2001) studied the reference evapotranspiration at Indore and found that modified Penman method was suitable for the region. Aloka *et al.*, (2001) found that FAO radiation; Jensen and Haise methods were found suitable for estimation of reference evapotranspiration. According to Goyal (2004) for arid zone the reference evapotranspiration predicted with Penman-Montieth method had close agreement with observed value. Singhandhupe *et al.*, (2007) tested different reference evopotranspiration equations for semi arid and sub humid region of Maharashtra and found that Penman Monteith equation predicted the reference evapotranspiration values with observed data in semi arid region and that of Penman model for sub humid climate. Rao and Rajput (1993) also studied different Penman based equations and compared reference evapotranspiration estimates with pan evaporations and found that Penman Monteith method gave reliable estimates. Thokal and Mahale (2007) developed the different empirical equations between, pan evaporation and metrological parameter and found that temperature, radiation; wind velocity had greater influence on pan evaporation while relative humidity has less influence on pan evaporation. Ingle *et al.*, (2009) concluded that under humid region of Maharashtra the estimation of reference evapotranspiration by Penman Monteith model had close conformity with measured Epan values.

These review showed that the PM-56 and Epan model was gave more reliable and accurate estimation of reference evapotranspiration with measured data. As the Epan model is simplest method for measurement of reference evapotranspiration and needs less data as compared to other estimation models. In the present study PM-56 and Epan models were studied. In pan evaporation method the reference evapotranspiration is estimated using pan factor and pan evaporation only and pan evaporation gave integrated effect of different climatologically parameters.

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The overall review pointed out that the Penman Monteith method and Epan methods were mostly used for reference evapotranspiration estimation depending upon the data availability. According to Smith *et al.*, (1992) the Penman Monteith method gives more consistent reference evapotranspiration estimates and performs better than other reference evapotranspiration methods when compared with lysimeter data and also suggested to compare and validate other methods with Penman Monteith. Therefore, in the present study an attempt was made to predict reference evapotranspiration for humid region of Maharashtra using Penman Monteith (PM-56) model and comparison of predicted reference evapotranspiration with Pan evaporation (Epan) model.

MATERIALS AND METHODS

The study was carried out Dapoli located at 17° 45' N latitude and 73° 26' E longitudes with an altitude of 250 above msl. The region is characterized by humid climate with average annual rainfall more than 3500 mm with moderate temperature ranging from as lower as 7.5°C to higher as 38.5°C. The average relative humidity ranges from 55% to 100%. In order to carry out the analysis the daily metrological data i.e. maximum and minimum temperature, maximum and minimum relative humidity, sunshine hours, wind speed and pan evaporation for 6 years (2000-2005) were collected from the metrological observatory, Department of Agronomy, Dr.B.S.K.K.V. Dapoli and were grouped in standard MW (metrological weeks), monthwise and seasonwise. The PM-56 and Epan models were used for estimation of reference evapotranspiration.

Penman Monteith method (FAO-56)

The Penman Monteith model FAO-56 (Allen *et al.*, 1998) is used for prediction of evapotranspiration. The general description of model as follows

$$ETo = \frac{0.480\Delta\,(Rn - G) + \gamma\,\frac{900}{T + 273}\,U2\,(ea - ed)}{\Delta + \gamma\,(1 + 0.34\,U2)}$$

Where,

ETo = grass reference evapotranspiration (mm day^{-1}), G = soil heat flux density (MJ m^{-2} d^{-1}), T = mean daily air temperature (°C), γ = psychometric constant (kPa $°C^{-1}$), Δ = slope of the saturation vapour pressure function (kPa $°C^{-1}$), ea and ed = saturation vapour pressure and actual vapour pressure (kPa), Rn = net radiation (MJ m^{-2} d^{-1}).

Pan evaporation model

Evaporation pan is most widely used device for evaporation measurement. Evaporation pan have been used for measurement of evaporation. In the present study the USWB Class-A pan is used for measurement of evaporation.

$$ETo = Epan \times Kp$$

ETo = reference evapotranspiration (mm day^{-1}), Epan = pan evaporation (mm day^{-1}), Kp = pan factor (0.7)

As pan evaporation provides a measurement of the combined effect of temperature, humidity, wind speed and sunshine hours on reference evapotranspiration (Doorenbos and Pruitt, 1977) for computation of reference evapotranspiration the pan factor was taken as 0.7. For a class-A evaporation pan the Kp varies 0.35 to 0.85. The average Kp of 0.7 was used for analysis (Brouwer and Heilbloem, 1986). The estimation of reference evapotranspiration using PM-56 model and Epan was done on daily basis, metrological week basis, monthly and seasonawise. The seasons were divided according to Standard Metrological Weeks (Goyal, 2004).

Summer season - 10th to 26th MW

Monsoon season - 27th to 44th MW

Winter season - 45th to 52nd MW and 1st to 9th MW

RESULTS AND DISCUSSION

The reference evapotranspiration from year 2000 to 2005 on daily basis was calculated. The analysis showed that the maximum evapotranspiration using Penman Monteith model and Epan model was observed in the month of April and May due to high temperature, low humidity and moderate wind speed. The maximum reference evapotranspiration for PM-56 model was ranges from 6.02 mm day^{-1} to 6.64 mm day^{-1} for different years. The average maximum temperature for PM-56 model was 6.03 mm day^{-1} similarly the minimum reference evapotranspiration using PM-56 was also ranges from 1.58 mm day^{-1} to 1.88 mm day^{-1} and average minimum reference evapotranspiration was 2.10 mm day^{-1}. The daily evapotranspiration by Epan model was also observed and the maximum evapotranspiration was ranges from 5.32 mm day^{-1} to 7.00 mm day^{-1} and minimum from 0.14 mm day^{-1} to 0.21 mm day^{-1}. The minimum reference evapotranspiration by Epan model was very less in the months of June, July, and August due to heavy rainfall. On daily basis the PM-56 model overestimates the average evapotranspiration by

18.29 percent over Epan model. The overall daily average reference evapotranspiration by PM-56 and Epan was 3.88 mm day^{-1} and 3.28 mm day^{-1}, respectively. The daily average reference evapotranspiration of Epan and PM-56 Model was compared in Fig. 1 and derived equation

$$ETo_{PM-56} = 0.78\ ETo_{pan} + 1.31 \quad (SE = 0.39\ mm\ day^{-1},\ r = 0.90) \quad (1)$$

The reference evapotranspiration estimation on monthly basis was also done. The maximum monthly reference evapotranspiration for PM-56 model was ranges from 5.29 mm day^{-1} to 5.85 mm day^{-1} for different year (2000-2005) while minimum reference evapotranspiration ranges from 2.70 mm day^{-1} to 3.01 mm day^{-1}. The maximum reference evapotranspiration by PM-56 model was observed in the month of April and May and minimum in the month of June and July. The reference evapotranspiration based on Epan model showed that the maximum evapotranspiration ranges from 4.15 mm day^{-1} to 6.15 mm day^{-1} and minimum from 1.54 mm day^{-1} to 2.09 mm day^{-1}. The minimum evapotranspiration by Epan model was observed in the month of June and July due to heavy rainfall. The detailed month wise evapotranspiration for different year was depicted in Table 1. The monthly average reference evapotranspiration of Epan and PM-56 Model was compared in Fig. 2 and developed equation as

$$ETo_{PM-56} = 0.27\ ETo_{pan} + 0.85 \quad (SE = 1.11\ mm\ day^{-1},\ r = 0.95)$$

For different metrological weeks the average maximum reference evapotranspiration using PM-56 model was recorded in the 19th metrological week (5.72 mm day^{-1}) and minimum in the 32nd metrological week (2.55 mm day^{-1}). The average maximum evapotranspiration by Epan model was 5.06 mm day^{-1} in 17th metrological week and minimum of 1.57 mm day^{-1} in 29th metrological week. The relationship between ETo_{PM-56} and ETo_{pan} showed that that the estimated reference evapotranspiration by both models was highly correlated (r = 0.94) and with less error (0.31mm day^{-1}). The relationship (Fig. 3) also showed that the reference evapotranspiration by PM-56 model was over estimate than Epan model.

$$ETo_{PM-56} = 0.84\ ETo_{pan} + 1.14 \quad (SE = 0.31\ mm\ day^{-1},\ r = 0.94)$$

The season wise reference evapotranspiration by PM-56 and Epan was estimated and depicted in (Fig. 4, 5, 6). For summer season the PM-56 predicts the reference evapotranspiration of 2.76 mm day^{-1} to 5.72 mm day^{-1}. The average reference evapotranspira-tion for summer season was 4.75 mm day^{-1}. Similarly Epan also estimated reference evapotranspiration in the range of 1.74 mm day^{-1} to 5.6 mm day^{-1} with average of 4.07 mm day^{-1}. For summer season, PM-56 model over estimates reference evapotranspiration by 16.70 percent over Epan. The standard error between Epan and PM-56 model was 0.30 mm day^{-1} with high correlation coefficient of 0.95. The linear relationship showed slope of 0.82 and intercept of 1.40. This clearly indicates that PM-56 model over estimates the reference evapotranspiration than Epan model.

The reference evapotranspiration for monsoon season was also predicted and ranges from 2.55 mm day^{-1} to 4.01 mm day^{-1}. The average reference

Table 1. *Reference evapotranspiration for different months (mm day^{-1})*

Months	2000		2001		2002		2003		2004		2005		Mean	
	PM-56	Epan	PM-56	Epan	PM-56	Epan	PM-56	Epan	PM-56	Epan	PM-56	Epan	PM-56	Epan
Jan.	3.51	3.02	3.33	2.18	3.42	2.31	3.28	2.51	3.48	2.54	3.32	2.52	3.39	3.02
Feb.	3.81	3.74	3.71	2.89	4.12	3.34	4.31	3.97	4.22	3.11	4.07	3.00	4.04	3.74
Mar.	4.48	4.15	4.14	3.41	4.68	4.28	5.08	4.56	4.93	3.46	4.57	3.45	4.65	4.15
Apr.	5.04	4.92	4.87	4.15	5.11	5.27	5.56	5.53	5.28	4.27	5.28	4.47	5.19	4.92
May	5.45	4.63	5.39	3.95	5.59	4.87	5.85	4.66	5.29	3.76	5.69	5.15	5.54	4.63
Jun.	3.62	2.56	3.49	2.30	3.36	3.02	3.17	1.92	3.58	2.09	4.08	3.42	3.55	2.56
Jul.	3.01	1.98	2.75	1.68	3.31	2.69	2.78	1.57	3.18	2.37	2.78	1.71	2.97	1.98
Aug.	3.15	2.07	2.76	1.54	2.70	1.81	3.43	2.10	2.83	2.31	2.76	2.10	2.94	2.07
Sept.	4.03	2.60	3.33	2.00	3.57	3.52	3.36	2.27	3.49	2.16	2.65	1.61	3.41	2.60
Oct.	3.90	3.25	3.61	2.49	3.68	4.07	4.09	2.52	4.05	3.19	3.32	3.17	3.86	3.25
Nov.	3.78	3.37	3.87	2.84	3.65	4.12	3.84	2.53	3.57	2.90	3.5[illegible]	2.57	3.70	3.37
Dec.	3.63	3.07	3.45	2.73	3.21	2.66	3.43	2.36	3.22	2.33	3.12	2.24	3.34	3.07

Table 2. *Seasonal evapotranspiration for PM-56 and Epan Model (mm day-1)*

Season	Epan			PM-56		
	Max	Min	Mean	Max	Min	Mean
Summer	5.06	1.74	4.07	5.72	2.76	4.75
Winter	3.90	2.80	3.30	4.41	3.22	3.63
Monsoon	3.68	1.57	2.50	4.01	2.55	3.30

evapotranspiration was 3.30 mm day^{-1}. Similarly Epan also estimates reference evapotranspiration from 1.57 mm day^{-1} to 3.68 mm day^{-1} with average of 2.50 mm day^{-1}. For monsoon season PM-56 model over estimates reference evapotranspiration by 32 percent over Epan model. The standard error of reference evapotranspiration by Epan and PM-56 was 0.22 mm day^{-1} with correlation coefficient of 0.87. The linear relationship showed slope of 0.60 and intercept of 1.80. For winter season the PM-56 model predicted the reference evapotranspiration of 3.22 mm day^{-1} to 4.41 mm day^{-1}. The average reference evapotranspiration was 3.63 mm day^{-1}. The Epan model showed reference evapotranspiration in the range of 2.80 mm day^{-1} to 3.90 mm day^{-1}

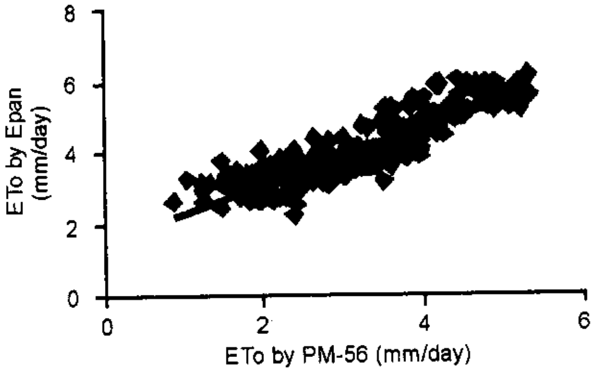

Fig. 1. Comparision of ETo by using Epan and PM-56 model on daily basis

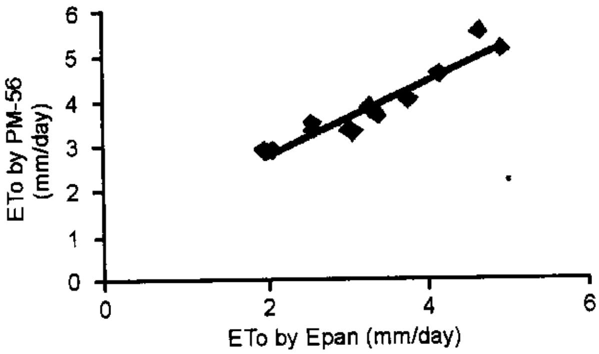

Fig. 2. Comparision of ETo by using Epan and PM-56 model on monthly basis

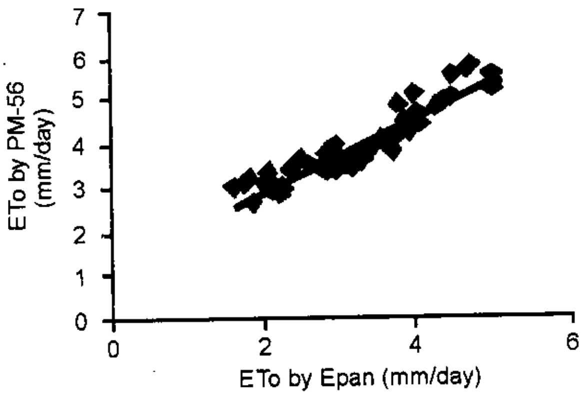

Fig. 3. Comparision of ETo by using Epan and PM-56 model on metrological week basis

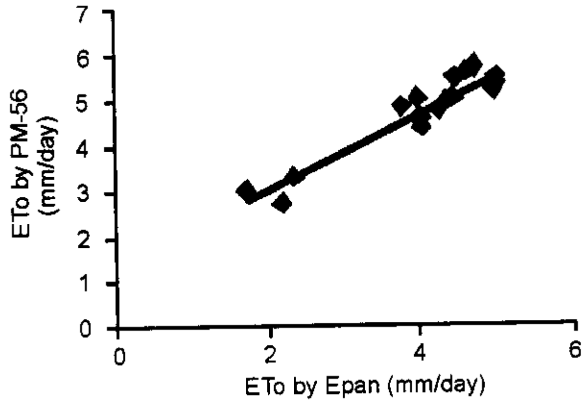

Fig. 4. Comparision of ETo by using Epan and PM-56 model on summer season basis

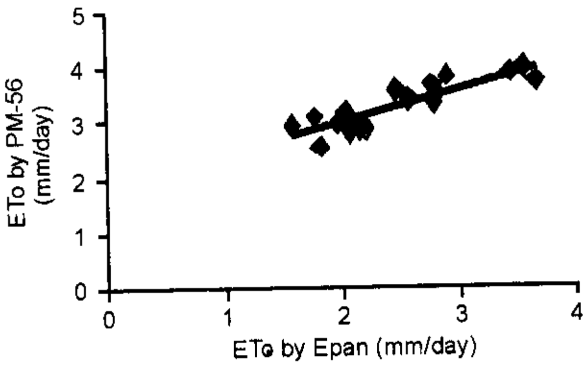

Fig. 5. Comparision of ETo by using Epan and PM-56 model on monsoon season basis

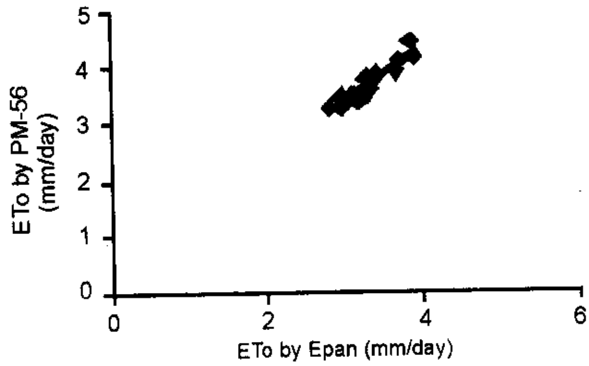

Fig. 6. Comparision of ETo by using Epan and PM-56 model on winter season basis

with average of 3.30 mm day^{-1}. For winter season PM-56 model over estimate reference evapotranspiration by 10 percent over Epan model. The standard error of reference evapotranspiration between Epan model and PM-56 model was 0.11 mm day^{-1} which was very less as compared to other seasons with correlation coefficient of 0.95. The linear relationship showed slope of 1.02 and intercept of 0.28. The analysis showed that the standard error was least during winter season (0.11 mm day^{-1}) and maximum in summer season (0.30 mm day^{-1}). As PM-56 model needs more data as compared to Epan model. The relationship Epan and ETo-(PM-56) will help to predict reference evapotranspiration from Epan values for daily, weekly, monthly, and seasonal crop planning.

The study concluded that the daily average evapotranspiration by Epan and PM-56 model was 3.28 mm day^{-1} and 3.88 mm day^{-1}, respectively. The maximum evapotranspiration by Epan and PM-56 model on monthly basis was 4.92 mm day^{-1} in the month of April and 5.54 mm day^{-1} in the month of May. The monthly analysis observed very less reference evapotranspiration in the months of June, July and August. The daily and monthly reference evapotranspiration by PM-56 model was over estimated by 18.29 percent over Epan model. The seasonal analysis found that there was less error in winter season (0.11 mm day^{-1}) and maximum in summer (0.30 mm day^{-1}). The overall correlation coefficient for daily, metrological week, months and season was more than 0.8, which indicates good correlation between Epan and PM-56 model. The developed linear relationship equations facilities easy and quick estimation of reference evapotranspiration from Epan model into PM-56 model.

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Sub-Basin Scale Water Congestion Evaluation for Drainage Improvement Planning for Coastal Area of West Bengal

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The main objective of the surface drainage schemes in the humid region is to reduce the damage to the living beings and property and also to enhance the agricultural productivity through flood control. The agriculture in the nearly flat plains of Sundarbans area frequently suffers from floods during the monsoon period. To evaluate the water congestion during Kharif period, three sub-basins such as Alitakhali, Jhumokhali and Dhosa in the East Mograhat Basin in South 24 Parganas district of West Bengal were selected for the present study. The water congestion was evaluated at (I) transplanting, (II) tillering, and (III) flowering/grain filling stages. At Dhosa sub-basin, about 50 percent area was waterlogged with excess water during the stage I with water depth greater than 15 cm. At tillering stage the waterlogged area increased to about 78 percent, where as it was reduced to about 73 percent in the stage III. At Jhumokhali sub-basin, about 46 percent area was waterlogged with excess runoff during the stage of transplantation with water depth greater than 15 cm. At tillering stages waterlogged area increased to about 83 percent, while at stage III reduced to 68 percent. At Alitakhali sub-basin, about 46% area was water logged in stage I with water depth greater than 15 cm. During tillering stage-waterlogged area increased increased to about 84 percent while reduced to about 76 percent during the stage III. There was about 50 percent reduction in paddy yield in the severely waterlogged areas in comparison to well-drained areas, where yield was about 4.05 t ha^{-1}. The improper land levels, poor network of conveyance system and malfunctioning of the outlets (sluice gates) were responsible for the inadequate drainage in this region.

(***Key words:*** *Sub-basin, Flat plains, Waterlogged, Drainage of excess water, Sluice gate, Yield*)

Timely drainage of excess water is essential for the optimum production of agricultural crops. The drainage systems may be natural which may have formed due to interaction of the surface physiographic and climatic conditions, or artificial to achieve the specific purpose. The capacity of the natural drainage system may not be sufficient to timely drain out the excess water especially in flat plains. To augment the flood control process in the agricultural lands, many artificial drainage systems has been designed and installed, so that water can be managed at local level as per the requirement. Drainage congestion causing surface water logging and flooding of areas suitable for growing Kharif and Rabi crops are the common problems during monsoon season in most of the downstream stretches of river basins in India (GFCC, 1986; Bhattacharya, 1992). Cross barriers created by construction of roads, railroads, embankments, encroachment of river's width by human interference besides natural depression of surface topography are main factors of drainage problems. However, other important factor is ineffective outlet condition to dispose off the excess monsoon runoff (Ambast, 1996).

The major part of coastal area in West Bengal remains in the districts of North 24 Parganas and South 24 Parganas, known as Sundarbans. The lands of the Sundarbans area are sedimentary in nature, with little or no slope and existing haphazardly. The sea water of Bay of Bengal invades into this region from the down stream side during the tide period through various tidal rivers, rivulets and creeks, and consequently restricts the drainage of excess run off water coming from the upstream side. The high tide situation creates more difficulties for drainage than the ebb. The people of this region are economically poor, mostly dependent on agriculture and practice only monocrop (paddy) every year. Water congestion is the common problem faced while any heavy down pour occurs in the Kharif season in the Sundarbans area of West Bengal. More than 80 percent of the annual rainfall occurs during the few months (June-September) of monsoon. The productivity of the monocrop i.e. paddy also reduces due to excess inundation of rainwater in the paddy fields. In this study, the water logging situations in some representative sub-basins were evaluated for planning drainage improvement in the region.

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MATERIALS AND METHODS

Three sub-basins such as Alitakhali, Jhumokhali and Dhosa in the East Mograhat Basin in South 24 Parganas district (Fig. 1) were selected for the present study. Each of the sub-basins has two sluice gate as outlet through which drain water coming from the overflowing paddy fields to the collector surface drain and is discharged to the Piali river (Fig. 2). The main outlet of the sub-basins is through a barrage at Kultali with 32 sluice gates. This barrage controls the incoming seawater through tidal river and drains the runoff water coming from upstream areas during the ebb period. The Kultali barrage checks the inward flow of sea water through Matla river during high tide situation, and during ebb time the upstream side run off water is discharged into the Matla river. The Alitakhali, Jhumokhali and Dhosa sub-basins are located at 3 km, 14 km and 19 km upstream from the Kultali outlet. The average annual rainfall in the East Mograhat basin is 1845 mm; with maximum yearly rainfall 6191 mm recorded during the year 1976 and minimum was 788 mm during the year 1988.

The presence of excess water in the agricultural fields reduces the productivity of the agricultural lands. Therefore, the water congestion was evaluated at transplanting (I), tillering (II) and flowering/grain filling (III) stages for on the spot assessment of the problem for planning the timely drainage of excess water from the agricultural lands. Each sub-basin area was divided into grid points at distances of 200 m and water inundation was evaluated at those points. Based on the inundation depths, characterization was made for different depths such as less than 15 cm, 15-30 cm and more than 30 cm. Simultaneously, the water congestion in the collector drains was evaluated at the different stages of cropping at distances of 100 m from the sluice gates. Paddy is the monocrop cultivated in all the three sub-basins during the Kharif season, which is transplanted during June/July and

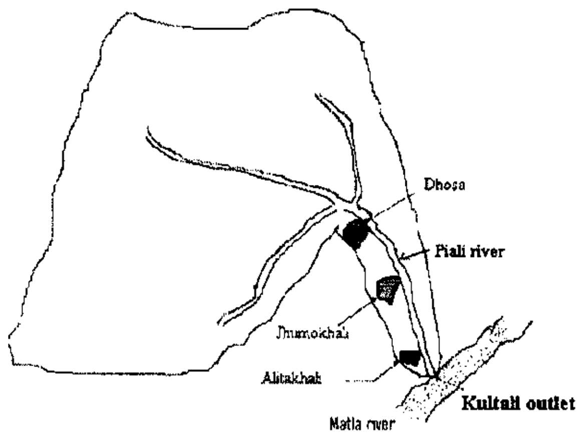

Fig. 1. The location map of the Dhosa, Jhumokhali, and Alitakhali sub-basins in East Mograhat basin

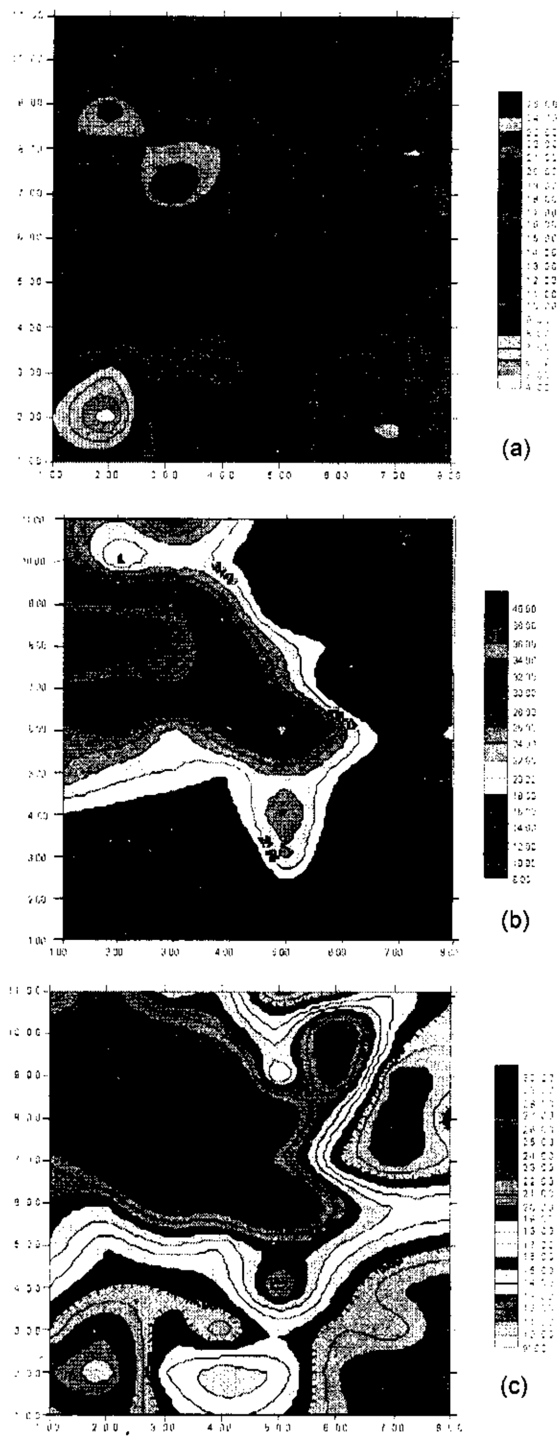

Fig. 2. The contour maps of waterlogged Dhosa sub-basin at (a) transplanting, (b) tillering and (c) flowering/grain filling stage

harvested during October/November. The varieties of paddy cultivated were Patnai, Dudheswar, Pankaj, Swarna etc., which were of long duration. The average paddy yield data was collected from the local farmers to evaluate the productivity.

RESULTS AND DISCUSSION

In the Sundarbans area, paddy is the only crop cultivated in most parts of all the three sub-basins during the Kharif season depending fully upon rainfall. At Dhosa sub-basin (Fig. 2), about 50 percent area was waterlogged with excess water during the transplanting stage (I) with water depth greater than 15 cm. At tillering stage (II) the waterlogged area increased to about 78 percent, whereas it was reduced to about 73 percent in the flowering/grain filling stage (III) (Table 1). At Jhumokhali sub-basin, about 46 percent area was waterlogged with excess runoff during the stage of transplantation with water depth greater than 15 cm. At tillering stages waterlogged area increased about 83 percent while at stage III reduced to 68 percent. At Alitakhali sub-basin, about 46 percent area was water logged in stage I with water depth greater than 15 cm. During tillering stage waterlogged area increased to about 84 percent while reduced to about 76 percent during the stage III. Rao (1980) has reported from a case study in Sundarbans Delta in West Bengal, which was provided with circuit embankment, and sluice gate that more than 70 percent area had still higher than the water level desired throughout the rice season. Similar observations were made by Aich (1987) and Biswas (1987).

The effect of water logging on the yield of paddy crops grown in this basin was studied. It was found that there was almost 50 percent decrease in yield (Fig. 3) in the most waterlogged (>30 cm) areas than the well drained (<15 cm) areas where average yield was about 4.05 t ha^{-1}. There was about 16 percent reduction in average paddy yield in the intermediate condition (waterlogged in between 15-30 cm depth).

From the measurement of the depths at 100 m interval grid points in different stages, it was found that there was no regular gradient towards the outlet (Table 2) and the drains were remained ponded with water due to no timely operation of the sluice gates which are hardly maintained and remained defunct during the entire agricultural period.

From the evaluation of water stagnation in above three sub-basins, it was found that improper functioning of the sluice gates was major cause for water stagnation. There was about 50 percent reduction in paddy yield in the severely waterlogged areas in comparison to well-drained areas, where yield was about 4.05 t ha^{-1}. The sluice gates should be repaired as outlet plays a major role in management of surface drainage water of the entire sub-basin. Bund should be constructed around the

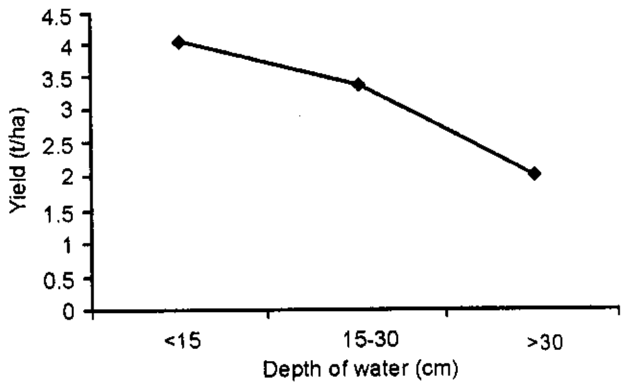

Fig. 3. The average paddy yield under different waterlogged conditions in East Mograhat basin

Table 1. *The water congestion problem in three sub-basins during* Kharif *season*

Sl. No.	Sub-basin	Stage	Depth(cm)		
			0~15	15~30	30~45
1	Dhosa	I	50.0	40.2	9.8
		II	21.7	44.2	34.1
		III	26.6	41.9	31.5
2	Jhumokhali	I	53.7	37.1	9.2
		II	16.8	39.1	44.1
		III	31.7	43.9	24.4
3	Alitakhali	I	53.8	46.2	0.0
		II	17.9	52.3	31.8
		III	24.0	55.7	20.3

Table 2. *The depth of water (m) in collector drain at different locations during the three stages*

Sl. No.	Sub-basins	Stages	Points							
			1	2	3	4	5	6	7	8
1	Dhosa	I	0.78	0.81	0.95	1.03	1.17	1.39	0.97	0.85
		II	0.85	0.94	1.07	1.15	1.27	1.45	1.05	0.94
		III	0.68	0.72	0.81	0.92	1.10	1.25	0.83	0.71
2	Jhumokhali	I	2.25	1.84	1.64	1.52	1.43	1.37	1 32	1.26
		II	2.37	1.95	1.76	1.68	1.51	1.42	1.38	1.35
		III	1.86	1.61	1.40	1.31	1.24	1.21	1.17	1.08
3	Alitakhali	I	1.82	1.70	1.63	1.52	1.20	1.08	0.93	0.91
		II	2.13	1.95	1.82	1.65	1.42	1.24	1.17	1.08
		III	2.05	1.81	1.71	1.58	1.35	1.13	1.04	1.10

fields so that entry of incoming water into fields can be controlled. The land should be systematically leveled and field channels may be maintained for better drainage of excess surface water. The outlets (sluice gates) should be operated in time so that smooth occurrence of drainage takes place and excess water congestion is avoided for getting better production.

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Ecological Threats of the Coastal Region, Adaptation Strategies for Mitigation and Management of Coastal Forestry

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As per latest forest cover estimates by Forest Survey of India, 36 per cent of the forest cover of India is borne by the nine coastal states. It averages 25 per cent of the geographical area of each state. However, it is as low as 7.46 per cent in Gujarat and as high as 58.10 per cent in Goa. The western coastal region also adjoins the famous biodiversity hotspot of Western Ghats. The variable topography of the coastal region supports a vast diversity of forest types including mangroves and a myriad of life forms. These are the regions where interplay of agriculture and fisheries takes place with forestry. Thus, the management of coastal forestry is important in development of these regions. Despite being one of the richest in forest resources, coastal regions have suffered from a number of ecological threats. Indiscriminate deforestation and degradation of forests has been a bane just as in the entire tropical world. The natural topography has also favored the destructive elements of erosion. Natural disasters like Tsunami have dealt severe blows to the mangrove ecosystems. It is necessary to stand up against these threats and come up with adaptive strategies to efficiently mange coastal forestry. Solutions appear in selection of appropriate species for plantation programmes, tree improvement programmes to improve the productivity of plantations, stringent legal action against unsustainable exploitation and incentives for sustainable forest management. We present an overview of available adaptive strategies through a review of important research findings.

(**Key words:** *Coastal region, Deforestation, Plantation, Sustainable forest management*)

Indian mainland coastline of nearly 8000 km length is extended in nine states of India namely West Bengal, Orissa, Andhra Pradesh, Tamil Nadu, Kerala, Karnataka, Goa, Maharashtra and Gujarat. These coastal states of India are rich in their forest resources. The overall forest cover in these states is around 18 per cent of the geographical area. However, states like Goa, Kerala and Orissa have forest cover as high as 58, 45 and 31 per cent respectively. West Bengal, Tamil Nadu, Karnataka, Andhra Pradesh and Maharashtra have forest cover in the range of 14 to 19 per cent.

However, when the states are compared on the basis of absolute forest cover area in square kilometers the trend is inverse i.e. Maharashtra, Orissa, Andhra Pradesh and Karnataka are the states with highest forest cover (Table 1). Of course this forest cover includes both coastal as well as inland regions of these states. But a look at the forest cover map of India (Fig.1) would also reveal that most of the coastal forest cover is located in the seven states of Kerala, Karnataka, Maharashtra, Goa, Gujarat, Orissa and Andhra Pradesh. Since coastal belt is a very narrow belt along the Western and Eastern coastlines, the extent of coastal forests is also limited. This perspective is important as forests are under the control of state governments and any policy decision for coastal forestry would be weighted with the overall forest area of the state. These forests in coastal region are of several types, which include mangrove forests, beach forests and coastal plantations (FAO 1998). All these are transitional ecosystems from terrestrial to aquatic ecosystem. So, a very high level of edge effect is observed in these forests. This results into a rich diversity of habitats, species and genes.

Mangrove forests

Mangroves are plant species including trees, shrubs, palms and ferns growing in saline intertidal coastal habitats such as estuaries and shorelines. There are more than 110 species of these plants throughout the tropics and subtropics. These species are physiologically adapted to overcome the problems of high salinity and frequent tidal inundation absence of Oxygen. They form estuarine tracts of mixed mangrove forests (Rosati *et al.*, 2008). Although mangrove forests are characterized by a low floristic diversity at any given place compared with most inland forests in the tropics, they are definitely a rich and typical ecosystem.

Mangrove forests are unique, highly productive and socially, economically and biologically important areas. Millions of people around the

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Table 1. *State of Forest Cover in Coastal states of India*

State	Geographical area (sq. km)	Forest cover (sq. km)	% of GA
West Bengal	88752	12994	14.64
Orissa	155707	48855	31.38
AP	275069	45102	16.40
TN	130058	23338	17.94
Kerala	38863	17324	44.58
Karnataka	191791	36190	18.87
Maharashtra	307713	50650	16.46
Goa	3702	2151	58.10
Gujarat	196022	14620	7.46
Total	1387677	251224	18.10

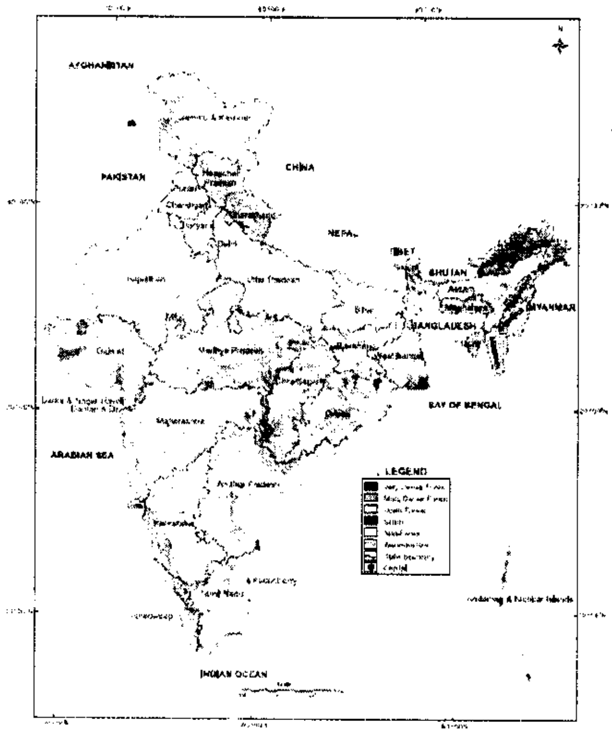

Fig. 1. Forest Cover map of India

Indian coast depend on mangrove forests for wood and a large variety of nonwood forest products like dyes, medicines, fodder, honey etc. Mangroves host a wide variety of organisms, including a number of endangered species. They serve as a valuable nursery to many shrimps, crustaceans and molluscs, and act as breeding and feeding ground for many commercially important fish species (Rosati *et al.*, 2008). Few species of animals are restricted entirely to the mangrove forests. Mangrove forests, on the other hand, are an ideal sanctuary for several migratory birds (FAO 1998). In addition, mangroves play an important role in protecting the coast, especially during surge storms, hurricanes and tsunamis. These ecosystems being small, isolated and fragile have been lost completely or have been degraded extensively (Rosati *et al.*, 2008).

In India, mangrove forests are found all along the coastline in varying extent. They occupy an area of four thousand forty five square kilometers (FSI 2009). The three major types of mangrove ecoregions found in India are Indus delta-Arabian sea mangroves found along the western coast, Godavari-Krishna mangroves found along the eastern coast and Sundarbans mangroves. The biggest single patch of mangrove forests is Sundarbans in West Bengal. This is the estuary of river Ganga and contributes nearly 50 per cent of the total mangrove cover of India.

Beach Forests

The beach forests or coastal forests, especially of western coast are classified as Malabar coast moist forest ecoregion. This ecoregion represents the semi-evergreen forests along India's Malabar Coast, a narrow strip of land lying between the Indian Ocean to the west and extending up to the 250-m contour of the steep Western Ghats Mountains to the east. It extends through the states of Kerala, Karnataka, Goa and Maharashtra (www.worldwildlife.org). The ample amount of rains brought by the southwestern monsoon largely influences the vegetation of this region. Although the forest is classified as semi-evergreen, the influence of rainfall and distance from equator has resulted into gradual trend from tropical wet evergreen in the south to drier and deciduous forests to the north. In addition, these forests have been largely replaced or interspersed with teak, giving the vegetation a semi-deciduous character; the teak is now considered indicative of a secondary successional stage or presence of plantations. A large variety of plant species in all the strata of forest ecosystem are found in these coastal forests. This ecoregion harbours nearly 100 and 300 species of mammals and birds respectively. Several of these are endemic and near-endemics (www.worldwildlife.org).

Coastal plantations

Plantation activity in India has taken up great strides in last two decades. The rate of plantation has been more than 15,000 square kilometers per year during this period (Puyravaud *et al.*, 2010). Coastal plantations have often been established for both production and protection purposes. The production functions involve supply of fuelwood and other NTFPs. The basic protection purpose is stabilization of coastal sand dunes, which keep shifting, in inland direction. One of the recent approaches is to create shelterbelt plantations as a mitigative strategy for cyclones and tsunamis (Forbes and Broadhead, 2007). The most popular and important species taken up for coastal plantations is *Casuarina equisetifolia* along with some mangrove species. Others include Acacia, Eucalyptus etc. Apart from these forest plantations, coastal areas have extensive plantations of coconut and arecanut that can be included in coastal plantations.

Ecological Threats of coastal forestry

Much of the Indian coastline is heavily populated. Approximately 26 per cent of the Indian population lives in coastal areas (MoEF, undated1). This exerts an insurmountable pressure on the coastal ecosystems. Despite their tremendous ecological and economic importance, India's coastal forests are under increasing threat due to the country's on going push for rapid economic growth over the past decade. There are also numerous direct and indirect pressures arising from different types of economic developments across the country. Major anthropogenic direct drivers of ecosystem degradation and destruction include habitat conversion to other forms of land use (for example through coastal development for roads, ports, tourist resorts, aquaculture etc.); overexploitation of species and associated destructive harvesting practices (for example through use of inappropriate fishing gear and methods); and the impacts of agricultural, domestic and industrial sewage and waste. Even though mangroves are often used for the collection of forest wood products, and as a source of subsistence for local populations, the removal of wood and non-wood forest products is rarely the main cause of mangrove habitat loss. Human pressure on coastal ecosystems and the competition for land for aquaculture, agriculture, infrastructure and tourism are often high and are major causes of the decrease in mangrove areas. One of the latest examples is the row over development of New Mumbai Air Port, which is supposed to thrash a large patch of mangrove forests. While this talk was being written, positive developments had taken place for excluding the mangrove patch from proposed area of airport.

In case of beach forests, more than 95 percent of the ecoregion's natural habitat has been cleared or converted. Throughout the region, the moist southern forests have been converted into coconut plantations and rice paddies and the northern forests into teak, rosewood, and rubber plantations. No large blocks of intact forest habitat now exist, although several smaller forest fragments have been preserved by local people as sacred groves. Continuing threats to this forest include habitat damage from livestock grazing and trampling, overexploitation and burning by pastoralists, unabated and frequent forest fires, flooding and related developments through hydroelectric projects and overall developmental activities (www.worldwildlife.org). Apart from these human-induced threats, climate change is expected to have a growing impact on coastal forests, including a likely increase in extreme weather events, as well as sea level rise, warming of the sea surface temperatures, and ocean acidification. Coastal habitats are also subject to powerful natural weather phenomena, such as cyclones, hurricanes and storms. Indirect drivers of ecosystem change include demographic, socio-political, cultural, economic and technological factors.

Adaptive strategies for coastal forestry

Several adaptive strategies have been tried and tested for management of coastal forestry. Important among these are physical and legal protection, enhancement through artificial plantations programmes. Some others that would be beneficial in coastal forestry situation are incentive programmes through sustainable forest management certification and carbon trading.

Declaration of Protected Areas

The concept of marine protected areas is much more complicated than terrestrial protected areas in India. And though coastal zone regulation is in place for last 20 years, several issues made it necessary to notify a new one in 2011 have frequently been altered. However, important steps have been taken up by the Indian Government through mangroves for the future programme (www.mangrovesforthefuture.org). India has established thirty three coastal and marine protected areas and three Marine Biosphere Reserves, with a total area of approximately 5,318.9 km2. However, these protected areas cover only less than 1.3 per cent of the Indian continental shelf and even less than 0.3 per cent of the Indian EEZ (MoEF undated 2). There is a need to strengthen this network and buttress it by creation of more protected areas inland.

Stringent legal action against unsustainable exploitation

Several policy and legislation measures are available to prevent the unsustainable exploitation of the coastal forests. Forest (Conservation) Act of 1980, Wildlife (Protection) Act of 1972, Environment (Protection) Act of 1986, Environmental Impact Assessment Notification of 1994 and Coastal Regulation Zone (CRZ) Notification of 1991 are some of the important central legislations concerning coastal forestry. Since writing this essay, the 1991 CRZ notification has been replaced by that of 2011. Several other state legislations are also available. However, integration and effective implementation of all these legal tools is important. The legal procedure stresses the principle of Ignorantia juris non excusat i.e. Ignorance of the law does not excuse. However, it is a duty of the state to make every citizen aware about the legislations relevant to them. Most of the legislations remain in the gazettes and magazines of high society. The actual drivers of unsustainable exploitation are many times unaware about the legal as well as physical consequences of their actions against forests. There is a role to play for non-governmental organizations as well in this aspect.

Choice of Suitable Plantation species

One of the major mitigation strategies for coastal belts against natural hazards of erosion and cyclones is plantation of shelterbelts. Plantations as a means of protection and production are useful but the responsible institutions must be careful that increasing plantations do not jeopardize the situation of native forests as indicated by a recent study (Puyravaud *et al.*, 2010) wherein they found that Forest Survey of India's claim of increasing forest cover is misleading when we consider the status of native forests. Further, most of the species used for coastal plantations are exotic and have significant implications for native biodiversity per se. Some have even turned into invasive weeds. Even in case of Casuarina, a recent study suggested that these plantations drastically reduced the populations of a skink species depriving them of their basking sites and original habitat (Subramanean and Vikrama Reddy, 2010). Therefore, careful investigation of ecological impacts of plantation species needs to be carried out prior to taking up any extensive plantation programmes.

Improvement programmes for plantations species

The role of mangroves and other shelterbelt species in prevention of disasters like tsunami has been well established despite doubts being raised on the adequacy of these vegetations. However, rather than debating, it is necessary to initiate species improvement programmes to address these concerns. Similarly, species improvement is essential from the perspectives of productivity enhancement and climate change adaptation. Improvement programmes are also essential for enabling species to sequester larger quantities of carbon from atmosphere as a climate change mitigation strategy.

Incentives for sustainable forest management

Sustainable forest management (SFM) is one of the emerging aspects of forest management and is comparable to drive for organic certification in case of agriculture. The SFM certification is one of the few ways to attract foreign in vestment in maintenance of existing forests and their expansion. This is particularly applicable to regions like Konkan of Maharashtra where forest lands are largely owned by private people. They need to be brought into the mainstream of sustainable forest management by awareness generation and capacity building. The criteria and indicators of SFM have already been evolved through several brainstorming years. These need to be brought to the doorstep of coastal people to apply to their forests.

Incentives through carbon trading

Carbon trading is emerging as a huge marketplace. Several instruments are available but Removal Units (RMU) are the most relevant to the forestry sector. These provide for marketing of carbon sequestered through landuse, landuse change and forestry (LULUCF) projects. These activities include conservation of existing carbon stocks, expansion of these carbon stocks. There is a vast scope to take up these activities in coastal forests. Even Casuarina is considered one of the best available species for sequestering large quantities of carbon from atmosphere. Studies are going on to identify most efficient carbon sequestering species. Communities can be made aware about these extra benefits that they can derive by just maintaining the existing coastal forests. One of the important tasks to quantify the existing carbon stocks and formulate these into dollar-earning initiatives.

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Genetic Analysis in Very Early Rice under Two Culture Systems in the Coastal Region of Cauvery Delta Zone

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A study was conducted with thirty very early genotypes under two culture systems viz., direct wet seeding and transplanting to understand the influence of culture systems on the genetic parameters. The characters, grain yield per hill, grains per panicle, dry matter production and panicle weight exhibited high genetic variability in conjunction with high heritability and genetic advance in both the systems. But the characters, days to maturity, panicle length, spikelet fertility and harvest index showed fluctuating values for the above parameters among the two culture systems. Based on strength of genotypic correlation and magnitude of direct effect, it was suggested that dry matter production and harvest index are the selection indices for yield improvement in direct seeded rice, whereas dry matter production alone needs to be considered as selection parameter for transplanted rice. The methods of cultivation greatly influenced the direction and magnitude of correlations of the other characters in the study. Separate breeding programme are required for each culture system.

*(**Key words:** Rice, Very early, Culture systems, Variability, Correlation, Path analysis)*

Rice (*Oryza sativa* L.) is the main crop grown in the coastal region of Cauvery delta zone in the states of Tamil Nadu and Puducherry. Cultivation of very early rice of less than 100 days duration is best suited for the first rice-growing season of this region called kuruvai. Transplanting is the traditional method of rice culture in this area. But this cultivation is highly labour intensive as it involves rising of nursery and planting and thus, costly. Besides, labour scarcity also adds problem. Therefore, there is a general tendency among the farmers to shift from transplanting to direct seeding. Direct seeding in irrigated/puddled condition, commonly known as wet or puddled seeding is a best substitute for transplanting. This type of direct seeded culture is cheaper as the requirement of labour is considerably reduced. The growth and yield of rice are modified to a greater extent by agronomic practices. In the absence of varieties developed exclusively for wet seeding, the farmers use the varieties developed for transplanting. Differential response of varieties under direct wet seeded and transplanted conditions has been brought about by agronomists (Balasubramanian and Hill, 2000). But breeding work in this aspect is meager. An attempt was made in the present study to analyze the effect of these two culture methods on the genetic expression of different traits in rice and to ascertain the need for separate breeding programme for the two agronomic practices.

MATERIALS AND METHODS

Thirty diverse very early rice genotypes consisting of varieties and breeding lines were grown in randomized block design with three replications separately under direct seeding and transplanting methods in the same field. For direct wet seeding, the dry seeds were dibbled in the puddled condition in lines at the rate of five seeds per hill. On seventh day, the seedlings were thinned to three seedlings per hill. For transplanting, the dry seeds were sown on the raised bed on the same day of puddled seeding and normal nursery practices were followed. Twenty days old seedlings were transplanted in the main field at the rate of three seedlings per hill. Other crop management practices adopted in both the culture systems were similar. In both culture systems, the spacing followed was 30 x 10 cm and each genotype was raised in five rows of one meter long row. Observations were recorded on five randomly selected hills per replication from each genotype in each of the two culture methods for days to flowering, days to maturity, plant height, panicles per hill, panicle length, panicle weight, spikelet fertility, grains per panicle, 100 grain weight, dry matter production, harvest index and grain yield per hill. The data were subjected to analysis of variance, genetic variability, heritability, genetic advance, genotypic correlation and path analysis as per the standard procedures described by Singh and Chaudhary (1977).

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Table 1. *Pooled analysis of variance over culture systems for twelve traits in very early rice*

Source	df	Mean squares											
		Days to flowering	Days to maturity	Plant height	Panicles per hill	Panicle length	Panicle weight	Spikelet fertility	Grains per panicle	100 Grain weight	Dry matter production	Harvest Index	Grain yield per hill
Genotype	29	163.89**	139.79**	701.96**	5.90**	14.29**	0.52**	0.01**	980.03**	0.22**	47.18**	0.01**	11.81**
Culture systems	1	1798.68**	1792.37**	144.62**	50.35**	25.10**	1.87**	0.00	810.06**	0.05**	1271.30**	0.02**	4.07**
Genotype x Culture systems	29	23.29**	8.43**	70.13**	5.45**	2.70	0.17**	0.01**	215.25**	0.00	22.96**	0.01**	7.92**
Error (Pooled)	116	1.01	1.92	4.03	0.91	1.82	0.04	0.00	16.06	0.00	0.66	0.00	0.33

Table 2. *Mean and genetic parameters for different traits under two culture systems*

Character	Mean		GCV (%)		h^2 (%)		GA (%)	
	DS	TP	DS	TP	DS	TP	DS	TP
Days to flowering	64.67	70.32	9.87	6.43	96.35	97.68	19.98	13.11
Days to maturity	90.38	96.48	4.78	5.04	89.99	94.77	9.35	10.12
Plant height (cm)	94.23	92.44	13.16	10.86	96.51	97.55	26.66	22.12
Panicles per hill	9.68	8.63	12.94	14.60	62.39	64.39	21.08	24.15
Panicle length (cm)	20.45	19.70	8.43	6.15	55.76	53.36	12.98	9.27
Panicle weight (g)	1.79	1.58	18.08	19.45	65.49	69.12	30.17	33.35
Spikelet fertility (%)	0.80	0.79	5.81	6.59	80.68	82.55	10.00	12.35
Grains per panicle	72.70	62.36	21.67	18.93	93.96	89.59	43.31	36.96
100 grain weight (g)	2.35	2.32	7.88	8.47	93.39	88.96	15.71	16.47
Dry matter production (g)	19.83	14.52	18.65	20.93	97.08	90.95	37.89	41.17
Harvest index	0.36	0.38	15.08	8.53	73.84	57.11	26.73	13.30
Grain yield per hill (g)	8.48	8.18	22.58	20.10	88.53	93.06	43.82	39.78

DS - Direct seeding TP - Transplanting

Table 3. *Genotypic correlation and direct (diagonal) and indirect effects of component traits on grain yield under two culture systems*

Characters	Culture system	Days to flowering	Days to maturity	Plant height	Panicles per hill	Panicle length	Panicle weight	Spikelet fertility	Grains per panicle	100 Grain weight	Dry matter production	Harvest index	r_g with grain yield
Days to flowering	DS	0.011	0.020	-0.001	-0.017	-0.058	-0.112	0.009	0.014	0.021	0.311	0.096	0.294
	TP	-0.064	-0.028	0.002	0.002	-0.054	0.046	-0.014	-0.040	0.030	0.474	0.144	0.476**
Days maturity	DS	0.005	0.041	0.053	-0.081	-0.012	0.045	0.004	-0.001	0.010	-0.131	0.022	-0.043
	TP	-0.023	-0.081	0.072	0.010	0.003	-0.132	-0.043	0.044	0.056	0.288	0.113	0.306
Plant height	DS	0.000	-0.012	-0.183	0.102	-0.023	-0.050	-0.002	0.007	0.011	0.325	-0.303	-0.128
	TP	0.000	0.021	-0.283	0.000	-0.077	0.207	0.019	-0.085	0.014	0.334	-0.053	0.097
Panicles per hill	DS	0.001	0.015	0.085	-0.220	0.028	0.069	0.001	-0.010	0.005	-0.029	0.247	0.191
	TP	0.003	0.018	-0.001	-0.046	0.090	-0.127	-0.010	0.122	-0.070	-0.132	-0.016	-0.170
Panicle length	DS	0.009	0.007	-0.057	0.083	-0.074	-0.153	0.002	0.020	0.019	0.192	0.173	0.224
	TP	-0.023	0.001	-0.143	0.027	-0.152	0.207	0.032	-0.150	0.010	0.439	0.045	0.383*
Panicle weight	DS	0.005	-0.008	-0.040	0.066	-0.049	-0.231	0.002	0.025	-0.001	0.467	0.279	0.516**
	TP	-0.009	0.032	-0.175	0.017	-0.094	0.335	0.045	-0.191	0.015	0.012	-0.070	-0.082
Spikelet fertility	DS	-0.003	-0.006	-0.010	0.007	0.005	0.015	-0.030	0.003	0.002	-0.146	0.117	-0.047
	TP	0.005	0.022	-0.034	0.003	-0.030	0.093	0.162	-0.106	-0.017	-0.225	-0.081	-0.209
Grains per panicle	DS	0.005	-0.001	-0.043	0.077	-0.053	-0.202	-0.003	0.028	0.021	0.361	0.036	0.226
	TP	-0.010	0.013	-0.090	0.021	-0.085	0.239	0.064	-0.268	0.078	0.072	-0.036	-0.001
100 Grain weight	DS	-0.004	-0.007	0.033	0.017	0.024	-0.005	0.001	-0.010	-0.060	0.039	0.094	0.123
	TP	0.009	0.021	0.019	-0.015	0.071	-0.024	0.013	0.097	-0.214	-0.241	-0.068	-0.331
Dry matter production	DS	0.004	-0.006	-0.061	0.007	-0.015	-0.110	0.005	0.010	-0.002	0.977	-0.131	0.778**
	TP	-0.029	-0.022	-0.090	0.006	-0.064	0.004	-0.035	-0.018	0.049	1.048	0.049	0.897**
Harvest index	DS	0.001	0.001	0.059	-0.058	-0.014	-0.069	-0.004	0.001	-0.006	-0.241	0.937	0.608**
	TP	-0.027	-0.026	-0.143	0.002	-0.019	-0.068	-0.038	0.028	0.042	0.348	0.246	0.430**

DS – Direct seedingTP – Transplanting* Significant at 1%** Significant at 5% rg- Genotypic correlation

RESULTS AND DISCUSSION

The two culture systems showed significant difference for all the traits except spikelet fertility and interaction of genotypes with culture systems was also significant for all the traits except panicle length and 100 grain weight (Table 1). The presence of strong genotype x system interaction for grain yield and its component traits suggested that it is necessary to test and choose different varieties for each system. More number of panicles per hill with longer panicle, higher panicle weight, more number of grains per panicle and increased grain weight apparently contributed for higher grain yield in direct seeding than in transplanting (Table 2). Direct seeded rice produced taller plants with higher dry matter production than transplanted rice, while harvest index was high under transplanting. Plants flowered and matured a week early in direct seeding which may be due to the absence of planting shock in this culture system as observed by Balasubramanian and Hill (2000).

High genetic variability in terms of genotypic coefficient of variation (GCV), heritability (h2) and genetic advance (GA) was observed for grain yield per hill, grains per panicle, panicle weight and dry matter production in both the culture systems, indicating improvement of these traits effectively through a simple phenotypic selection in very early rice irrespective of the methods of cultivation. Shanmugavalli *et al.*, (1999) also reported similar results for these traits in very early rice. The traits, days to maturity, panicle length, spikelet fertility and harvest index showed fluctuating values for these three genetic parameters among direct seeding and transplanting, the maximum fluctuation was observed for harvest index. This showed that the culture systems had significant influence on the expression of genetic potentiality of characters. In general, direct seeding provided a better environment than transplanting for good expression of characters, particularly harvest index.

Results on genotypic correlation and path analysis indicated that the strength and direction of correlations and direct effects of component traits on grain yield fluctuate among the culture systems (Table 3). Dry matter production and harvest index are identified as the selection indices for improvement of grain yield in direct seeded very early rice as these two component traits showed more or less equal and strong positive correlations as well as high positive direct effects on grain yield under this culture system. Whereas, for very early rice grown under transplanting the dry matter production alone is considered as the single most yield contributing trait as this trait alone recorded strong positive correlation in combination with high positive direct effect with grain yield. Such a difference in selection parameter was noted among two cropping systems viz., sole crop and intercrop in soybean by Sood and Sood (2001). Other than dry matter production, all the remaining component traits studied showed great difference among the two culture systems in the magnitude and direction of their correlations, direct effects and indirect effects with grain yield, indicating high influence of culture systems on the expression of characters.

Table 4. *Genotypic correlations between culture systems*

Characters	r_g
Days to flowering	0.262
Days to maturity	0.503**
Plant height	0.382*
Panicles per hill	0.231
Panicle length	-0.088
Panicle weight	0.101
Spikelet fertility	0.114
Grains per panicle	0.143
100 grain weight	-0.004
Dry matter production	0.598**
Harvest index	0.207
Grain yield per hill	0.301

r_g Genotypic correlation

High positive genotypic correlation between two culture systems for dry matter production, days to maturity and plant height (Table 4) indicated that there is no need for adopting separate breeding programme to improve these traits. All the other traits including grain yield showed insignificant correlation coefficients among the culture systems. These traits also recorded significant genotype x culture system interaction (Table 1). Under such circumstances separate breeding programme are required to be adopted to improve yield and its components for each culture system. Sood and Sood (2001) also reported such a requirement of separate breeding programme for mono and intercropping in soybean. It is thus justified from the present study that separate breeding programme are essential for direct wet seeding and transplanting rice culture systems.

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Genetic Engineering for Salt Tolerance

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Breeding efforts using salt-tolerant relatives of crop plants has had only limited success, although the mapping of quantitative trait loci (QTL) in tomato and rice. Methods such as somatic hybridisation hold promise as a combination of conventional breeding and a molecular approach. The availability of genome sequence information and the utility of yeast as a model system for functional testing have made the identification of desirable genes much faster. Attempts to improve the salt tolerance of crops through conventional breeding programmes have met with very limited success, due to the complexity of the trait: salt tolerance is complex genetically and physiologically. Tolerance often shows the characteristics of a multigenic trait, with quantitative trait loci (QTLs) associated with tolerance identified in barley, citrus, rice and tomato and with ion transport under saline conditions in barley, citrus and rice. Physiologically salt tolerance is also complex, with halophytes and less tolerant plants showing a wide range of adaptations. The assessment of tolerance is complicated by changes occurring during the ontogeny of a plant and may be technically difficult under field conditions; there is evidence of a genetically complex trait showing heterosis, dominance and additive effects. The major determinants of yield vary with the environmental conditions and quantitative traits typically exhibit a large environment x genotype interaction.

(***Key words:*** *Genetic engineering, Salt tolerace, Adaptation*)

Salinity imposes two stresses on plant tissues, a water deficit that results from the relatively high solute concentrations in the soil and ion-specific stresses resulting from altered K^+/Na^+ ratios and Na^+ and Cl^- concentrations that are inimical to plants. As salinity stress is a continuing and increasingly deleterious obstacle to the growth and yield of crop plants, owing to irrigation practices and increasing demands on fresh water supply, the engineering of salt tolerant crop plants has been a long held and intensively sought objective. Breeding efforts using salt tolerant relatives of crop plants has had only limited success. Methods such as somatic hybridization hold promise as a combination of conventional breeding and a molecular approach. The availability of genome sequence information and the utility of yeast as a model system for functional testing have made the identification of desirable genes much faster.

Salinity is an ever present threat to crop yields, especially in countries where irrigation is an essential aid to agriculture. Although the tolerance of saline conditions by plants is variable, crop species are generally tolerant of one third of the concentration of salts found in seawater. Attempts to improve the salt tolerance of crops through conventional breeding programmes have met with very limited success due to the complexity of the trait salt tolerance, which is complex genetically and physiologically. Tolerance often shows the characteristics of a multigenic trait, with quantitative trait loci (QTLs) associated with tolerance identified in barley, citrus, rice, and tomato. Physiologically salt tolerance is also complex, with halophytes and less tolerant plants showing a wide range of adaptations. Attempts to enhance tolerance have involved conventional breeding programmes, the use of in vitro selection, pooling physiological traits, interspecific hybridization, using halophytes as alternative crops, the use of marker-aided selection, and the use of transgenic plants.

Improving crop salt tolerance

Earth is a salty planet, with most of its water containing about 30 g of sodium chloride per liter. This salt solution has affected the land on which crops are grown. Although the amount of salt affected land (about 900×106 ha) is imprecisely known, its extent is sufficient to pose a threat to agriculture. In irrigated agriculture there is a strong link with salinization, throws an immediate question over the sustainability of using irrigation to increase food production. Improving crop salt tolerance is therefore primarily necessary, for increasing food production.

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Genetics of salt tolerance

Perhaps the first attempt to evaluate the inheritance of salt tolerance was made by Lyon (1941). An interspecific cross of Lycopersicon esculentum and L. pimpinellifolium showed fruit yield of the hybrid was more sensitive to increasing salt (sodium sulphate) than that of either parent. Other crosses of wild and cultivated tomato also suggested a complex genetics.

In rice sterility, an important factor in yield under saline conditions is determined by at least three genes (Akbar and Yabuno, 1977). In diallel analysis the effects of salinity on the seedling stage and on sterility suggested both additive and dominance effects, some with high heritability. Evidence of dominance of tolerance is also seen with pigenopea (*Cajanus cajan*), where a cross with Atylosia albicans (one of the most salt-tolerant relatives of pigeonpea) produced intergeneric hybrids that behaved as the wild parent, indicating dry weight production was determined by a dominant genetic factor. There is also evidence of dominance in the salt tolerance of sorghum. Diallel analysis, based on assessing tolerance to NaCl as relative root length in salt treated as compared with control plants, showed that there were both additive and dominance effects of NaCl. These examples suggest that while the assessment of tolerance is complicated by changes occurring during the ontogeny of a plant and may be technically difficult under field conditions. There is evidence of a genetically complex trait (Shannon, 1985), showing heterosis, dominance and additive effects.

Physiological complexity

As well as the genetic evidence, there is physiological evidence to support the view that salt tolerance is a complex trait. Halophytes show a wide range of adaptations from the morphological to the biochemical, adaptations that include the ability to remove salt through glandular activity. Although control of ion uptake is exercised at the root, the ability to secrete ions has evolved into a successful strategy for salt tolerance. Some (but by no means all) halophytes utilize salt secreting glands to remove excess ions from their leaves (Thomson *et al.*, 1988), reducing the need for very tight balancing of ion accumulation and growth .Within less tolerant species, intraspecific variation in tolerance is also associated with variation in a wide variety of physiological traits.

Rice growing under saline conditions showed that net accumulation of both sodium and potassium to be heritable (with narrow sense heritabilities of between 0.4 and 0.5), although shoot sodium and potassium concentrations were unrelated, suggesting that the pathways for net accumulation of sodium and potassium in rice are separate (Garcia *et al.*, 1997a). A high degree of heterosis and large environmental effects on Na/K ratios are characteristic of this aspect of salt tolerance in rice behaving as a quantitative trait. The rice OsHKT1 is down-regulated after osmotic shock (with 150 mM NaCl) of plants growing in a low (micromolar) potassium concentration and more so in a vigorous tolerant landrace than in a sensitive dwarfed variety (Golldack *et al.*, 2002).

In bread wheat, the discrimination between potassium and sodium in their transport to the shoot, manifested as K/Na ratio in shoot tissue, is apparently determined by a locus described as Kna1 and confirmed by RFLP analysis to be completely linked to five markers on the long arm of Chromosome 4D (Gorham *et al.*, 1997). That the ratio of K to Na in a plant is determined at a single locus, if proved true, is surprising, given the number of proteins that might contribute to Na and K transport from root to shoot, unless they or their control are clustered in a particular chromosomal location. The K/Na discrimination trait can be transferred from durum to bread wheat (Dvorak *et al.*, 1994). However, control of the K/Na discrimination itself cannot be confined to the D genome, as in durum wheat (*Triticum turgidum* L. *ssp durum*) discrimination equivalent to that found in the hexaploid bread wheat has been found in lines which contain no D genome (Munns, 1999).

Quantitative trait loci

There considerable evidence to support the view that salt tolerance and its sub-traits might be determined by multiple gene loci. In an intergeneric cross of tomato quantitative trait loci (QTL) were found associated with fruit yield in plants growing under saline conditions (Breto *et al.*, 1994) although some of the QTL identified were later shown to be dependent on the parentage of the cross. An important conclusion stemming from this work was that QTL are treatment sensitive. Some QTL associated with aspects of fruit yield were found regardless of whether the plants were grown with or without salt. Others were detected only under saline or under non saline conditions (Monforte *et al.*, 1997). Other crosses have also identified both stress (salt and cold) specific and stress-non-specific QTL: the stress-non-specific QTL generally exhibited larger individual effects and accounted for a greater portion of the total phenotypic variation under each condition than the stress-specific QTL (Foolad , 1999). As for the QTL identified for fruit yield, QTL associated with germination depend upon the conditions under which germination is assessed. A similar situation exists for citrus, where about half of the potential QTL identified depended on the presence or absence of salinity and in rice (Gong *et al.*, 2001,) where less than 10% of the QTL were detected both in the presence and absence of salt. Clearly, the major determinants of yield vary with the environmental conditions and quantitative traits typically exhibit a large environment X genotype interaction.

Methods for adaptation of salt tolerance

*Conventional breeding programmes
*Use of in vitro selection
*Pooling physiological traits
*Interspecific hybridization
*Halophytes as alternative crop
*Use of marker-assisted selection
*Use of transgenic technique

Salt stress responsive genes/proteins in selected crop species

Plant Species	Genes/ Proteins
Arabidopsis thaliana	At myb 2, Sal
Brassica napus	BnD 22
Citrus sinensis	Cit-SAP
Hordium vulgare	hval., 26 and 27 kDa protein
Lycopersicon esculentus	Osmotin, TSW 12, le 16
L. pimpinellifolium	14.5 kDa protein
Medicago sativa	psm 1409, pa9
Nicotiana tabaccum	Protein of 30 and 43 kDa, osmotin
Oryza sativa	rab 21 Sal T. Em gene, SAP 90, 104

Conclusion and Future Prospects

It is conceivable that approaches that identify specific genes that are up or down regulated either through the analysis of RNA or proteins might provide a specific focus for transformation, although choosing key genes for tolerance is currently far from happening. Transgenic technology will undoubtedly continue to aid the search for the cellular mechanisms that underlie tolerance, but the complexity of the trait is likely to mean that the road to engineering such tolerance into sensitive species will be long. In the meantime, it would be beneficial to continue to invest in other avenues such as the manipulation of ion excretion from leaves through salt glands and the domestication of halophytes. Experience suggests authors should avoid hyperbole in their titles and summaries, as this does little service to the long-term aim of improving the salt tolerance of crops in the field.

Transgenic approaches for increasing plant tolerance to dehydration stresses are experimentally feasible. Preliminary results are encouraging for enabling scientists to better understand the effects of single-gene transfers to plants. However, it should be emphasized that the success to date represents only a beginning. Much more work is needed to gain a better understanding of the biochemical and physiological basis of stress tolerance. Once it is better understood how different single genes work, it is likely that several genes will need to be simultaneously transferred into plants to produce high levels of stress tolerance. This may more closely resemble what occurs in nature where stress tolerance is the cumulative effect of several genes. Recent advances in transformation of agronomically important crops and the development of better expression systems in terms of using stress inducible promoters and adding MAR sequences hold much promise in this directing. These and other advances are needed to produce stress tolerant transgenic crop plants that give significantly higher productivity under field conditions.

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Per se Performance of Lines, Testers and Hybrids for Yield and Yield Contributing Characters in Tomato

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The crossing programme between five lines and five testers was carried out to obtain 25 hybrids by line x tester design. Thirty entries was evaluated for their *per se* performance for eighteen characters. The evaluation of performance of the lines, testers F_1 hybrids and F_2's revealed that, there was a wide range of variation among the lines, tester, F_1 hybrids and F_2's for various characters which indicated that a wide scope for making selection. The hybrids TH-2312 x Hawaii 7998, DPL-T-14 x BT-105, H-62 x Sonali, DPL-T-14 x Sonali and H-63 x DPL-T-4 had good *per se* performance, high heterosis and high sca effects having potential to develop superior hybrids. The hybrids, DPL-T-14 x Arka Alok and DPL-T-14 x BT-105 had bacterial wilt resistance and increased fruit yield which can be used as a superior bacterial wilt resistant hybrids. Maximum fruit weight was recorded by hybrids DPL-T-14 x BT-105 followed by DPL-T-14 x Sonali and TH-2312 x BT-105. For early duration the cross DPL-T-14 x DPL-T-4 should need to be exploited. Quality characters, vitamin C content and highest TSS was observed in high yielding hybrid H-62 x Sonali (5.00 ° Brix). H-63 x Arka Alok, DPL-T-14 x DPL-T-4 and DPL-T-14 x Arka Alok were the promising F2's need to be further evaluated for developing superior purelines.

(**Key words:** *Tomato, Per se performance, Line and Tester*)

Tomato (*Lycopersicon esculentum* Mill.) is an important commercial vegetable crop grown widely throughout the world including tropical, sub-tropical and temperate regions. Nearly 115 and 7 million tons of tomatoes harvested with the productivity of 26 and 14 t ha^{-1} from over 4 million ha and over 5 lakh ha of land in the year 2006 in the world and India, respectively (Anon., 2007). Maharashtra is having 30,620 ha area under tomato during the year 2004 and production of 487565 tones with the productivity of 15.92 t ha^{-1}, while Konkan is having 550 ha and the production of 7590 tones with the productivity of 13.80 t ha^{-1} (Anon., 2005).

Per se performance is considered as the most simple and effective way to get first hand information on the genotypes parents with good per se performance are expected to yield desirable recombination's. Therefore, such selected phenotypes can be further used to exploit heterosis for commercial utilization, application with this objective present investigation was undertaken to study the evaluation of performance of parents and hybrids. The assessment of performance of lines and testers help for selecting better parents and hybrids.

In the coastal region of Maharashtra production of tomato has suffered a lot due to prevalence of bacterial wilt disease to the tune of 30-100 per cent (Fugro *et al.*, 1999). Bacterial wilt incidence showed a considerable range of variation.

MATERIALS AND METHODS

Five tomato lines viz., Hawaii 7998, Sonali, DPL-T-4, Arka Alok and BT-105 were crossed with five tester viz., H-62, H-63, CO-3 and DPL-T-14 in a line x tester mating design during Rabi 2005-2006. The 25 F_1's hybrids along with five lines and five testers were evaluated in randomized block design with three replication at Vegetable Improvement Scheme, central farm, Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri (MS) during *Rabi* 2006-07. Observations were recorded for five competitive plants for quantitative and qualitative characters. Analysis of variance for all the characters under study was carried out as per the formula given by Cochran and Cox (1957).

RESULTS AND DISCUSSION

Analysis of variance

Analysis of variance for parents and their hybrids for eighteen characters viz., plant height, days to first flowering, days to 50 per cent flowering, days to first fruit set, days to first fruit harvest, number of branches plant^{-1}, number of clusters plan^{-1}, number of fruits cluster^{-1}, number of fruits plants^{-1}, fruit yield plant^{-1}, average fruit weight,

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number of locules fruit^{-1}, fruit diameter, fruit length, ascorbic acid per 100 ml of fruit juice, total soluble solids (TSS) Brix, acidity and bacterial wilt incidence are presented in (Table 1). It was exhibited that parents and hybrids differed significantly among themselves for most of the characters under study indicating the possibility of getting maximum heterotic combinations from the parents used in the present investigation.

Mean performance of lines, testers, F1 hybrids and F2's

The evaluation of performance of the lines, testers and their hybrids is a pre-requisite for evaluating better hybrids. The assessment of performance of the lines, testers and their hybrids help in selecting the better lines, testers and hybrids. The promising parents and hybrids based on per se performance are presented in (Table 2 and 3). The variation due to parents and hybrids was found to be highly significant for all the yield contributing characters indicating lot of variation among the lines, testers and hybrids. The mean squares due to parents were also significant for almost all the characters indicated variation in the parents. Mean squares due to hybrid vs. parent were also significant for most of the characters indicating the possibility of getting maximum heterotic combination from the lines and testers.

Plant characters assume greater significance as growing stage of the plants life cycle is an important stage culminating into fruit yield. Hence, in the present investigation, a number of adult plant characters viz., plant height, number of branches, flowering characters, days to fruit set and fruit harvest, number of clusters, number of fruits, fruit yield, average fruit weight and fruit diameter and length were studied.

Plant height has a great importance, which denotes the overall stature of the plant and shows growth vigour in the plant. More plant height accompanied by more number of branches will accommodate more number of clusters ultimately results into production of more number of fruits plant^{-1} in tomato result into increased fruit yield. A large amount of variation was observed for plant height among the lines, testers and hybrids studied. The lines varied 70.73 to 83.40 cm. Among the testers, the variation ranged from 57.85 to 95.90 cm while in hybrids, this character ranged from 55.50 to 96.73 cm. Amongst the hybrids, DPLT-14 x DPLT-4 was the tallest plant. When the performance of these hybrids with reference to their lines and testers was considered, it was interesting to note that the highest yielding hybrids for plant height were not the hybrid having taller parents. In general, it was observed that F_2 generation had less height as compared to F_1 generation. This reduction may be due to loss of vigour suggestive of inbreeding depression. In F_2, it ranged from 50.50 to 92.50 cm. Maximum height in F_2 generation was observed in DPL-T-14 x Arka Alok (92.50 cm) followed by DPL-T-14 x Hawaii 7998 (91.88 cm) while dwarfest plant was noticed in H-63 x Sonali (50.50 cm). Among these crosses good yield potential was found only in DPL-T-14 x Arka Alok (1.447 kg). The progenies from this may be selected to develop high yielding varieties with maximum height. These observations are conformity with those of Jawarlal and Veeraragavathatham (2003) and Tiwari and Lal (2004).

Next to plant height, the flowering characters also have resemblance on yield. It is known fact that the hybrids usually give better performance than the lines primarily due to better vigor and earliness. Early flowering is beneficial in tomato due to its impact on early yield. Minimum days for first fruit harvest is a character of immense importance. It was seen from the data that variation in the lines ranged from 32.67 to 46.00 days for days to first flowering, 52.67 to 47.33 days for days to 50 per cent flowering, 43.67 to 50.33 days for days to first fruit set and 83.00 to 90.33 days for days to first fruit harvest. The variation in testers ranged from 40.67 to 43.33 days for days to first flowering, 47.33 to 48.00 days for days to 50 per cent flowering, 48.67 to 49.67 days for days to first fruit set and 84.33 to 90.33 days for days to first fruit harvest. The variation in hybrids ranged from 31.67 to 46.67 days for days to first flowering, 35.67 to 50.00 days for days to 5(per cent flowering, 40.00 to 52.33 days for days to first fruit set and 81.33 to 89.33 days for days to first fruit harvest. In general, the hybrids showed intermediate performance for these characters. The performance of lines was better than the performance of testers for this character. DPL-T-14 x DPL-T-4 and H-63 x Hawaii 7998 were the earliest flowering hybrids both for first and 50 per cent flowering, while H-63 x Sonali was the latest in the hybrids. H-63 x Hawaii 7998 and DPL-T-14 x Arka Alok was the earliest in first fruit set and harvest, respectively. In general, the hybrids derived from early lines and testers were earlier than other hybrids. Among F_2 progenies, the range of days to

Table 1. *Analysis of variance for line x tester*

Source of Variation	Degrees of Freedom	Plant height (cm)	Days to first flowering	Days to 50 % flowering	Days to first fruit set	Days to first fruit harvest	Number of branches plant^{-1}	Number clusters plant^{-1}	Number of fruits cluster^{-1}	Number of locules fruit^{-1}
		1	3	4	5	6	2	8	9	7
Lines	4	605.16	15.71	1.11	13.78	3.88	2.29	15.08	0.95	2.39
Testers	4	1451.37**	20.08	22.61	20.18	7.85	24.12**	143.5**	0.57	2.88*
L x T	16	337.58**	63.07**	50.32**	39.43**	20.65**	2.63**	12.46**	0.94**	0.98**
Error	68	4.56	13.96	8.79	12.23	11.33	0.08	0.03	0.12	0.04
Total	104	170.44	25.33	18.10	17.09	15.41	2.23	10.11	0.40	0.72
Source of Variation	Degrees of Freedom	Fruit yield plant-1 (kg)	Average fruit weight (g)	Number of fruits plant-1	Fruit Diameter (cm)	Fruit length (cm)	Ascorbic Acid (mg/100g)	TSS 0 Brix	Acidity (%)	BWI (%)
		11	12	10	13	14	15	16	17	18
Lines	4	524873.06	106.48	366.47	1.28**	1.04	245.21**	0.68	0.01	131.3
Testers	4	1685020.99**	72.80	1299.4**	0.19	3.23**	13.31	3.65**	0.07**	304.7
L x T	16	326859.32**	63.83**	155.95**	0.39**	0.58**	25.92**	1.20**	0.01**	190.5**
Error	68	22744.69	3.29	17.07	0.07	0.11	0.13	0.03	0.00	97.25
Total	104	216465.33	71.35	143.06	0.26	0.39	19.49	0.52	0.01	136.50

Table 2. *Mean performance of parents (male and female) in tomato*

Sr. No.	Characters	Male					Female				
		Hawaii 7998	Sonali	DPL-T-4	Arka Alok	BT-105	TH-2312	H-62	H-63	CO-3	DPL-T-14
1	Plant height (cm)	83.40	79.75	70.73	82.27	75.13	95.90	57.85	75.23	60.31	76.67
2	Days to first flowering	32.67	43.00	39.00	36.67	46.00	40.67	42.33	43.33	40.67	42.00
3	Days to 50 % flowering	48.33	47.33	48.67	47.67	52.67	48.00	47.67	48.67	47.33	47.67
4	Days to first fruit set	43.67	50.33	47.67	46.67	48.67	49.33	49.67	49.67	48.67	49.67
5	Days to first fruit harvest	85.33	90.33	86.33	83.00	88.00	90.33	89.00	84.33	86.67	90.33
6	Number of branches plant^{-1}	8.27	9.80	7.03	8.07	6.57	5.40	4.03	7.13	9.03	7.53
7	Number of clusters plant^{-1}	14.53	14.83	10.57	8.77	10.33	8.93	6.73	8.77	10.23	12.83
8	Number of fruits cluster^{-1}	3.52	4.15	3.34	3.73	3.44	3.08	3.03	3.52	4.23	3.77
9	Number of fruits plant^{-1}	51.67	61.48	35.33	32.71	35.51	27.53	20.36	30.83	43.24	48.33
10	Fruit yield plant^{-1} (kg)	1.134	2.026	1.123	1.292	1.456	1.924	0.554	0.723	1.835	1.200
11	Average fruit weight (g)	22.05	32.95	31.78	39.49	41.02	69.97	27.15	23.43	42.42	24.82
12	Number of locules fruit^{-1}	2.17	2.27	3.23	4.37	3.30	5.07	2.67	2.63	4.97	2.27
13	Fruit diameter (cm)	3.40	3.66	4.42	4.45	5.03	4.02	3.81	4.01	4.12	3.50
14	Fruit length (cm)	3.44	4.55	4.01	3.67	4.29	3.79	4.54	3.00	3.75	4.22
15	Ascorbic acid (mg 100g^{-1})	32.16	26.05	24.45	22.96	33.94	29.44	20.97	21.48	21.98	24.49
16	TSS 0Brix	4.77	5.57	5.13	4.77	4.50	5.90	4.13	5.57	3.93	5.87
17	Acidity (%)	0.58	0.58	0.68	0.64	0.54	0.58	0.40	0.41	0.50	0.57
18	BWI (%)	3.33	3.33	6.67	6.67	13.33	23.33	23.33	26.67	23.33	16.67

Table 3. *Mean performance of F_1 and F_2 population in tomato*

Sr. No.	Hybrids	Plant height (cm)	Days to first flowering	Days to 50 % flowering	Days to first fruit set	Days to first fruit harvest	Number of branches plant^{-1}	Number clusters plant^{-1}	Number of fruits cluster^{-1}	Number of locules fruit^{-1}
1	TH 2312 x Hawaii 7998	92.45	38.33	50.00	47.00	83.00	7.50	12.67	3.80	3.40
2	TH 2312 x Sonali	77.10	34.67	42.67	50.67	81.67	7.87	12.53	3.60	3.73
3	TH 2312 x DPL-T-4	80.83	39.67	49.00	48.67	85.67	7.17	10.03	3.16	3.93
4	TH 2312 x A. Alok	89.60	34.00	43.33	42.33	83.00	7.63	13.43	2.21	3.17
5	TH 2312 x BT-105	91.27	37.33	45.33	46.33	84.00	7.93	15.30	2.37	3.23
6	H-62 x Hawaii 7998	88.17	39.67	44.67	48.00	84.00	7.03	14.70	2.43	2.43
7	H-62 x Sonali	89.57	39.33	48.00	47.00	83.00	9.90	17.17	3.70	2.57
8	H-62 x DPL-T-4	91.80	40.00	48.67	46.67	89.33	6.97	10.43	3.40	2.43
9	H-62 x A. Alok	87.27	40.33	47.33	43.33	87.00	9.53	15.23	2.78	3.17
10	H-62 x BT-105	78.57	34.00	41.67	41.67	81.67	8.13	13.07	2.37	3.33
11	H-63 x Hawaii 7998	55.50	31.67	35.67	40.00	81.67	5.23	5.77	3.23	2.27
12	H-63 x Sonali	46.20	46.67	48.33	52.33	84.67	4.93	6.83	3.55	2.27
13	H-63 x DPL-T-4	70.83	37.00	45.00	49.33	83.67	5.73	8.67	3.20	2.93
14	H-63 x A. Alok	78.23	35.00	45.33	44.00	82.67	6.83	9.80	2.87	3.40
15	H-63 x BT-105	92.13	37.00	45.33	46.33	88.00	6.57	8.63	3.08	3.63
16	CO-3 x Hawaii 7998	89.97	41.00	46.33	50.33	84.67	8.13	7.83	2.28	2.67
17	CO-3 x Sonali	56.87	37.33	41.67	41.33	82.33	6.83	12.33	2.35	2.33
18	CO-3 x DPL-T-4	57.10	35.67	44.33	46.67	82.67	5.93	7.33	3.03	4.37
19	CO-3 x A. Alok	68.90	38.67	45.33	47.00	85.33	6.57	10.63	2.78	4.93
20	CO-3 x BT-105	79.90	45.33	48.67	49.67	82.00	6.67	7.23	2.80	3.57
21	DPL-T-14 x Hawaii 7998	87.80	44.33	47.00	50.33	88.00	8.07	14.07	2.50	2.40
22	DPL-T-14 x Sonali	79.80	34.67	44.67	45.67	83.67	8.03	10.52	3.67	2.33
23	DPL-T-14 x DPL-T-4	96.73	31.67	36.00	46.67	80.33	9.97	17.50	2.05	2.50
24	DPL-T-14 x Arka Alok	87.83	41.33	44.00	49.33	81.33	9.63	16.27	2.90	2.33
25	DPL-T-14 x BT-105	92.13	43.33	45.33	50.67	83.00	9.90	9.67	3.07	3.40
	Mean	80.26	38.32	44.95	46.85	83.85	7.55	11.76	2.96	3.07
	S.E. ±	0.71	1.25	0.99	1.17	1.12	0.09	0.06	0.11	0.07
	C.D. at 5 %	2.05	3.58	2.84	3.35	3.22	0.26	0.17	0.33	0.19

Table 3 Cont.

Sr. No.	Hybrids	Fruit yield $plant^{-1}$ (kg)	Average fruit weight (g)	Number of fruits $plant^{-1}$	Fruit diameter (cm)	Fruit length (cm)	Ascorbie acid (mg $100g^{-1}$)	TSS ^{0}Brix	Acidity (%)	BWI (%)
1	TH 2312 x Hawaii 7998	1.573	32.67	48.13	3.52	3.59	33.56	5.03	0.61	6.67
2	TH 2312 x Sonali	1.263	28.21	45.05	3.02	3.14	32.16	5.40	0.58	10.00
3	TH 2312 x DPL-T-4	0.868	27.33	31.71	3.88	3.78	26.05	5.97	0.59	16.67
4	TH 2312 x A. Alok	1.003	33.91	29.70	4.02	3.50	24.45	4.23	0.69	6.67
5	TH 2312 x BT-105	1.490	41.11	36.28	3.87	3.58	22.96	4.63	0.63	3.33
6	H-62 x Hawaii 7998	1.198	33.61	35.78	3.48	3.26	33.94	5.13	0.53	6.67
7	H-62 x Sonali	2.034	32.02	63.47	3.56	3.21	29.44	5.00	0.58	6.67
8	H-62 x DPL-T-4	1.115	31.41	35.50	3.37	3.61	20.97	5.17	0.40	20.00
9	H-62 x Arka Alok	1.531	36.07	42.42	3.73	2.38	21.48	5.30	0.41	0.00
10	H-62 x BT-105	1.125	36.47	30.91	4.58	3.72	21.98	5.23	0.51	13.33
11	H-63 x Hawaii 7998	0.759	40.75	18.63	3.93	4.34	24.49	3.37	0.57	13.33
12	H-63 x Sonali	0.621	25.51	24.29	3.09	3.30	32.16	4.57	0.58	6.67
13	H-63 x DPL-T-4	0.895	32.07	27.82	3.25	3.45	26.05	5.07	0.59	23.33
14	H-63 x Arka Alok	1.071	37.59	28.24	3.12	3.92	24.45	6.03	0.69	26.67
15	H-63 x BT-105	0.932	34.80	26.56	3.97	3.80	22.96	4.73	0.63	23.33
16	CO-3 x Hawaii 7998	0.628	35.06	17.90	3.19	3.55	33.94	5.13	0.53	20.00
17	CO-3 x Sonali	1.062	36.56	29.01	3.92	4.32	29.44	4.97	0.58	20.00
18	CO-3 x DPL-T-4	0.863	38.71	22.26	3.32	4.22	20.97	4.17	0.40	3.33
19	CO-3 x Arka Alok	1.171	39.64	29.61	3.86	3.73	21.48	5.07	0.41	13.33
20	CO-3 x BT-105	0.784	38.47	20.23	3.70	4.66	21.98	4.23	0.51	3.33
21	DPL-T-14 x Hawaii 7998	0.963	27.61	35.13	3.47	3.62	24.49	3.87	0.57	3.33
22	DPL-T-14 x Sonali	2.190	62.67	34.94	3.78	4.72	32.16	4.03	0.58	16.67
23	DPL-T-14 x DPL-T-4	1.284	35.74	35.88	3.24	4.34	26.05	3.23	0.59	16.67
24	DPL-T-14 x Arka Alok	1.648	34.84	47.17	3.67	4.07	24.45	4.53	0.69	0.00
25	DPL-T-14 x BT-105	2.154	75.10	29.74	4.56	5.33	22.96	3.87	0.63	0.00
	Mean	1.21	35.12	34.43	3.64	3.81	26.20	4.72	0.56	12.19
	S.E. ±	0.50	0.60	1.38	0.09	0.11	0.12	0.06	0.001	3.29
	C.D. at 5 %	1.44	1.74	3.96	0.26	0.31	0.34	0.17	0.004	9.45

Table 3 Cont.

Sr. No.	F_2's	Plant height (cm)	Days to first flowering	Days to 50 % flowering	Days to first fruit set	Days to first fruit harvest	Number of branches plant^{-1}	Number clusters plant^{-1}	Number of fruits cluster^{-1}	Number of locules fruit^{-1}
1	TH 2312 x Hawaii 7998	85.97	35.33	44.33	48.67	85.00	7.20	10.10	3.61	2.40
2	TH 2312 x Sonali	80.73	34.33	47.33	42.00	89.00	6.35	10.20	3.12	2.60
3	TH 2312 x DPL-T-4	80.10	34.33	41.33	42.33	85.00	8.10	8.90	3.20	3.40
4	TH 2312 x A. Alok	81.03	41.33	48.00	45.33	85.00	7.05	14.60	2.38	3.80
5	TH 2312 x BT-105	79.07	39.33	50.33	47.33	93.00	8.55	13.50	2.94	3.40
6	H-62 x Hawaii 7998	91.18	33.33	41.00	46.67	85.00	6.70	12.10	2.10	2.60
7	H-62 x Sonali	80.93	41.33	42.67	51.67	89.00	9.20	14.40	3.45	2.40
8	H-62 x DPL-T-4	76.47	41.00	52.00	56.33	93.00	9.30	9.90	3.29	2.40
9	H-62 x A. Alok	80.17	43.33	53.67	53.33	96.00	8.80	14.30	2.71	2.60
10	H-62 x BT-105	81.53	33.67	35.00	40.67	82.00	7.30	11.90	2.89	3.40
11	H-63 x Hawaii 7998	51.03	36.67	43.33	46.67	85.00	6.40	4.30	2.41	2.20
12	H-63 x Sonali	50.50	36.67	48.33	52.33	93.00	6.25	10.66	2.84	3.40
13	H-63 x DPL-T-4	72.27	49.33	50.33	53.67	93.00	6.70	8.65	2.89	4.40
14	H-63 x A. Alok	77.80	33.33	50.33	40.67	85.00	7.90	10.90	2.46	3.60
15	H-63 x BT-105	84.97	36.33	53.00	57.67	96.00	7.40	7.40	3.06	2.40
16	CO-3 x Hawaii 7998	81.30	34.67	46.00	43.33	93.00	10.10	9.10	2.56	2.60
17	CO-3 x Sonali	51.50	31.33	34.67	37.67	82.00	7.30	8.00	2.36	2.00
18	CO-3 x DPL-T-4	51.43	39.33	50.00	43.33	93.00	5.70	9.20	2.34	3.40
19	CO-3 x Arka Alok	73.80	34.33	48.00	41.33	93.00	6.90	9.00	3.40	3.60
20	CO-3 x BT-105	74.00	47.33	54.33	55.67	89.00	6.80	8.80	2.40	2.40
21	DPL-T-14 x Hawaii 7998	91.88	43.33	54.33	54.67	89.00	8.10	12.10	2.64	2.80
22	DPL-T-14 x Sonali	71.73	35.33	43.33	43.67	89.00	7.50	11.00	2.34	2.60
23	DPL-T-14 x DPL-T-4	82.87	34.33	50.00	41.33	89.00	9.50	17.00	2.31	3.80
24	DPL-T-14 x Arka Alok	92.50	33.67	42.00	42.67	85.00	8.30	17.40	2.96	3.40
25	DPL-T-14 x BT-105	80.53	35.33	53.67	40.33	85.00	8.70	9.20	3.10	3.60
	Mean	**76.21**	**37.54**	**47.09**	**46.77**	**88.84**	**7.68**	**10.76**	**2.76**	**3.01**
	S.E. ±	0.68	1.31	1.03	1.21	1.15	0.1	0.04	0.09	0.09
	C.D. at 5 %	1.95	3.76	2.96	3.48	3.30	0.29	0.11	0.26	0.26

Table 3 Cont.

Sr. No.	F_2's	Fruit yield plant^{-1} (kg)	Average fruit weight (g)	Number of fruits plant^{-1}	Fruit diameter (cm)	Fruit length (cm)	Ascorbic acid (mg 100g^{-1})	TSS ^{0}Brix	Acidity (%)	BWI (%)
1	TH 2312 x Hawaii 7998	1.316	37.13	35.53	3.80	3.24	33.94	5.00	0.534	13.33
2	TH 2312 x Sonali	0.811	22.33	36.31	3.29	3.05	29.44	5.50	0.582	10.00
3	TH 2312 x DPL-T-4	0.642	23.35	27.49	3.92	3.32	20.97	4.80	0.523	23.33
4	TH 2312 x A. Alok	0.746	23.47	31.78	3.85	3.41	21.48	5.20	0.642	10.00
5	TH 2312 x BT-105	1.130	34.22	33.03	3.79	3.43	21.98	4.50	0.512	6.67
6	H-62 x Hawaii 7998	0.493	17.23	28.64	3.47	3.47	24.49	4.80	0.572	10.00
7	H-62 x Sonali	1.204	22.10	54.48	4.00	5.21	32.16	4.60	0.580	3.33
8	H-62 x DPL-T-4	1.025	30.92	33.13	4.30	3.85	26.05	4.90	0.492	20.00
9	H-62 x Arka Alok	1.189	30.39	39.13	4.43	4.28	24.45	5.00	0.462	3.33
10	H-62 x BT-105	0.955	32.59	29.31	4.74	3.70	22.96	4.70	0.634	10.00
11	H-63 x Hawaii 7998	0.245	25.57	32.33	3.45	3.63	33.94	4.00	0.534	13.33
12	H-63 x Sonali	1.277	42.14	29.63	3.53	4.17	29.44	4.90	0.572	10.00
13	H-63 x DPL-T-4	0.909	31.96	28.39	3.76	3.31	20.97	5.00	0.492	20.00
14	H-63 x Arka Alok	1.858	56.62	31.91	4.15	3.53	21.48	4.80	0.582	33.33
15	H-63 x BT-105	0.776	33.71	23.02	3.92	3.77	21.98	4.90	0.620	30.00
16	CO-3 x Hawaii 7998	0.526	24.10	21.26	3.92	3.36	24.49	4.80	0.572	13.33
17	CO-3 x Sonali	0.638	32.29	19.76	3.65	5.34	32.16	4.50	0.580	13.33
18	CO-3 x DPL-T-4	0.572	29.41	19.44	3.94	3.80	26.05	5.00	0.462	13.33
19	CO-3 x Arka Alok	0.766	29.00	26.40	4.03	3.59	24.45	5.40	0.592	6.67
20	CO-3 x BT-105	0.849	33.65	25.23	4.11	3.86	22.96	5.00	0.634	3.33
21	DPL-T- 14 x Hawaii 7998	0.728	24.62	29.20	3.58	3.40	33.94	4.10	0.534	13.33
22	DPL-T-14 x Sonali	0.952	31.87	30.95	4.64	4.78	29.44	4.10	0.582	20.00
23	DPL-T-14 x DPL-T-4	1.373	37.21	36.89	4.56	3.81	20.97	3.30	0.552	13.33
24	DPL-T-14 x Arka Alok	1.447	29.44	50.81	4.12	3.24	21.48	4.20	0.584	3.33
25	DPL-T-14 x BT-105	0.937	34.57	27.29	4.51	5.31	21.98	3.90	0.612	5.00
	Mean	**0.935**	**31.52**	**29.93**	**3.98**	**3.83**	**25.75**	**4.68**	**0.56**	**12.87**
	S.E. ±	0.47	0.54	1.37	0.08	0.12	0.14	0.05	0.003	2.89
	C.D. at 5 %	1.36	1.55	3.94	0.23	0.34	0.40	0.14	0.01	8.30

first flowering, days to 50 per cent flowering, days to first fruit set and days to first fruit harvest were from 33.33 to 47.33 days, 34.67 to 54.33 days, 37.67 to 57.67 days and 82.00 to 96.00 days, respectively. In F_2, CO-3 x Sonali showed earliness for days to first flowering (31.33 days), days to 50 per cent flowering (34.67days) and days to first fruit set while H-62 x BT-105 (82.00 days) showed earliness to first fruit harvest. All these progenies had also good yield potential and hence hybrids with higher yield and early maturity can be produced. Similar observations were recorded by Bhatt *et al.* (1999) and Joshi and Thakur (2003).

Number of branches plant^{-1} is another important character having indirect relation with fruit yield via increase in number of clusters and ultimately increased number of fruits. Number of branches is an indication of size of infrastructure responsible for generation of source as well as sinks attributes. Number of fruits plant^{-1} is the most important yield contributing character in tomato. A wide range of variation was observed for number of branches plant^{-1}. In the lines, the variation ranged from 9.80 to 6.57 for number of branches plant^{-1}, 8.77 to 14.83 for number of clusters, 3.34 to 4.15 for number of fruits cluster^{-1} and 32.71 to 61.48 for number of fruits plant^{-1}. Among testers, variation ranged from 4.03 to 9.03 for number of branches plant^{-1}, 6.73 to 12.83 for number of clusters, 3.03 to 4.23 for number of fruits cluster^{-1} and 20.36 to 48.33 for number of fruits plant^{-1}. Among 25 hybrids, variation ranged from 4.93 to 9.97 for number of branches plant^{-1}, 5.77 to 17.50 for number of clusters, 2.05 to 3.80 for number of fruits cluster^{-1} and 17.90 to 63.47 for number of fruits plant^{-1}. In general, hybrids had maximum number of branches, clusters and fruits than lines and testers. In general, hybrid DPL-T-14 x DPL-T-4 had better performance for these characters and also noted maximum number of branches plant^{-1} i.e. 9.97, followed by H-62 x Sonali (9.90) and DPLT-14 x BT-105 (9.90), number of clusters plant^{-1} in DPL-T-14 x DPL-T-4 (17.50) followed by H-62 x Sonali (17.17), number of fruits cluster-1 in TH-2312 x Hawaii 7998 (3.80) followed by TH 2312 x Sonali (3.60), H-63 x Sonali (3.55) and number fruits per plant in H-62 x Sonali (63.47). DPL-T-14 x DPL-T-4 was not the hybrid having maximum yield plant^{-1}, though, it had highest number of fruits plant^{-1}. It might be due to the fact that their average fruit was low than other hybrids. In F_2, number of branches plant^{-1} ranged from 5.70 to 10.10 while variation for number of fruits cluster^{-1} ranged from 2.10 to 3.61 and 19.44 to 54.48 for number of fruits plant^{-1}. Among F_2 highest number of branches plant^{-1} was exhibited by CO-3 x Hawaii 7998 (10.10) followed by DPL-T-14 x DPL-T-4 (9.50) whereas highest number of clusters plant^{-1} had given by DPL-T-14 x Arka Alok (17.40) followed by DPL-T-14 x DPL-T-4 (17.00). TH 2312 x Hawaii 7998 (3.61) and H-62 x Sonali (54.48) exhibited maximum number of fruits cluster^{-1} and highest number of fruits plant^{-1}, respectively. All these progenies had good yield potential with higher yield and more number of branches, clusters and fruits can be exploited for the development of suitable varieties. Earlier researchers were agreed with the present findings are Raijadhav *et al.*, (1996), Sekar (2001) and Dudi and Sanwal (2004).

Tomato, being a vegetable crop, fruit characters had tremendous importance on which consumer's choice and market depends. People prefer medium fruit weight and maximum diameter while long fruit length is preferred for table purpose whereas short fruit length is preferred for curry purpose. High weight is the main yield contributing character. Highest yield was noted when fruit weight was maximum along with more number of fruits. Among the fruit characters, average fruit weight, fruit diameter and length showed a wide range of variability. In lines, variation ranged from 22.05 to 41.05 g for average fruit weight, 3.40 to 5.30 cm for fruit diameter and 3.44 to 4.55 cm for fruit length. Among testers, variation ranged from 23.43 to 64.97 g for average fruit weight, 3.50 to 4.12 cm for fruit diameter and 3.00 to 4.54 cm for fruit length. By and large, the hybrids were bigger in size than the lines and testers. Among the hybrids, variation ranged from 25.51 to 75.10 g for average fruit weight, 3.02 to 4.56 cm for fruit diameter and 3.14 to 5.33 cm for fruit length. DPL-T-14 x BT-105 (75.10 g) had given maximum fruit weight among the hybrids. Fruit having maximum diameter and length was recorded in H-62 x BT-105 (4.74 cm) and DPL-T-14 x BT-105 (5.33 cm), respectively. Minimum length was recorded in H-62 x Arka Alok (2.38 cm) while minimum fruit length was given by DPL-T-14 x BT-105 (4.72 cm).

In F_2, average fruit weight ranged from 17.23 to 56.62 g while fruit diameter and length varied from 3.29 to 4.74 cm and 3.05 to 5.34 cm, respectively. Among F_2, maximum average fruit weight was given by H-63 x Arka Alok (56.62 g) while maximum fruit diameter was observed in H-62 x BT 105 (4.74 cm) and minimum fruit length was exhibited in TH 2312 x Sonali (3.05 cm). Superior high yielding varieties can be isolated from these progenies. Singh *et al.*, (2003) recorded positive heterosis over better parent for average fruits weight and Singh and Gopalkrishnan (2000) had revealed maximum fruit diameter than their parents.

Yield is the major aim of any breeding programme. It is a complex phenomenon involving the interaction of different contributing characters. Increase in yield is mainly due to increase in number of fruits, average fruit weight, number of branches and plant height (Sekar, 2001). Fruit yield plant^{-1} varied among lines between 1.123 to 2.026 kg, in testers variation ranged from 0.554 to 1.924 kg. Among hybrids, fruit yield plant^{-1} ranged from 0.621 to 2.190 kg. Maximum fruit yield plant^{-1} was observed in DPL-T-14 x Sonali (2.190 kg) followed by H-62 x Sonali (2.034 kg), DPL-T-14 x Arka Alok (1.648 kg) and TH 2312 x Hawaii 7998 (1.573 kg). In F_2, it ranged from 0.493 to 1.858 Kg. Among F_2, maximum fruit yield plant^{-1} was recorded in H-63 x Arka Alok (1.858 kg) followed by DPL-T-14 x Arka Alok (1.466 kg). High yielding lines may be selected from these progenies. Chadha *et al.*, (2000), Resende *et al.*, (2000) and Suneetha *et al.*, (2006) also reported wide range of variation for fruit yield and maximum heterosis over better parent and standard variety.

Quality characters assume greater significance as it is important vegetable crop and has tremendous demand in processing industry. The number of locules in tomato fruit has a great influence on quality of tomato yield (Rai *et al.*, 1998) as well as it is one of the factors of fruit firmness which determines the transportability of fruit and also a major component in fruit size. Low loculi number is associated with firmness and is important from processing point of view along with acidity. High acidity reduces the processing time and temperature and allows improving colour, texture and vitamin C retention. It also provides flavour and acts as a preservative in the canned product. Total soluble solids content is an important parameter of quality, which exhibited a direct influence on the taste, and flavour of fresh tomato as well as of processed products. TSS is highly correlated with sugar content in tomato fruit and important in yield of concentrated tomato products. Hence, in the present investigation, a number of qualitative characters viz., number of locules fruit^{-1}, ascorbic acid content, total soluble solids and acidity were studied.

A wide range of variation was observed for number of locules fruit^{-1}. The variation in lines ranged from 2.17 to 4.37 for number of locules fruit^{-1}, 22.96 to 33.94 mg per 100 g for ascorbic acid content, 4.50 to 5.57° Brix for TSS and from 0.54 to 0.68 per cent for acidity, while variation in testers ranged from 2.27 to 5.07 for number of locules, 20.97 to 29.44 mg per 100 g for ascorbic acid content, 4.13 to 5.90° Brix for TSS and from 0.40 to 0.58 per cent for acidity. Among hybrids variation ranged from 2.27 to 4.93 for number of locules per fruit, 20.97 to 33.94 mg per 100 g for ascorbic acid, 3.23 to 6.03 ° Brix for total soluble solids and from 0.40 to 0.69 per cent for acidity. H-63 x Hawaii 7998 and H-63 x Sonali, CO-3 x Hawaii 7998, H-63 x Arka Alok showed better performance for number of locules per fruit, ascorbic acid content, TSS and acidity among the hybrids studied. In general, hybrid showed intermediate performance for number of locules per fruit. Among F_2, number of locules fruit^{-1} and ascorbic acid ranged from 2.00 to 3.80 and 20.97 to 33.94 mg, respectively, whereas total soluble solids were varied in between 3.30 to 5.50 ° Brix and 0.46 to 0.64 per cent for acidity. Among F_2, least number of locules fruit^{-1} was noted in CO-3 x Sonali (2.00) while maximum ascorbic acid was recorded in TH 2312 x Hawaii 7998 and H63 x Hawaii 7998 (33.94 mg). Among 25 F_2, maximum content of total soluble solids was observed in TH 2312 x Sonali (5.50 ° Brix) while maximum acidity was noticed in TH 2312 x Arka Alok (0.64 %). Mangeshwari and Natarajan (1999), Datta *et al.*, (2001) and Patgaonkar *et al.*, (2003) reported highest values of variation for number of locules fruit^{-1}, acidity, total soluble solids and ascorbic acid.

The variation in the lines ranged from 3.33 to 13.33 per cent while it ranged from 16.67 to 26.67 per cent in testers. Among hybrids variation ranged from 0.00 to 26.67 per cent. H-62 x Arka Alok, DPL-T-14 x Arka Alok and DPL-T-14 x BT-105 recorded no bacterial wilt incidence. In F_2, bacterial wilt incidence increased slightly and ranged from 3.33 to 33.33 percent. As like F_1's, DPL-T-14 x Arka Alok (3.33 %) had minimum incidence of bacterial wilt but not at zero level. Similarly, another two hybrids also recorded 3.33 per cent wilt incidence were CO-3 x BT-105 and H-62 x Sonali. By and large, performance of hybrids was better than the performance of lines and testers for this character. Choudhary (2000) and Gopalkrishnan *et al.*, (2000) also reported similar kind of findings.

Most of the top ranking hybrids recorded the medium to high fruit weight. Among these, highest fruit weight was recorded by hybrids DPL-T-14 x BT-105 followed by DPL-T-14 x Sonali and TH-2312 x BT-105. For early fruit yield DPL-T-14 x DPL-T-4 should need to be exploited. Quality characters, vitamin C content and highest TSS was observed in high yielding hybrid H-62 x Sonali (5.00 ° Brix).

H-63 x Arka Alok, DPL-T-14 x DPL-T-4 and DPL-T-14 x Arka Alok were the promising F_2's need to be further evaluated for developing superior purelines. All these above hybrids indicated their utility in developing superior hybrids. Extensive screening of these hybrids for bacterial wilt resistance need to be done to assess the bacterial wilt resistance reaction in Konkan region as good hybrid with bacterial wilt resistance is one of the major objectives of plant breeder in Konkan region of Maharashtra.

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Agricultural Marketing Efficiency of Major Vegetables Crops in Coastal Districts of West Bengal - Current Status and Way Forward

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Functioning of efficient marketing system is essential to increase the area under vegetables and to ensure remunerative prices to the primary producers' particularly perishable commodities like, vegetables. The study was undertaken to analyse the prevailing marketing systems in coastal districts of West Bengal, covering three major vegetables grown in the coastal areas, such as brinjal, bhindi and tomato. Marketing efficiency parameters such as producers' price on consumer rupee and Acharaya's modified method and marketing costs marketing margins have been estimated based on the primary information collected from sample farmers and traders. The producers' prices on consumer rupee were estimated to be 44 % under marketing of brinjal followed by bhindi (37%) and tomato (26%). Total marketing cost was estimated to be hovering around 20% and the total marketing margin was in the range of 34-45 % under the specified commodities. In general it was observed, whole agricultural marketing system is operating under a vicious cycle like - large no of small producer are producing low marketable surplus which is resulting in low bargaining power and low profit. Then these commodities passes to a large no of small traders who are handling these produce in a small-scale, subjected to high degree of post harvest losses and ultimately the whole marketing system operating in a non-commercial venture. Because of this low volume of operation both farmers or traders tries to dispose off his entire produce in quickest possible time as either they cannot afford to store the produce (if storage facility is available) or mostly the storage facility is not available. To increase the marketing efficiency of the vegetables, it has been suggested to increase the volume of handling through organized retail chain to make the business more commercialized. This increased volume of trading also likely to offer more stabilized price at the market and benefiting both consumers and producers.

(**Key words:** *Marketing efficiency, Vegetables, Coastal agriculture*)

The horticulture sector plays a significant role towards sustainable rural livelihoods in all farming systems including the marginal areas. The credibility of horticulture has been well established in improving productivity of land, generating employment, improving economic conditions of the farmers and entrepreneurs, enhancing exports and above all providing nutritional security to the people. West Bengal produces highest vegetables in India among all states. During 2007-08, the state produced more than 22 million tones of vegetables. Vegetables are grown quite extensively across all the districts including in and around the districts of Kolkata. In the coastal areas of Sundarbans of West Bengal, the land is mostly mono-cropped with rice during *Kharif* season, and around 11 percent of total gross cropped area is under vegetables cultivation. Out of which brinjal, bhindi and tomato occupy a major share in cropping pattern in this salt-affected soils. However, growing vegetables in these problematic soils are subjected to multifarious constraints (management as well as marketing), which pose as the major challenge to increase the area under vegetable crops in the area. Establishing and functioning of efficient marketing system may increase the area under vegetables and may ensure remunerative prices to the primary producers. Present study was undertaken to analyse the prevailing marketing channels and the marketing efficiency therein Study covered three coastal districts of West Bengal, namely, South 24 Parganas, North 24 Parganas and East Midnapore with the following objectives; first, to *estimate* the marketing cost and marketing margin of different functionaries for selected vegetables under dominant supply chains; second, to *analyze* the price spread, marketing efficiency and farmer's share in consumer rupee in various supply chains;

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third, to *identify* the possible implication of corporate entry into agricultural marketing system; and finally, to *suggest* suitable strategies to enhance the marketing efficiency for vegetables in west Bengal.

MATERIALS AND METHODS

Study area

Present study was based on primary data collected from sample farmers through pre-structured and tested farm survey schedule. In some analysis relevant secondary data has also been used. In the study area marginal farmers are the most dominant (86 percent) category of farmers, followed by very few small farmers (12 percent). So, for data collection and analysis, no separate classification has been made for the farmers. Study has been conducted in three coastal districts of West Bengal, namely, South 24 Parganas, North 24 Parganas and East Midnapore.

Selection of crops and sampling methods

Based on the importance of crops in terms of maximum area and production pattern, 3 vegetables i.e., brinjal, bhindi and tomato have been selected. Since these vegetables are widely grown in these two districts across the blocks, therefore farmers have been selected randomly. Overall the data collection on production and marketing of these selected crops were obtained from the farmers distributed over 15 blocks of these three districts. These were, Bangaon, Baruipur, Bhangore, Budge budge, Canning I & II, Contai I, II & III, Kasipara, Magrahat II, Mathurapur II, Nonakhali, Ramnagar and Swarupnagar. To facilitate easy access for data collection, farmers were interviewed in various market places where they visited for selling their produce frequently. These were mainly rural or primary *haat*, wholesale market at block level or at wholesale market in Kolkata. Total sample size was 385, which includes farmers (272 no) and middlemen (113 no). Out of the total farmers interviewed, 115 farmers were brinjal growers, followed by bhindi, (65 farmers) and tomato (53 farmers). Beside, various wholesale markets in Kolkata, such as Nafar Babur Bazar, Math Pukur Bazar, Bantala Market, and Baruipur Kachari Bazaar have been surveyed in detail.

Status of the vegetables production

West Bengal is one of the leading states in terms of producing vegetables in India. The state is accounted for 17.8 percent of total vegetable production from 16.8 percent area of India. Vegetables are grown widely across all the districts of West Bengal. Brinjal, bhindi and tomato are the major vegetables grown by the farmers in the coastal districts of West Bengal. Together, these three coastal districts were accounted for producing 14 percent (370 thousand tones) of Bengal's brinjal production (2699 thousand tones) from an estimated 19 percent (of WB) area (under brinjal cultivation) (Table 1). Similarly, in case of bhindi these study districts are producing 22 percent from 23 percent area of West Bengal, and, for tomato 18 percent production from 19 percent area of West Bengal. But the productivities vegetables were comparatively lower in these districts as compared to the west Bengal due to the salinity problem in this area.

RESULTS AND DISCUSSION

Market intermediaries and their function

After harvesting of crops, the produce are brought in the market by farmers or the village level traders collect the produce and used to bring in the market. First interaction point between farmers and traders occurred at primary market or village level market. Various primary market or '*haat*' operates during specific time of the day or specific time in weekly or weekly basis. Farmers sell their produce to the traders called '*fariah*' who are usually the first middlemen functioning in the market. They

Table 1. *Area, Production and Yield of Fruits, Vegetables and Flowers in Study Area (2006-07)*

Name of crops	North 24 Parganas			South 24 Parganas			East Midnapore			West Bengal		
	A	P	Y	A	P	Y	A	P	Y	A	P	Y
Vegetable (total)	67	875	13	67	819	12.3	47	441	9.3	904	12088	13.4
Tomato	4	70	17.1	4	74	17.6	1	14	11.1	51	869	17.1
Bhindi	5	57	11.9	7	69	10.5	4	43	10.1	68	762	11.2
Brinjal	9	131	15	9	145	16.7	9	94	11.1	153	2699	17.7

Note: (1). A : Area in 000 ha, P : Production in 000 tonnes and Y: Yield in t ha^{-1}.
Source: Govt. of West Bengal, (2010)

collect the produce from different farmers through direct bargaining from the farmers. However most commonly farmers used to bring their produce to the commission agent called '*arhatdar*' in the market and they arrange the auction for selling of the produce. After inspecting quality of produce traders (*fariah*) offer bidding price and based on the maximum bid the produce is sold. Commission agent charges for this function either through cash payment or keeping some quantity of produce which various from produce to produce and also market to market. It has been estimated, in terms of value the commission agent charges around 5-7 percent of the total value of the produce sold. Key intermediate functionaries in the marketing include farmers, village traders (*fariah*)/middlemen - wholesaler - retailer and consumer. Primary grading and standardization is done by farmers and second time the grading, standardization is made by the traders before the produce goes to wholesale market. Functions of various intermediaries are summarized in table below.

Marketing Cost

Marketing costs are incurred by the various functionaries in the market starting from farmers, middlemen, wholesalers and retailer. Marketing cost for farmers include sorting, packing (mostly packed in gunny bags or in basket) transportation and others (eg. loading, unloading, bribing or paying fees for undisclosed reason). Total marketing cost included by all market intermediaries/functionaries (farmers, traders, wholesaler and retailers) has been calculated to be Rs. 335/q for brinjal, Rs. 330/q for bhindi, Rs. 345/q for tomato. In terms of percent share to total marketing cost for brinjal has been estimated to be 18 percent of final consumers' price. Similarly, for bhindi the marketing cost was calculated to be 23 percent for guava 21 percent and for marigold 5 percent to the final consumer's price.

Marketing Margins

Marketing margins are the net profit by the market functionaries/intermediaries and have been calculated by deducting the marketing cost incurred by particular intermediaries from actual price paid by him. For farmers the margin has been calculated by deducting the production cost plus marketing cost from the price received by him. Total marketing margin has been calculated to be Rs. 990/q for brinjal marketing, and the same was Rs. 778/q for bhindi and Rs. 894/q for tomato. In regards to brinjal marketing 29 percent of the total marketing margin was received by the producer followed by Assembler (25 percent), retailer (25 percent) and wholesalers (20 percent). Under bhindi marketing 31 percent of the total marketing margin was received by the retailer followed by assembler (26 percent), producer (24 percent) and wholesaler (19 percent). Under tomato marketing major marketing margin was shared by retailer (34 percent), followed by wholesaler & assembler (28 percent) and least by the producer (11 percent). It was the general observation for vegetables marketing that as the open market prices rises intermediaries like wholesaler, retailer or assembler enjoyed larger marketing margins than as compared to the producer. In other words high open market prices increase the margin for all intermediaries in a greater magnitude as compared to farmers' margins. This situation prevails under highly price volatile market situation; such was the case of tomato marketing during 2009.

Producers' share in consumer rupee

Producers share in consumers' rupee is an important criterion to judge how efficiently the producers are being marketed in the marketing channel. Higher is the producer's share in the consumers' price implied higher is the market efficiency. Under the present study, in case of brinjal the producers' share in the consumers' price was estimated to be 44 percent and the same was 37 percent under bhindi and 26 percent under tomato As the open market prices become more volatile the higher prices are shared by the intermediaries but not transferred to the producers in same magnitude.

Marketing efficiency

Marketing efficiency of the selected commodities has been estimated by following Acharyas modified method as well as shepherd formula. Under Acharya's modified formula (Acharya and Agrawal, 2001) net price received by the farmers has been calculated by deducting transportation cost plus value of loss incurred by farmers (while transportation of commodities to the market) from the absolute price received by the farmers. Estimated marketing efficiency is an index and as the index value is high, more is the market efficiency. The marketing efficiency has been estimated as 0.79 under brinjal, 0.58 for bhindi and 0.36 for tomato marketing (Table 2). The marketing efficiency of these vegetables can be termed as poor. However this marketing efficiency is also various widely even within a day and the index value is an indicative, not an absolute way to judge the marketing efficiency.

Table 2. *Estimation of marketing efficiency* of major marketing channel*

Particular/Commodities	Brinjal	Bhindi	Tomato
Price received by farmers (FP)	900	600	500
Net Price received by farmers (NP)	820	530	410
Marketing cost (MC)	335	330	345
Marketing Margin (MM)	700	590	800
Marketing Efficiency (FP/(MC+MM)	0.79	0.58	0.36

*Acharya's modified method applied for marketing efficiency estimation for the most common marketing channel, Producer-Middleman- Wholesaler -Retailer-Consumer

Corporate entry into agricultural marketing – what does it imply?

It is always assumed that organized retail marketing channels are more efficient and also their post harvest handling is better than the traditional marketing system. The organized retailers are capable of offering better quality of commodities almost at same price as other retailers are offering. Under the traditional marketing system, the traders often add (on dipped produce into) artificial colour or additives to the commodities to increase keeping quality and make it attractive, eye-catchy to fetch higher retail price. But these additives are very often not safe for health. This calls for enforcement of stringent regulation in food safety and food quality, which is presently almost non-functional. Organized retailers handle these produce in a better way through the cool-chain system and the quality of the produce are expected to be more safe and healthy. The expectation from corporate retailers is to provide quality produce at competitive price and also to provide better prices to farmers. But these marketing channels are likely to have some implications on all levels of market functionaries, which need to be looked into carefully. Some of the implications are- (1) Organized retail marketers are sourcing the produce from various collection centers. Mostly traders/middleman bring the produce at this collection centers. Farmers who are producing commodities at a small-scale hardly can take advantage to sell directly to these retailers. Therefore, middlemen on disguise of farmers sell the produce to the retailer and enjoy the margin as like in traditional marketing system. Unless the retailer marketers will be allowed to purchase directly form the farmers (presently not happening due to various interference) or farmers are made capable (more volume) of selling their produce to these organized retailer, the producers price on consumer rupee would not be improved significantly. (2) In West Bengal almost all the producers are small-scale producer and lands are highly fragmented. In one had the retail markets are becoming consolidated and the producers are becoming further fragmented, making the non-level playing situation. Thus as the investment in these organized retail chain would be increasing, they would have more control on agricultural trading and in other hand the small-scale producers would further loose their bargaining power or in other word the marginal producers would be excluded from the advantage of the organized retail marketing system. (3) Entry of organized retailer in large scale would likely to displace large number of traders and retailers. Under West Bengal condition, large amount of unemployed persons are involved in this unorganized employment sector. Alternative employment opportunities must be created for this large number of displaced people to avoid social tension. In presence of these active middlemen and burgeoning retail investment in the agricultural commodity there would not be any real benefit to the producers' particularly. (4) The biggest advantage of organized retail marketing (as argued) is likely to be the elimination of large number of middlemen and reducing the marketing margins so to provide lower price to consumer and better price to farmers. However, the most important issue is whether the benefit of elimination of middlemen would be passed on to the producers proportionately or the retailer would enjoy the larger share of benefit only. To ensure the distribution of benefits, besides providing free and fair business environment to organized retailer also strong regulation needs to be enforced. Most importantly more number of agri-retailer has to be operative in the market so that market control should not be in the hands of only few organized retailers. (5) Organized retailers procure the commodities of specific qualities after suitable sorting and grading but farmers produce same commodity in varying quality, therefore, they need to depend on other marketing channels to dispose their rest amount of produce. Also retailers would have special interest on purchasing in bulk quantity, favouring the large producers or from some other collectors (or middlemen). (6) Corporate retail of agricultural marketing might be favourable for large farmers, farmers with large investment capacity and endowed with adequate capital adequacy. But the marginal farmers are constrained with all types of resources including financial capital, thus unless their production capacity increases, they might be again by-passed. (7) Organized retailer may offer predatory pricing to attract the consumer to eliminate the competitions or other small-scale retailers from the market. Once the market control is established the cost of predatory pricing may be passed on to the producers and they may offer below-cost pricing to the producer. For this there is again need of strong regulation from the government eliminate any exploitation. (8) Organized retail marketing would be successful model with win-win-win situation for all (producer-retailer-consumer) of free and fair marketing system if promoted through implementation of Agricultural Produce and Market Committee (APMC) Act (for detail please see Agmarknet 2010), and with stringent regulation by the government. Investment capacity of the marginal farmers must be increased. Marginal farmers' access to financial resources and other inputs such as irrigation water, seed, fertilizer etc needs to be enhanced. Finally farmers or growers association must be formed to take advantage from the organized retail marketing and to reduce the functioning of middlemen.

Way forward

Corporate entry into the agricultural marketing is inevitable and the issues can be sorted out by shouldering the responsibility by Government as well as corporate sector. Government need to reform present marketing act in favour of free and fair implementation of APMC Act and simultaneously infusion of Corporate Social Responsibility (CSR) by the private players would improve the marketing conditions of the state as well as would ensure fair price to the farmers. A Successful marketing model should have three components like offering best price, insurance coverage and finally making availability of technical know how. Government may even think for proposing some kind of base-price model or floor pricing for selling of the agri-commodities through market intervention scheme. Commissioning an arbitrator or personnel on behalf of Government may also facilitate fair pricing of agricultural produce. This will facilitate the appropriate price discoveries of agricultural produce, which is one of the biggest problems for current agricultural marketing system. Marketing efficiency of agricultural commodities can be increased significantly with certain intervention such as 1) up-scaling of the volume of produce handled, either through increase in production or through formation of self-help groups or formation of grower's association so that farmers' marketing cost reduces. 2) Improving the market functioning system particularly transparency on commission charged, 3) Integration among various markets through better transportation facilities and approach road to reduce the transportation cost. 4) Regular timely inflow of information to farmers about the prevailing wholesale market prices of commodities. 5) Providing market intelligence support to the farmers particularly on the time to grow certain crops and making availability of suitable seed/variety for crops. 6) Basic infrastructure in the market yard should be improved in a greater way so that interaction between large number of farmers and traders can be made freely.

In production side, the small-scale producers are reasonably efficient in production and the production systems were labour and input intensive, but their marketing efficiencies were poor. Alternative marketing systems or organized retail marketers are ready for entry into the agriculture retail marketing in a big way. Marketing efficiencies of organized marketing channels are high but they prefer to procure in bulk quantity, which marginal farmers cannot offer individually. Organized retailer would depend on bulk suppliers; therefore presence of middlemen would be active even in the case of organized retail marketing. So far the entry of these retail chains were not affecting the traditional agr-retailing in a significant way because their trading volume was meager in terms of total volume of fruits and vegetables traded through other wholesale markets in the state. Therefore, relationship between corporate retailing and improvement in the farmers' share in consumer rupee was not well established. Large investments from corporate houses on value addition to the agricultural produces are still awaited in the state, which would probably be beneficial for both producers and consumers. It is inevitable under the ongoing economic liberalization process, that corporate houses would increase their market share and market control over the trading agricultural commodities in future, it is also certain that marketing efficiencies through these alternative marketing channels are likely to be improved in terms of creation of value addition and reduction in transaction cost, but the most important issue is, how to include the marginal farmers category (who are dominating class and producing tiny marketable surplus from fragmented land in West Bengal) into this corporate marketing channels suitably or directly. Market economy has one unique attribute to pull the growth for those who are in advantageous position or who have better access to natural and financial capitals, but utterly excludes those who are in disadvantageous situation (like marginal farmers) or those who are not having adequate access to the resources/ inputs to produce larger quantity. The fact is that the marginal farmers operate under a host of difficult socio-economic condition in which they produce small quantity with high production efficiency but they are poor in marketing efficiency. On one hand corporate retailers are consolidating rapidly asking for bulk purchase of agri-commodities, and on other hand producers are becoming more and more fragmented and producing small quantity of marketable surplus, so farmers must be organized to increase their volume of trading to increase their bargaining power to take advantage of these marketing systems.

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Characteristic Features of Garole Sheep with Special Emphasis on Worm Infestations

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Garole sheep is reputed for multiple births and this hardy breed can thrive well in the coastal agro-climatic zone of Sundarban. They are also habituated with knee-deep grazing in water logging area with high disease resistance property. Randomly selected 250 numbers of respondents from five different blocks of Sundarban have been studied with the help of administering structured interview schedule which revealed that the coat colour of this breed is mostly creamy white and often black patches are seen in the face, belly and leg also. Distribution of the breed according to their ear size viz. rudimentary (1 to 3 cm), medium (4 to 8 cm) and long (more than 8 cm) are 16.94%, 62.81% and 20.25% respectively in ram and 11.99%, 47.08% and 40.94% respectively in case of ewe. The study also revealed that they attained 10-13 kg body weight within a year. Single, twin, triplet and quadruplet birth are estimated as 37.67%, 46.82%, 14.57% and 0.93% respectively. The age of puberty is noticed within 7-24 months of age and the length of gestation period ranges from 145-160 days. The post partum oestrus generally occurs within 60-180 days and the birth weight of the lamb varies from 0.9 –1.5 kg. Three hundred faecal samples were collected from five different blocks and tested for worm infestation. The observation revealed that 87.33% samples were positive for worm infestation. Mixed types of infection were found among the animals. Faecal sample examination revealed that 68.66%, 51.66%, 14.00%, 10.66% and 56.33% were positive for Amphistome, Strongyle, Strongyloides, Trichuris and Coccidia Oocyst respectively. No faecal sample with Fasciola infection was found.

(***Key words:*** *Garole. Litter size. Reproductive performance. Worm infestation*)

Sheep rearing in our country continues to be a backward profession, primarily in the hands of poor, landless, small and marginal farmers who possesses either an uneconomical land holding or no land at all and thus graze their sheep on natural vegetation and crop stubbles supplemented by tree looping. It plays an important role in Indian rural economy. Although sheep is having a pivotal role in rural economy, the production potentiality of Indian sheep is low due to scarcity of grazing land, disease incidence, and lack of organized efforts for genetic improvement. Most of the Indian sheep breeds have evolved naturally through adaptation to agro-ecological conditions. Garole sheep of Sundarban, West Bengal, India is one of such sheep breed, which is well adapted to harsh climate. Besides agriculture, the Sundarban farmers have the preference of rearing Garole sheep as an alternative source of income, which stabilizes their meager income from the land, based cropping system, mainly mono-cropped in nature. Garole sheep is reported for multiple births and this hardy breed can thrive well in the coastal agro-climatic zone of Sundarban.

They are also habituated with knee-dip grazing in water logging area (Ghosh et al., 1999). Due to its high prolificacy and disease tolerance, the sheep may serve a great role as subsidiary income generating avenue and may be considered as a living bank for the farmers by providing flexible financial reserves during economic stress and suffering against crop failure. The present study was carried out to find out some breed characteristics of Garole sheep and also to find out the worm infestation of naturally grazing sheep without deworming.

MATERIALS AND METHODS

The district South 24-Parganas of West Bengal, India was selected purposively. In the district, five blocks namely Joynagar-I, Joynagar-II, Mathurapur-I, Mathurapur-II and Pathar Pratima and five villages from each of the blocks were selected purposively. From each of the selected villages, 10 respondents were selected randomly. A total number of 250 respondents as the sample of present study were selected from five different blocks. Before going to final data collection, a pilot study was carried out by direct face-to-face interview and accordingly

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appropriate changes in the construction of interview schedule were made. The schedule was then finalized. Data were collected through face-to-face interview and by direct observation method. Ear length of garole sheep was measured at 10 - 12 months of age. Birth weight of lambs was documented by directly interviewing the respondents. A total of 645 lambing were considered for the calculation of birth pattern. For the purpose of faecal sample examination, 60 faecal samples from each block were collected for the present study. For this purpose faces was collected in a moisture tight container and was fixed by mixing it with 10% formalin (Anon, 1971). Faecal samples were examined for the presence of parasitic eggs through sedimentation by Gravitation method and Floatation by Levitation method by Willi's technique (Solusby, 1968).

RESULTS AND DISCUSSION

Different types of ear in garole sheep are presented in Table 1. Rudimentary, medium and long type of ears are 16.94%, 62.81% and 20.52% respectively in ram; 11.94%, 47.08% and 40.94% respectively in case of ewe.

Table also depicts that the average length of rudimentary type of ear in ram and ewe were 1.57cm and 1.88 cm respectively. Length of medium and long type of ear in ram and ewe were 6.73 cm and 6.87 cm; 6.83 cm and 9.32 cm respectively. It's evident from the table that in all the three types of ear, length is more in case of ewe than ram. This might be due to the hormonal effect. The distribution pattern of the breed according to ear size is more or less similar as was in the findings of Bose (1996).

Table-2 shows that body weight at the time of birth and 10-12 months of age varies from 0.9-1.5 kg and10-13 kg respectively. It also reveals that birth weight of male and female lamb is 1.17 kg and 0.98 kg respectively. Body weight of Garole sheep within the age group of 10-12 months are 11.39 kg and 10.88 kg in ram and ewe respectively. The difference in body weight between the two sexes of garole sheep might be due to the effect of growth hormone. Body weight of Garole sheep at the time of birth and at one year of age was slightly higher in the findings of Nimbkar *et al.*, (1998). Pan and Sahoo (2007) reported that body weight at 12 months ewe and ram were 10.37 ± 0.14 and 10.88 ± 0.14 kg which were more or less similar with the present investigation.

Multiple birth patterns of Garole sheep has been presented in the bar diagram. Single, twin, triplet and quadruplet birth are estimated as 37.67%, 46.82%, 14.57% and 0.93% respectively. Average litter size was 1.78 in the present study.

Present findings support the earlier work of Nimbkar *et al.*, (1998). According to his study the distribution of litter size was 35% single, 57% twins, 7% triplets, and 1% quadruplets, which is more or less similar in the present study. But the distribution of litter size according to Ghalsasi and Nimbkar (1993) was 9% singles, 65% twins, 21% triplets and 5% quadruplets with average litter size of 2.23 which is higher than the present study and that of Nimbkar *et al.*, (1998). These findings might indicate that the prolificacy of Garole sheep is in decline trend.

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

Type of Ear	Male (242)			Female (684)			Pooled (926)		
	Length (cm)	Number of sample	Percent	Length (cm)	Number of sample	Percent	Length (cm)	Number of sample	Percent
Rudimentary (1-3 cm)	1.57	41	16.94	1.88	82	11.94	1.78	123	13.28
Medium (4-8 cm)	6.73	152	62.81	6.87	322	47.08	6.83	474	51.19
Long (more than 8 cm)	9.32	49	20.52	9.61	280	40.94	9.57	329	35.53

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

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

Figures in the parenthesis indicate the number of samples

Table 3. *Reproductive performance of Garole Sheep*

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

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

N=300

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

Reproductive performance of Garole sheep was recorded on the basis of interview of the farmers and has been shown in Table 3. The age at puberty was within 210 - 730 days of age with an average of 272.85 days. This finding was in agreement with the findings of Mahanty and Mishra (1992) who reported that Ganjam sheep attains puberty on an average 280 ± 2.9 days and in Bolangir sheep 290±2.64 days. Average length of gestation period is 151.14 day and ranges from 145 - 160 days. Post partum oestrus generally occurs within 60-180 days. Mean post partum oestrus period is 92.36 days, which is little bit high. Delayed puberty and post partum oestrus might be due to some mineral and vitamin deficiency.

Worm infestation in naturally grazing Garole sheep has been shown in the Table 4. It was found that 87.33% faecal samples were positive for worm infestations. Mixed types of infestations were found among the animals. Table reveals that 68.66%, 51.66%, 14.00%, 10.66% and 56.33% positive cases for Amphistome, Strongyle, Strongyloides, Trichuris and Coccidia infestations respectively. From the table, it is evident that most of the naturally grazing Garole sheep are positive for Amphistome and Strongyle infestations. No faecal sample with Fasciola infestation was found. However, the present study was in full corroborative with the observation of Choudhuri (2004) where major species of GI parasites of sheep were Paramphistomes. *Trichostrongylus, Strongyloides* and *Trichuries spp.* Nwosu *et al.*, (2007) observed that nematode infestation in small ruminants of Nigeria were *Strongyles* sp. (22.5 percent), *Trichuries* sp. (5.9 percent) and *Strongyloides* sp. (4.9 percent) which was also in agreement with the findings of present study.

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Short Communication

Socio-Economic Profile and Resource Structure of Dairy Farmers in Goa State

Goa is progressing well in socio-economic front except agriculture and animal husbandry especially dairying has a stagnant growth. Half of the required amount of milk for daily consumption was drawn from the nearby states and poses critical challenges to policy makers to make it self-sufficient. Hence the study was undertaken to understand the socio-economic profile and resource structure of the Goa dairy farmers. Data was collected from crossbred and buffalo dairy farmers. The study revealed that the land area for forage crops is very much limited. The farmers are rearing animals by purchased feeds and fodders from nearby states. It was found that non-availability of crossbred milch bovines and good quality fodders were the two most important limiting factors in the study area. The investigation, in nutshell, has highlighted that to develop dairy farming into an income generating enterprise, the solution lies in improving the productivity of cattle and buffalo by artificial insemination and creating fodder bank to ensure fodder availability throughout the year.

Milk is an important livestock product for infants, growing children and adult population. Milk as a food stands as a perfect complement to cereal based diet and milk production as an enterprise with high yielding milch animals and improved technologies yield high net return to the dairy farmers. Nutrition experts and statisticians estimated that India is not producing sufficient quantities of milk to provide minimum nutritional requirements to its population. The ICMR recommends 250 g of milk per person to meet out the nutritional requirements. Goa is progressing well in socio economic front except agriculture and animal husbandry especially dairying showing a stagnant growth. Half of the required amount of milk for daily consumption was drawn from the nearby states and poses critical challenges to policy makers to make it self-sufficient. To know the limitation of milk production process in the state, the socio-economic aspects of various categories of animal keepers need to be examined (Kumar and Singh 2008). Therefore the current study focuses on the socio-economic milieu of livestock rearing and resource structure of the dairy farmers in the Goa state.

The study covered the whole state of Goa, which consists of two districts namely North Goa and South Goa. Multistage stratified sampling was used to select taluk and village. To have a homogeneous study area, both districts were selected. The data was collected from 204 dairy farms of which 132 belonged to cattle dairy farmers and 72 were buffalo dairy farmers.

The selected households were post stratified into small, medium, large in cow and small and large herd size in buffalo by applying cumulative square root frequency method (Singh 1975). In crossbred cattle, small herd consisted of 1to 4 animals unit, medium consisted of 4-8 animals unit and large herd consisted above 8 animals unit. Similarly in buffalo, small herd consisted of 1to 4 animals unit and above 4 animals were grouped under large size category. The information pertaining to demographic particulars, literacy status, farm and livestock details, farm earnings, cropping pattern, economic traits of productive animals and resource structure were analysed. Tabular analysis was used to interpret the results.

The size and composition of family are the important factors those affect the size of dairy enterprises. The overall family size of the sample households was 5.55 persons, which was on par with 2001 census data in rural households of Goa state. There was no marked difference in the family size between small and medium herd size categories, but the size of family was large (6.5) on large herd category.

In buffalo herd, the overall size of family was 5.91. The small herd had 5.21 persons and large herd as 6.22 persons respectively in their family. The average number of adult member was 2.35, which were comparatively lesser than average number of children in small herd category. However, it was reverse in case of large herd category.

The ability to take effective managerial decision depends upon the level of education of the head of the household. In general, it was observed that about 60 % of head of the families were having formal education and more than 40% studied up to matriculation and above in cattle herd. The illiteracy level had decreased and the percentage of those who had studied beyond matriculation level increased with the increase in herd size. It may be due to their economic status. Overall, the education status of the head of the family belonging to buffalo herd was 51.40 %.

Dairying was occupation in all categories of herd. The small, medium and large herd has 70, 93 and 80% respectively. The overall average was 81% and other source of income such as agriculture, service and business was only 19% (Baruah et al., 1996). The same trend was observed in the occupation pattern of buffalo dairy farmers.

The study was confined to the crossbred cow and buffalo. The crossbred cattle maintained were grouped into 4 types of crosses namely, Holstein Friesian, Jersey, Red Sindhi and miscellaneous crosses (Sudheer *et al.*,1999).

Age at which the first calf is born has great economic significance for dairy cattle keepers. The average age at first calving was 34 months for crossbred and it differed significantly among herd size. The lowest age at first calving was observed in large herd size 32 months followed by medium and small herd. The statistical result was also same for all sizes of the herd.

For an economic cattle keeping, it has been suggested that an animal should calve regularly, preferably once in every year, with dry period of about 60 days. The average lactation length was 300, 300 and 295 days and inter calving period was 400, 390 and 370 days for small, medium and large herd respectively (Sharma and Singh 1994). The comparison of these parameters among the herd size categories revealed that lactation length was more or less similar in all categories, while dry period and inter calving period were considerably longer in small herd. Interestingly, the dry period was observed to be the shortest for the large herd. In buffalo the average lactation length was 305 days, which was slightly higher than crossbred cow, but the dry period and inter calving period were considerably longer. (Dev *et al.*, 2009).

The total investment of animals, cattle sheds and stores and other dairy equipment by the dairy farmers according to type and various herd size category were presented. Investment on crossbred cattle constituted the major component followed by cattle housing and dairy equipment. Out of total investment Rs. 1.23 lakhs for cattle herd 66.3% was for cows, 28.5% for shed and 5.2 % for dairy equipments. Small herd had invested Rs.36,756/- and medium herd had a total investment of Rs.79,388/-. Highest investment was found in large herd to the extent of Rs. 2.53 lakhs (Siwach *et al.*, 1994). The investment on housing for small herd was 31.4% followed by large herd 28.8% and medium herd 26.2%. The investment on dairy equipment was negligible and constituted 3.7, 4.6 and 5.6 % of total investment by small medium and large herd respectively.

The total investment for buffalo herd was comparatively lesser than cowherd. The overall investment for buffalo dairy farm was Rs. 46,653/-. The small and large buffalo herd had invested Rs. 24,357/- and Rs.68,950/- respectively. Value of animal and shelter constituted 98% of total investment. Very meagre percentage was invested for equipments etc.

The value of animals maintained by large herd size category was generally higher followed by medium and small herd size category. The increase in the value of the animals according to herd size category has also been reflected in the increase in milk production per animal per day.

The resource structure revealed that grazing pressure in these areas is much higher than the recommended value of 2 ACUs/ha (Katoch, 1996). Due to unawareness, villagers do not attach importance to aspects like carrying capacity and nutritional status. Villagers were not using efficiently tree leaf of forest resources available in the states. At the end of winter and during summer the availability of green fodder is scarce. Overall the resource structure revealed that non-availability of improved crossbred milch bovines and good quality fodders were the two most important constraints in the study area as a profitable venture.

The investigation, in nutshell highlighted that the solution lies in improving the productivity of cattle and buffaloes by artificial insemination and creating fodder bank to ensure fodder availability is essential for dairy industry in the Goa state.

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J. Indian Soc. Coastal agric. Res., 29(1), 106-109, 2011 **Short Communication**

Alien Flora into the Fragile Ecosystem of Andaman and Nicobar Islands - A Major Concern

The Andaman and Nicobar group of (A and N) Islands epitomize a diverse bio-geographic zone characterized by rich heritage of biological wealth. These Islands are very far from any part of mainland and developed its own flora by evolution and also gathered flora of South East Asia. The insular flora of A and N Islands consisting of about 2574 species belonging to 219 families and 1046 genus within a land area of 8249 km^2 on 572 Islands and islets is a momentous feature, making them a cynosure not only for plant taxonomists but also for conservationists. The rare and distinct flora, which evolved through millions of years due to the insular nature of the territory, physical isolation between the Islands and also from the neighboring continental landmasses, is unique in India. There are 316 indigenous plant species (Pandey and Diwakar, 2008), out of which 130 species were entered in the red data book (Rao *et al.*, 2003). Therefore utmost care should be taken to save these from invasive plant species. There are many wild relatives of horticulturally important species, out of which 12 species are found endemic. Tribes of these Islands also use around 231 plant species as flock medicines.

The A and N Islands possess an apparently uniform tropical humid and warm climate, showing considerable variation in the biodiversity and vegetation patterns. According to Island biogeography mode that is based on species-area relationship (Mac Arthur and Wilson, 1967) the number and nature of species in an Island ecosystem depends upon its area and distance from the mainland. Smaller animals and small seeded plant species mainly dominate islands far away from mainland, while larger animals and plant species dominate Islands closer to mainland. However exact form of species area relationship can be accurately described by formula given by Mac Arthur and Wilson (1967).

$S = CAZ$

Where S = Number of species on an Island, A = Area of Island, C and Z = Constants

Introductions of plant species by humans can be described as either intentional or accidental. Intentional introductions have been motivated by individuals or groups who believe that the newly introduced species will be in some way beneficial to humans in its new location. Unintentional or accidental introductions are most often a byproduct of human movements, and are thus unbound to human motivations. An introduced species might become invasive if it can out- compete native species for resources such as nutrients, light, physical space, water or food. Invasive species often coexist with native species for an extended time and gradually the superior competitive ability of an invasive species become apparent when its population grows larger and denser often after it adapts to its new location. Normally an introduced species must survive at low population densities before it becomes invasive in a new location. At low population densities, it is often difficult for the introduced species to reproduce and maintain it self in a new location, but often due to human actions a species might be transported to a location a number of times before it become established. Repeated patterns of human movement from one location to another, such as ships sailing to and from ports or cars driving up and down highways, allow few species to have multiple opportunities for establishment. Ever since the time of Darwin and Wallace, Islands have been recognized as natural laboratories for the study of evolution and plant species diversity and adaptation.

The assumption that an Island of given size can support only a limited number of species and that when this "saturation point" has been reached further colonization must be balanced by extinction of some species. Forest species which are generally highly heterozygous in nature required a specific number of plants on a given Islands to maintain its heterozygosity and vigor. If this number is affected their survival on the small Islands is doubtful.

All the literature available of Flora of A and N Islands were scrutinized for introduced species time to time. The present paper deals with 592 introduced or non-indigenous plant species of crops, weeds and other flora belonging to 99 families and 379 genera was introduced into this Islands. These were classified as number of available herbs, shrubs, trees and climbers in each family. Important species caused damage to the indigenous species were discussed. Indirect effect of the bio-recycle of forest products, extraction of economically important species ruthlessly and their effect, cultivation of rice in reserve forest close to National park and its effect on indigenous plants also pointed out in this paper.

It has been observed (Pandey and Diwakar, 2008; Mohanraj, *et al.*, 1999; Dagar and Singh, 1999; Awasthi and Jacob, 1987; Balakrishnan and Rao, 1984) that maximum number of genera (30) of family Poaceae followed by genera (24) of family Fabaceae, genera (21) of family Asteraceae and genera (13) of family Acanthaceae are introduced into these Islands. Maximum 41 number of species of the family Poaceae, followed by 37 species of family Fabaceae, 31 species of family Euphorbiaceae, 25 species of family Araceae, 24 species of family Asteraceae were introduced.

Forty-one herbs of family Poaceae followed by 21 herbs of family Asteraceae and Fabaceae and 16 herbs of family Araceae were the largest among the introduced herbs. Maximum 16 shrubs of family Euphorbiaceae followed by 12 shrubs of family Acanthaceae and 11 shrubs of family Rubiaceae are introduced. In the tree category, 13 trees of family Caesalpiniaceae, followed by 12 trees of family Arecaceae is the largest number. Among the climbers as there are large number of vegetables, 12 climbers of family Cucurbitaceae followed by 9 climbers of family Fabaceae and 7 climbers of Araceae and Convolvulaceae are introduced into these Islands.

The insular nature of territory of A and N Islands, chiefly characterized by high humidity and rainfall around eight months of a year. Due to very highly humidity and rainfall this Island is immensevely rich in genetic diversity of tropical flora and fauna. Out of 572 Islands only flora of south Andaman and Car Nicobar have been studied in great details. However in other parts of A and N Island flora is being studied by different botanist at different time frame.

Some species that are intentionally introduced for example agricultural crops, fodder and timber plants may escape from the captive or cultivated populations and subsequently establish independent breeding populations. Some weeds like *Parthenium hysterophorus* (congress weed), *Mikania cordata, Eichhornia crassipes* (water hyacinth) that was introduced as recreational flora have now become a invasive threat found growing at an alarming rate. Oil palm which was introduced in early 1960 is also spreading in these Islands and occupies some prime areas and may affect the local tropical palms. Increasing rate of human travel, natural calamities etc. are providing accelerating opportunities for species to be accidentally transported into areas in which they are not considered native. Abiotic factors like wind and water are equally responsible for the transport of plant seeds to distant Islands. Introduction or invasion of such large number of species into these Island ecosystems with special reference to small Islands and islets will cause genetic erosion of native species as their habitat will be populated with these introduced species. These species may also become a carrier of pest which will affect the native species, which might not have tolerance to the new pest. Root crops like *Manihot esculenta* (tapioca), *Zingiber officinale* (ginger), *Ipomoea batatas* (sweet potato) were introduced into these Islands and were cultivated on hill slopes. These crops are harvested during summer and the dug out soil get eroded causing soil loss along with nutrients. One or two crops like this will make the top soil unfertile and crops and local species will also get damaged. The soil will erode along with rain water and block the coral reef area as well as other habitat of local species. Among plant species rates of out crossing (interbreeding with other individuals of the same species, as opposed to self pollination) appears to be higher in tropical plant species than in temperate once (Bawa, 1992). Higher rates of out crossing may lead to higher level of genetic variability, local adaptation and speciation. Introduced species carrying the inoculum of the disease or the insect pests will be always present in the microenvironment and may cause damage to the local species. The bird population which affect the dispersal of forests flora seeds is also getting reduced because of indiscriminate pesticide use and other natural disaster like *Tsunami*. Most of the extinction of birds during the last 350 years have occurred on Islands (King, 1985) and at least 90% of the endemic plants of oceanic Islands are extinct or in danger of extinction. Many species of forests completely depend on birds for their seed dispersal. Important species like *Momordica cochinchinensis* requires a bird's gut passing of its seeds for germination. Successful survival of a plant species in a new geographical area is affected by many factors like climatic, soil profile, competition, and genetic factors of that plant (Spielman, *et al.*, 2004). Among these factors competition plays very important role in the survival and success of introduced flora in the new habitat. According to

Charles Darwin every organism has capability to produce maximum number of offspring's for success in competition and for survival in the nature. Thus the introduced species produces maximum number of seeds and other reproductive bodies for retaining identity of its species.

Thousands of species are going extinct as a result of human activities. The highest species extinction rates during historic times have occurred on Island ecosystems as reported by IUCN, 1998, Reid and Miller, 1989. Wherever major extraction activities have taken place, large numbers of people were brought as forest labor got themselves settled and started cultivation of rice. The cultivation of rice starts with puddling of the land in the heavy rain period, which in turn discharges large amount of soil during the heavy rains. This flows to the sea affecting coral reefs. A typical example is Rutland in South Andaman. This Rutland Island is having most of the species suppose to be present in southern groups of Islands and because of human activities, plant and other species extinction is happening at an alarming rate. Island species are particularly vulnerable to extinction because many of them are endemic and mainly through habitat destruction. Island species have usually evolved and undergone speciation with reduced level of competition, predation and threat of diseases. In contrast, competition, predation and disease competitiveness in species from mainland are introduced in these Islands. They decimate the Island species, which have not evolved any defense against them. Humans have radically altered this pattern by transporting species throughout the world. In pre-industrial times, people carried cultivated plants and domestic animals from place to place as they set up new farming areas and colonies. In modern times a vast array of species has been introduced deliberately and accidentally into the areas where they are not native (Mooney and Drake, 1986). The control of introduced or invasive species can involve their eradication or their containment within a specified area. This can be done either by mechanical removal of plants or by using chemicals like herbicides to kill these invasive plants. While the former method is labor intensive and requires a large time investment, as treatments must often be applied several times to ensure success and the latter is dangerous, as the chemicals lack target specificity and kills desirable plant species. A new approach of biological control can be applied with proper research. This method is both environmentally safe and successful. Preventing the establishment of introduced or invasive species is always the best method of control. Stopping harmful species at this stage can be difficult. Many governments try to limit the entry of invasive species into their lands with thorough inspections of international shipments, customs checks, and proper quarantine regulations. The creation of a list of safe and potentially harmful species can be helpful in regulation. This has to be carried out in these Islands also. The general public can also participate in invasive species prevention by educating themselves about invasive species and by making informed decisions.

Long term monitoring of ecosystem processes (temperature, rainfall, humidity, soil acidity, water quality, discharge rates of streams, soil erosion etc.), communities (species present, amount of vegetative cover, amount of biomass present at each tropic level) and population number (number of individuals present in a particular species) is necessary to protect biological diversity since it is otherwise difficult to distinguish normal year to year fluctuations from long term trends (Magnusan, 1990). For example, many amphibians, insects and annual plant populations are highly variable from year to year. So many years of data are required to know whether a particular species is actually declining in abundance over time or merely experience in a number of low population years that are increased with its regular pattern of variation. Therefore long-term research sites should be established and monitored for conservation. A mega project on these lines has to be planned and executed without loosing any further time. Year marking the Islands on their floral diversity, size specific, location specific and geological factors should be taken under consideration for these studies.

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Short title: It is to be given at the top of the first page of the manuscript and should not exceed 40 characters in 12pt. (Times New Roman) in Sentence case as: 'Saline water use'. The short title should indicate the topic in a most concise form.

Title: Except for prepositions, conjunctions, pronouns and articles the first letter of each word should be in capital letter, bold, 14 pt. (Times New Roman) single space, centre alignment as: 'Evaluation of Rice Varieties for Salt Affected Soils'.

Name of the Author(s): Upper case, 12 pt. (Times New Roman), centre alignment, Single space as: 'B. MANDAL*, A. R. BAL, D. PAL and P. E. SINGARE'. Put an asterisk mark superscripted on the name of the corresponding author and give his e-mail id as a footnote. In case any author (s) has left the Institute where the work was conducted his address should be indicated in the footnote with a superscript number on the name of the author as: 'D. BURMAN*, C. KARPAGAM[1], S. MANDAL and D. ROY'

Institute Address: The address of the Institute where the work was conducted to be given in full with PIN code number. Except for prepositions, conjunctions, pronouns and articles the first letter of each word should be in capital letter, 12 pt. (Times New Roman) single space, centre alignment as: 'Central Soil Salinity Research Institute, Karnal, Haryana-132001'

Abstract: The Abstract should be concise and not to exceed 300 words. It is to be without heading (centre alignment), 12 pt. (Times new Roman), justified alignment, double space. Do not mention any Reference, Figures, Tables and abbreviations in the text of the Abstract.

Key words: To be given in bracket, italics (Title in bold but words are normal), each item starts with a capital letter and items are separated by a coma, 12 pt. (Times New Roman), justified alignment, double space as: '(***Key words:*** *Copper fungicides, Movement of copper, Iron deficiency)*'

Introduction: Without formal heading, text in 12 pt. (Times New Roman), justified alignment, double space

Materials and Methods: Heading in 14pt (Times New Roman) centre alignment, bold as: '**Materials and Methods**'. Text: double space, 12 pt. (Times New Roman), justified alignment.

Results and Discussions: Heading in 14pt (Times New Roman), centre alignment, bold as: '**Results and Discussions**'. Text: Double space, 12 pt. (Times New Roman), justified alignment. In text, the tables to be referred as Table 1 or (Table 1) and Figures as Fig. 1 or (Fig. 1) as the case may be.

Table title: Title of the Table to be in italics and placed at the top of the Table. The Table number to be given in bold (italics) with a space as: '***Table 3****. Characteristics of the soil profiles*'.

Each Table should be typed in separate sheet. Maximum size of a Table should be such that it can be conveniently accommodated in a A4 size paper. Over-sized Tables will be rejected. Approximate position of the Tables in the text to be indicated on the margin of the manuscript.

Figure: Figures include diagrams and photographs. Title of the Figure to be in italics and placed at the bottom of the Figure. The Fig. number to be given in bold (italics) with a space as: '***Fig. 3****. Salinity of groundwater in different months*'.

Laser print outs of the diagrams are acceptable but not the dot-matrix print outs. Alternatively, each illustration can be drawn on white art paper or tracing paper using proper stencil so that it can be reduced to accommodate in the single column in the Journal page. Figures with free hand drawing or free hand writing will be rejected. Legends if any should be included within the illustration but the title of the figure should be at the outside of the illustration. The name of the authors and the title of the article should be written well below the illustration for identification. One set of original figure along with its soft copy must be submitted along with the manuscript.

Only Black and white photographs are accepted. Two hard copies of the photograph along with a soft copy in digital form are to be submitted.

References: Heading in 14pt (Times New Roman, centre alignment), bold as: '**References**'. The text/ citations should be in 12 pt. (Times New Roman), double space and left alignment. The style of citing different categories of literature is given below.

Journal articles: Abbreviations of periodicals are not acceptable. Fully expanded name of the Journal is to be given and volume number be bold as: Sen, H. S., Mandal, A. B. and Mahanta, K. K. (2007). Characteristics of salt tolerant rice varieties for the coastal region. *Journal of the Indian Society of Coastal Agricultural Research* **25**: 45-52.

Citing reference in the running text: As : 'It was observed by Biswas and Prasad(2008) that......; Similar results were also reported by others (Panigrahi *et al.*, 2006; Dutt and Polara, 2004)' as the case may be.

Books: As: (i)Russel, E.W. (1973).*Soil Conditions and Plant Growth*, Tenth edition, The English Language Book Society and Longman, London. 848 p. (ii) Biswas, T. D. and Mukherjee, S. K. (1989). *Text Book of Soil Science*, Second edition, Tata McGraw-Hill Publishing Company Limited, New Delhi. pp 90- 152.

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, Ganning 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.

Symposium Proceedings: As: Pampattiwar, P. S. and Mane, T.A. (1983). Evaluation of sprinkler method of irrigation for summer groundnut, Proceedings National Seminar on *Evaluation of sprinkler irrigation*, Indian Society of Agricultural Engineers, January 2-5, 2008, Engineering Staff College, Pune, Maharastra, India. pp 88-95.

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.