LOWLAND RICE IN COASTAL SALINE SOILS – A REVIEW

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ABSTRACT

In India, the coastal areas have lagged behind in production owing to the fragility of the ecosystem and presence of various constraints thereby suffering from lower productivity with slow positive trend in the growth rate in comparison to several inland areas. Salinity coupled with flooding promotes the cultivation of traditional rice varieties that are tolerant to both submergence and salinity. The use of amendments viz., organic and inorganics enhances the yield as the amendments in addition to the supply of nutrients, improves the soil physical conditions and provides a buffering action against adverse soil conditions. The type of amendment may depend on the cost, availability and quantity. The materials available locally and crop wastes can be used effectively for reclamation. The present review was aimed to examine the impact of amendments and management practices on rice growth and grain yield to enhance rice yield under lowland ecosystems in the coastal saline environment by adoption of better management strategies.

In India, about 7 m. ha of land is considered as saline soils and about 30 per cent of it is in the coastal regions (Yadav et al., 1983). The coastal tract spread over several states along more than 7000 km and is endowed with a wide variety of soils, climatic conditions and physiographic features. The coastal zone ecosystems are highly productive and fragile. This ecosystem is characterized by sea water intrusion, low lying water logged areas, flood prone and ill drained lands. Soil salinity is present in several coastal areas and it hampers crop production particularly in the post rainy season. In this ecosystem, soil salinity is caused primarily by the tidal effects and intrusion of sea water. In the east coast, rice cultivation contributes to two-thirds of the total rice area in India that is cultivated under diverse conditions.

Rice is one of the crops ideally suited for cultivation under coastal saline environments. Productivity of rice yield is relatively lower in these regions due to adverse conditions of soil and climate. The use of improved cultivation practices such as suitable genotypes with higher yield potential and management practices together contribute to higher productivity.

Saline soils: Salinity is one of the major constraints that cause serious hazards in agriculture thereby limiting agricultural productivity. All over the world, millions of hectares of land are affected by salinity and sodicity and the area is expanding year after year because of salt accumulation. The problem of salinity has become a serious agricultural concern in arid zones where rainfall is not sufficient to leach down salts from the plant root zone. In India, 8.3 m. ha of land has been affected by the accumulation of soluble salts and utilization of these salt affected soils by reclaiming can lead to additional production of 35-50 m tonnes every year as reported by Lal et al. (2003).

Sadana (2002) reported that in India, a potential area of 20 m. ha of land is affected by varying degrees of salinity or sodicity or both of which 7 m. ha are seriously affected by salinity. The saline soils are characterized with a saturated extract conductivity of more than 4 m mhos cm⁻¹, pH of less than 8.5 and Exchangeable sodium percentage (ESP) of less than 15 per cent (U.S. Salinity Laboratory, 1954). Chlorides and sulphates of sodium, calcium and magnesium are the dominant salts present in saline soil. Besides these, smaller amount of potassium salts

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and bicarbonates and nitrates are also present in the soil (Das, 1993). Mishra (1995) observed that rice is the most preferred and adapted than any other crop for salt affected soils because of the inherent genetic mechanism for salinity tolerance.

Coastal saline soils: Saline lands may be further classified as inland saline and coastal saline soils. The salinity status of the soil fluctuates with seasonal variation (Yadav et al., 1983). The coastal saline soils in India may broadly be classified into two physiographic groups viz., the coastal soils of East coast i.e., along the sea coast of the Bay of Bengal and coastal soils of West coast i.e., along the sea coast of the Arabian Sea. These soils occur in river deltas and in narrow strips of land ranging from a few kilometers to about 50 km close to the sea coast along the low lying lands, estuaries and inland depressions (Yadav, 1979).

Bandyopadhyay et al. (1987) observed that coastal saline soils are characterized by clay loam either along with silt or sand with E.C. ranging from 0.5 to 9.2 and with sodium as dominating salts. Biswas et al. (1990) observed that coastal saline soils generally have highly saline shallow underground water table with gradual upward movement of saline water during summer months and subsequent evaporation of the water that contributes to soil salinity during dry periods. Salinity is one of the major obstacles to high yields in deltas, estuaries and coastal fringes in the humid tropics. It is a serious impediment to growth of irrigated rice (Ponnampenuna, 1972).

In the coastal areas, the excess rainfall during monsoon cause flooding and deep water submergence leading to enormous nutrient losses and low crop yields (Yadav, 1996). Biswas and Bhattacharya (1987) observed that salinity is the major limiting factor towards increasing productivity in coastal soils. Kothandaraman (1987) reported that rice is grown as a major crop in most of the coastal areas during the North East monsoon season. Agarwal (1983) observed that in coastal saline soils, the problem is further complicated by inundation through backwash from sea, tidal waters, wind borne salts and underground intrusion of sea water in sub soils. The salinity of the soil varies with the season. It reaches the maximum between January and May and decreases thereafter with the onset of monsoon (Bandyopadhyay and Bandyopadhyay, 1984). This cyclic salt accumulation and intermittent flood make these regions predominant in rice cultivation.

Salinity on growth and yield of crops: Salinity has an adverse effect on growth and yield of plants. Dagar (1996) found that the presence of excess salts hampers plant growth in various ways such as effect on physiological processes and uptake of nutrients and water. Soil salinity influenced plant growth by creating water imbalance in the plant and ionic imbalance due to the presence of toxic ions. Salt affected plants exhibit stunted growth and have darker leaf colour. The root growth is less affected than shoot growth and the root to shoot growth increases as observed by Munns (2003). The root length decreased with the increase in salinity CSSRI (2002).

Sharma (1995) found that high soil salinity is one of the most important constraints of rice production in developing countries. Yoshida (1981) observed that under salinity stress, the growth of rice is influenced by many factors such as salinity level, nature of salt, duration and exposure of salinity, pH of the substrate and stage of development of the crop. Govindaraju and Balakrishnan (2002) reported that plant height, number of productive tillers per hill and 1000 grain weight were significantly decreased with increasing salinity level leading to the substantial reduction in grain yield of rice. In the chlorophyll content of rice, it was observed that both chlorophyll a and chlorophyll b content
decreased with soil salinity and chlorophyll b was more sensitive than chlorophyll a and the decrease was substantially higher than decrease in chlorophyll a content (Djanaguiraman et al., 2004).

There was about 50 per cent reduction in the shoot biomass of rice grown under salinized conditions (Poss et al., 2004). Khan et al. (1991) observed a significant reduction in yield attributes viz., number of panicles, panicle length, number of spikelets panicle\(^{-1}\), filled grain percentage and 1000 grain weight and grain yield plant\(^{-1}\) under saline conditions. Choi et al. (2003) reported that in medium saline soils, the panicle number per unit area and percentage of filled grains decreased drastically. Djanaguiraman et al. (2004) found that there was a general trend of decrease in root length, shoot length and germination percentage with increase in salt content in rice rhizosphere. Nitrogen application in the form of urea alone was the best to increase the growth of the seedlings by reducing the adverse effect of salinity in saline soils (Gill and Singh, 1992). Zaman et al. (1995) observed that panicle number, spikelet number and 1000 grain weight decreased with increase in salinity.

**Salinity and nutrient uptake**:

In wheat, application of zinc to saline soils increased the dry matter yield and produced maximum yield when Zn was applied along with recommended dose of NPK (Dar et al., 2004). Singaravel et al. (1996) reported that coastal saline soils had low organic matter content and the soils were poor in nitrogen status. In coastal saline soils, it was found that the amount of Zn available to the plants decreased with submergence (Maji and Bandyopadhyay, 1990). Chloride salinity caused more inhibition in the uptake of essential macronutrients such as nitrogen and potassium and relatively more accumulation of toxic salts in the plant parts in wheat (Sharma et al., 1994). Pandey and Saxena (1987) found that salinity caused significant reduction in the potassium content of plants as compared to those of normal soils in different rice varieties.

**Reclamation of saline soils**: Saline soils can successfully be cultivated by removing excessive soluble salts through reclamation techniques. Reclamation of saline soils depends on the local conditions, available resources and the kind of crops that can be grown during reclamation. Reclamation can be accomplished in the long run by continued irrigation and cropping, inclusion of rice in cropping system together with incorporation of large quantities of organic manure (Gupta and Abrol, 1990). Reclamation of saline soils is by reducing the soil salinity to acceptable levels. In saline soils, maintenance of crop productivity at optimum level requires consideration of salt distribution within root zones that is influenced by the water extraction pattern of the crop, the method of water application, soil profile modifications, mulching, rain water leaching and adoption of an appropriate crop rotation involving salt tolerant cultivars (U.S. Salinity Laboratory, 1954).

**Management practices**

**Salt tolerant crop (Lowland rice)**: Rice is relatively tolerant to salinity compared to other field crops. Being moderately salt tolerant, rice is being recommended for cultivation during the reclamation of salt affected soil (Hassan et al., 2001). After submergence the soil pH is reduced throughout the crop growth. Abrol and Bhumbla (1971) found rice to have high levels of tolerance and the yield of rice was higher compared to other crops in salt affected soils. Maas (1998) classified plants according to their salt tolerance and reported that rice tolerates up to an E.C. of 3 dS m\(^{-1}\) without yield loss and 50 per cent of yield was reduced when E.C. exceeded 7.2 dS m\(^{-1}\). Bandyopadhyay and Bandyopadhyay (1984) revealed that in the coastal saline soils of West Bengal, rice was the only crop grown throughout the region in Kharif season due to soil salinity tolerance and resistance to submergence due to flooding. In coastal saline

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soils, the land gets frequently inundated with saline sea water and with the onset of monsoon, salinity decreases making rice cultivation possible in the wet season (Biswas et al., 1990). Kothandaraman (1987) observed that in the coastal areas of Tamil Nadu, rice is the dominant crop cultivated in many districts of the state. Gupta and Singh (1988) found that rice culture releases abundant CO2 that causes a reduction of soil pH and exchangeable sodium content through mobilization of carbonates.

**Leaching** : As a hydro-technical method of reclamation, leaching is the removal of soluble salts beyond the root zone, especially in shallow rooted crops. The amount of water used for reclamation of saline soils depends on degree of soil salinity, quality of irrigation water, the soil depth to be reclaimed and the water application techniques. Minhas and Khosla (1986) demonstrated that intermittent ponding did not result in saving of water for leaching of salt under high evaporative demand conditions. Ramkrishnan (1985) reported that leaching for rice increased the grain yield by 8.6 per cent in sown crop and by 6.9 per cent in transplanted crop over no drainage but the increase was not statistically significant.

Aich et al. (1996) observed that the grain yield of rice increased under leaching as compared to no leaching treatment. The process of leaching was successful in the cyclone affected areas of Orissa and the salt concentration was brought down to permissible limits in the quickest time thus making it possible to obtain normal yield of rice in the first year of reclamation itself (Rao et al., 1994). Thiripú et al. (1987) observed that the saline soils saturated with salts can be brought under plough after two years of leaching after cutting off the saline water. Keller and Al-Farraj (1966) revealed that continuous ponding has generally been recognized as the most practicable means of reclaiming soils and under irrigated conditions, leaching is done by allowing excess water to pass through the soil profile.

Sharma and Khosla (1984) observed leaching to remove excess salts was the first step towards reclamation of salt affected soils. Leaching reduced the original salt content of the soil layer by 65-90 per cent during reclamation of saline soils (Raj and Nath, 1984). Leaching requirement varied from 0.30 to 4.43 cm of water per cm of soil depth and that requirement varied with soil types (Minhas and Khosla, 1986).

Leaching is an inevitable process for reclamation and leaching behaviour and efficiency differ with ground water depth and soil physical characteristics (Kuligod et al., 2000). Gupta (1992) found that the amount of water required for reclaiming one cm of soil under field condition varied between 0.30 and 2.58 cm with continuous leaching.

**Effect of amendments** : Various amendments like gypsum, sulphur and organic manures like farm yard manure, pressmud, green leaf manures etc, can be used for amelioration of saline soils (Sharma et al., 1996). Prasad et al. (1983) observed that soil amendments influenced the physical properties and counteracted the deleterious effect of the bulk density.

**Gypsum** : Being easily and available and cheap source of calcium, gypsum is commonly used for amelioration of saline and saline-sodic soil. Singh et al. (1981) reported that surface application of gypsum @ 25 or 50% GR before transplanting of rice gave higher grain yield in a saline-sodic soil. Siddique et al. (1988) investigated that effect of gypsum @ 75% GR and 67 kg ha-1 fertilizer application gave maximum yield of rice and followed 50% GR treatment at same fertilizer dose on saline sodic soil. Patel and Goswami (1995) observed that the application of amendments such as gypsum and farm yard manure reduced the soil pH in the coastal saline soils. Babu et al. (2001) reported that combined application of gypsum, pressmud and FYM recorded the highest rice yield in a saline-sodic soil.
Organic amendments: Organic amendments are the important source for the reclamation and restoration of the physical condition of the soil. The organic acids secreted from these materials reduce the pH of the soil and provide several nutrients to the soil (Chhipa and Lal, 2003). In problem soils, organic and inorganic amendments were found to reduce the soil pH and improve the soil carbon content and other chemical properties of the soil (Duraisamy et al., 1986; Verma and Gupta, 1985; Kumar et al., 1991). Swarup (1992) reported that addition of organic manures influenced the soil pH, Exchangeable Sodium Percentage (ESP) and supplied macro and micro nutrients. The organic amendments reduced erosion hazards, increased the availability of nutrients, reduced losses of nutrients and in turn increased the soil fertility (Selvakumari et al., 1993). Sharma and Mittra (1992) observed that the crop uptake improved phenomenally with the addition of amendments viz., farmyard manure and farmyard manure.

Combined application of organic amendments like farmyard manure and tank silt increased the availability of nitrogen, phosphorus, potassium and the organic carbon content (Subburaj and Ramaswami, 1994). Organic amendments in combination with N, P and K increased the growth attributes of rice (Kadu et al., 1991). Application of farmyard manure @ 5 to 10 t ha\(^{-1}\) increased the productivity and sustainability of yield under coarse textured soils (Panda and Sahoo, 1989; Mathew et al., 1993). Sheeba and Kumarasamy, (2001) found that the organic carbon content was higher in manure applied plots 1.27, 1.06, 1.33 and 0.75 per cent, respectively, in farmyard manure, urban compost and in control plots in rice cultivated under lowland conditions.

Farm yard manure: Farmyard manure is especially beneficial as it improves soil physical structure and provides nutrients for plants. It has been reported that the use of acid or acid forming material including organic matter is likely to improve the soil by solubilizing calcium from the calcium carbonate present in the soil (Verma and Abrol, 1980). Sharma et al., (2000) reported that organic manures were effective in increasing yield and good physical condition of the soil.

Sharma (1997) reported that the application of farmyard manure alone or in combination with inorganic amendments increased the grain yield of wheat and rice in salt affected soils, but rice was more tolerant to salinity than wheat. Tomar et al. (1992) revealed that in a rice-wheat cropping system, application of farmyard manure alone or rice husk at 5 t ha\(^{-1}\) to transplanted rice increased the yield of both crops by maintaining soil physical properties. Bandyapadhyay and Bandyapadhyay (1984) reported that the application of farmyard manure was found to produce higher yield of rice in coastal saline soils than normal fertilizers alone. Higher doses of farmyard manure were however required as the rate of mineralization is slower. Kulkami and Kulkami (1982) observed that in rice-wheat system in saline soils, farmyard manure alone produced no beneficial effect but in combination with NPK fertilizers produced higher yield than use of chemical fertilizers alone. The combined application of phosphorus fertilizer and farmyard manure had contributed to the build up of phosphorus status of the soil (Singh and Sarkar, 1992).

Dutta et al. (2003) found that the inclusion of farmyard manure, in rice - prawn agro-eco-system in low lying waterlogged conditions of coastal saline zones, was beneficial for improvement of the total productivity of rice. Keshwa and Singh (1992) observed that in wheat cultivated under saline conditions, farmyard manure at 25 t ha\(^{-1}\) was comparable with gypsum and pyrite application and the yields were higher than control. Farmyard manure
application to rice was found to increase the uptake of nitrogen, phosphorus and potassium and was superior to nitrogen uptake from application of wheat straw (Kumar et al., 2003).

Arokiaraj (1988) observed that application of farm yard manure in saline soil increased yield parameters such as productive tillers m², weight of panicle, number of filled grains and there was an increase in grain yield by 17.7 per cent over no organic amendment. Ali et al. (1974) and Ramaswami and Kothanackaraman (1985) have shown a build up of total nitrogen and nutrient availability due to organic amendments. Amendments with farm yard manure increased the availability of nutrients and reduced N losses due to the formation of organo mineral complexes (Yoshida and Padre, 1976; Singh et al., 1981). Mahimairaja and Mayalagu (1986) observed that farm yard manure application increased both the grain yield and straw yield of rice. Farm yard manure with recommended 100 per cent NPK in saline soil gave the highest grain yield (5.16 t ha⁻¹) over control (4.28 t ha⁻¹) and the application of farm yard manure contributed to yield up to 50 per cent of the recommended NPK in rice (Singh et al., 2000). Vanathi and Mohamed Amanullah (2007) observed that application of FYM at 12.5 t ha⁻¹ along with recommended NPK recorded the highest rice yield of 4.72 t ha⁻¹ in coastal saline soil.

**Green leaf manure:** Green manuring and green leaf manuring are used as amendments in saline soils. It increases the nitrogen content, phosphorus availability and organic carbon status, reduces high pH and improves general physical and chemical condition of the soil (Dargan et al., 1982). Mani et al. (1993) found that in saline-sodic soils, application of green leaf manure Delonix eleaata at 5 t ha⁻¹ along with inorganic amendment gypsum and 25 kg MgSO₄ produced the highest grain yield of rice. Jeyaraj (1991) observed that application of Leucaena leucocephala as green leaf manure in saline soil significantly increased the growth characters of rice such as plant height and total number of tillers per hill. Aruna et al. (1999) reported that in rice, green leaf manuring with Pongamia glabra in combination with gypsum produced higher NH₄-N during mineralization for plant uptake and favourable effect on soil structure and microbial growth that accelerated the rate of decomposition and mineralization.

The application of green leaf manure Azadirachta indica in a saline sodic soil increased the number of panicles per m², more filled grains per panicle (13.3 per cent) and had a positive effect on thousand grain weight and grain yield (Arokiaraj, 1988). Gupta and Woodhead (1989) observed that the organic carbon content of the soil increased with the addition of soil amendments such as farm yard manure and green manure. Use of Sesbania as green leaf manure in coastal rice ecosystem promoted higher agronomic efficiency, maximum energy output maximum nutrient balance with the highest phosphorus and potassium uptakes (Raju and Reddy, 2000). Mythili et al. (2001) observed that the inclusion of green manure Sesbania aculeata in sandy loam and clay loam soils were superior in increasing the availability of Zn and S compared to treatments without green manure.

The application of green manure (6.25 t ha⁻¹) along with recommended NPK and gypsum recorded significantly higher yield by 17-24 per cent over NPK alone (Nagarajan et al., 2000). Shanmugan and Veeraputhran (2000) found that the combined application of organic manures such as green manure (Sesbania aculeata at 6.25 t ha⁻¹) or farm yard manure at 12.5 t ha⁻¹ with biofertilizers and inorganic fertilizers N 150 kg ha⁻¹ with 25 kg ZnSO₄ ha⁻¹ enhanced the growth and yield of rice. Karthikeyan (1999) observed that Chlortropis gigantea application as green leaf manure with 2 per cent DAP spray was found to increase grain yield with enhanced growth and yield attributes in rice. Naik and Yakadri (2004) observed that
green manuring with Sesbania rostrata recorded maximum grain and straw yields with enhanced yield attributes in rice. Vanathi and Mohamed Amanullah (2007) found that application of green leaf manure Calotropis gigantea at 6.25 t ha$^{-1}$ along with recommended NPK recorded higher yield of rice in coastal saline soil.

**Soil salinity and zinc application**: Rice is cultivated intensively in the state and due to continuous usage of chemical fertilizers and intensive cropping, Zn deficiency frequently occurs in the soils. Duraisamy et al. (1986) reported that rice grain yield was enhanced by the addition of conjunctive use of Zn and amendments by increasing the number of productive tillers and grain yield. The interaction effect showed that the highest Zn content of rice was observed when Zn was applied with farm yard manure compared to lowest content of Zn in control (Duraisamy et al., 1988). Ponnampenura (1972) observed deficiency of Zn in high pH soils. Zn deficiency has been observed in saline soils under Australian conditions (Tiller and Wassermann, 1972).

Misra and Gupta (1974) recorded an increased yield of rice grain by application of gypsum and ZnSO$_4$ in saline soils. Sadhana and Singh (1983) studied the effect of application of Zn at 11.2 kg ha$^{-1}$ along with gypsum 50 per cent gypsum requirement and 15 t ha$^{-1}$ of farm yard manure and found that the treatment gave higher rice yields. Maji and Banerjee (1990) reported that there was a non-significant interaction between salinity and applied Zn on the uptake of Zn by rice. The interaction between organic manures and ZnSO$_4$, was significant and application of farm yard manure with 25 kg ZnSO$_4$ recorded higher seed yield that was 22.8 per cent more than that of control (Channabasavanna et al., 2001). Application of Zn enriched organic manures produced significantly increased grain yields and there was an increase of 4.5 – 46.1 per cent over control with Zn application (Mani et al., 2001).

Rao and Shukla (1999) observed that all Zn treated plots recorded higher harvest index over control. Organic manures and inorganic nitrogen with Zn application increased uptake of P and K with the application of 187.5 kg N and 25 kg ZnSO$_4$ ha$^{-1}$ (Shanmugam and Veeraputhran, 2001). Chitdeshwari and Krishnasamy (2000) stated that the application of 5 mg kg$^{-1}$ recorded a two-fold increase in Zn content over no Zn application and Zn enriched organic manures influenced the micronutrient availability.

From the foregoing reviews, information pertaining to management practices for rice under coastal saline ecosystems is very meager. With recent accentuation on sustainability and crop productivity exploitation of coastal ecosystems would pave way for boosting rice yield under adverse environments. It is evident that there is possibility of integrating organic and inorganic sources of plant nutrients for higher productivity under problem soils. But, there is lacuna in the current state of knowledge regarding the combined use of amendments and nutrients on the productivity of rice and management under rainfed conditions. In this context, the future investigations should be planned in such a way to develop better management practices for rice in coastal saline ecosystems under lowland and conditions.

**REFERENCES**


