Soil management intervention in cyclone affected coastal areas

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Saline soils in coastal areas 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). The coastal saline soil has been used by various workers almost synonymously with coastal soil per se which is not correct since all coastal soils are not saline in nature. Velayutham *et al*. (1999) revealed that saline soil resources and their potentials for different Agro-ecological Sub Regions (AESR) of India. It shows total 10.78 million hectare area under this ecosystem (including the islands) in India, which was the first scientific approach for delineation of the coastal soils.

General characteristics of coastal saline soils

In coastal saline soil, the salinity status widely fluctuates from ECe 0.5 dS m^{-1} in monsoon to 50 dS m^{-1} in summer/ dry month. Mostly NaCl followed by Na_2SO_4 are the dominant soluble salts, with abundance of soluble cations in the order of Na>Mg>Ca>K. Chloride is the predominant anion, and bicarbonate is found in traces. In India, the soils are, in general, free of sodicity except in a few pockets in the South and West coast. Saline soil can be classified as the soils having pH less than 8.5, ESP less than 15, and preponderance of chlorides and sulfates of sodium, calcium and magnesium.

Bandyopadhyay et al. (1987) observed that coastal saline soils are characterized by clay loam with varied presence of silt and sand. The electrical conductivity ranges from 0.5 to 9.2 dS m^{-1} with sodium as dominating castion in the 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 crop yield in deltas, estuaries and coastal fringes in the humid tropics. It is a serious impediment to growth of irrigated rice (Ponnamperuma, 1972). 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.

A. Salinity build – up

The main obstacle to intensification of crop production in the coastal areas is seasonally high content of salts in the root zone of the soil. The salts enter inland through rivers and channels, especially during the later part of the dry (winter) season, when the downstream flow of fresh water becomes very low. During this period, the salinity of the river water increases. The salts enter the soil by flooding with saline river water or by seepage from the rivers, and the salts become concentrated at the surface through evaporation. The saline river water may also cause an increase in salinity of the ground water and make it unsuitable for irrigation. 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.

B. Productivity constraints

Coastal soils in a number of situations are constrained by various factors limiting agricultural productivity, which 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 underground aquifers, (v) Shallow 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) Fine 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.

Nutrient availability and management in cyclone affected coastal areas

A. Nitrogen

Most of the coastal saline soils are deficient in nitrogen. Besides lesser utilization of nitrogeneous fertilizers, especially in coastal areas, the mineralization of soil organic nitrogen, and thus the release of native soil nitrogen to the plant available form, is also slowed down in the salt-affected soils due to decrease in the population as well as activity of microbes with increase in soil salinity. It was revealed from a study at CSSRI, Regional Station Canning that the rates of both mineralization and immobilization of nitrogen in soil were considerably reduced at soil salinity of ECe 10 dSm^{-1} and above. Under salt-stress conditions, the uptake of N by crop plants is generally affected (Alam, 1999). A substantial number of laboratory and greenhouse studies have shown that salinity reduces N nutrition in plants. It has been reported that an increase in Cl^- uptake and accumulation is accompanied by a decrease in shoot nitrate concentration. In their experiment, Aslam et al. (1984) have reported that Cl^- inhibited NO_3^- uptake more than SO_4^{2-} when these anions were present on an equal molarity basis. In contrast to the effect of Cl^- on NO_3^- uptake, reported data indicated that increased NO_3^- in the substrate decreased Cl^- uptake and accumulation. The possible decrease in N uptake by increasing salinity has been partly attributed to a probable substitution of Cl^- for NO_3^-. Both the chloride salts of Na and K inhibited the nitrate uptake similarly, suggesting that the process was more sensitive to anionic salinity than to cationic salinity (Aslam et al.,1984). Although, Cl^- salts were primarily responsible for reduced NO_3^- uptake by plants, NO_3^- reduction in plants was not affected by salinity in studies with barley (Aslam et al.,1984). Salinity also stimulated nitrate reductase activity in peanut plants but decreased the nitrate reductase activity in tomato and cucumber (Cucumis sativus L.) plants. Reduction in NRA may be due to inhibition of NO3-uptake by Cl^- in plant species (Abdul-Kadir and Paulsen, 1982).

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). Rice is grown as a major crop in most of the coastal areas during the North East monsoon season. The increasing loss of nitrogen through NH_3 volatilization from applied nitrogeneous fertilizer with increase in soil salinity was studied under field condition at Canning in West Bengal. While comparing among different sources at two soil salinity levels, viz. ECe 3-4 and 7-8 dSm^{-1}, the loss was found to be maximum under ammonium sulphate, followed by prilled urea, and minimum under placement of urea (in paper packet) at 5 cm depth, whereas the conventional slow-release sources as lac-coated urea, sulphur-coated urea, and placement of urea briquette occupied the intermediate positions. Reduction in loss when compared with prilled urea broadcast under cropped condition was maximum (73.1%) for placement of urea.

B. Phosphorus

Phosphorus, which plays crucial role in the energy metabolism of cells, is involved in a number of anabolic and catabolic pathways (Alam, 1999). A recent study indicates that salinity may increase the P requirement of certain plants. Awad et al. (1990) found that when NaCl increased in the substrate from 10 to 50 or 100 mM, the P content in the tomato leaf increased from 58 to 70 and 97 mmol kg^{-1} of dry weight. The influence of salinity on P accumulation in crop plants is variable and depends on the plant and experimental conditions. In many cases, salinity decreased the P concentration in plant tissue (Sharpley et al., 1992). It is unlikely that Cl and H_2PO_4 ions are competitive in terms of plant uptake. However, it has also been observed that Cl may have a suppressing effect on P uptake in tomato shoots (Papadopoulos and Rendig, 1983). The presence of Cl as well as SO_4 reduced P uptake in barley and sunflower plants. In other cases, a reduction in plant P concentration by salinity may result from the reduced activity of P in the soil solution due to the high ionic strength of the growth media (Awad *et al.*, 1990). Phosphate solubility and its availability are reduced in saline soils not only because of ionic strength effects that reduce the activity of phosphate but also the P concentration in soil solution is tightly controlled by sorption processes and by the low solubility of Ca-P minerals. It is, therefore, understandable that P concentrations in field-grown agronomic crops decreased as salinity increased in the media. When plants are P-deficient, they may be more sensitive to salinity (Sharpley *et al.*, 1992).

Gibson (1988) observed that adequate phosphorus nutrition was essential for effective ion compartmentation by contributing to efficient carbohydrate utilization in salt-stressed wheat. The level of phosphorus in the coastal saline soils is highly variable, and depends largely on the nature and degree of salinity. The availability of soil phosphorus largely depends on the pH of the soil developed after hydrolysis of salt. An increase in soil pH on hydrolysis reduces the availability of soil phosphorus. Very little work has been done on the transformation and availability of P to crops in coastal saline soils.

C. Potassium

The availability of potassium depends largely on the parent material, clay minerals and weathering conditions. It also depends on the nature and amount of salts in the soil. It was reported from CSSRI, Regional Station Canning that the coastal saline soils are rich in water soluble, exchangeable, non-exchangeable and available K. Thus, with regard to soil fertility, the coastal soils are usually rich in available K and micronutrients (except Zn), low to medium in available N, and are variable in available P status (Bandyopadhyay et al., 1985, Bandyopadhyay, 1990, Maji and Bandyopadhyay, 1991). Major portion of the applied N fertilizer is lost through volatilization (Sen and Bandyopadhyay, 1987).

The higher K/Na ratio in shoots of barley cultivars compared with that in root medium solution indicated selective uptake of K, which seems to be among the processes involved in tolerance of cultivars to salinity stress (Alam, 1999, Niazi et al., 1992). Addition of K suppressed the uptake of other cations by rice and tomato plants in the order of Na>Mg>Ca. The depression of K uptake by Na could be due to the antagonism between the two cations. It is widely recognized that a high Na concentration inhibits K uptake by plants. On the other hand, Na appeared to stimulate the K uptake by plants. Salinity stress has significant inhibitory effects on the concentrations of K, Ca, and Mg as well as stimulatory effects of these nutrient elements on different crop plants (Alam, 1999). With the increasing concentration of NaCl salts, K concentration decreased in the leaves, stems and roots, and was accompanied by a substantial increase of Na in the organs.

In lowland rice, plants adapt to saline conditions and avoid dehydration by reducing the osmotic potential of plant cells. Antagonistic effects on nutrient uptake may occur, causing deficiencies, particularly of K and Ca under conditions of excessive Na content. For example, Na is antagonistic to K uptake in sodic soils with moderate to high available K, resulting in high Na:K ratio in the rice plant and reduced K transport rates. Sodium-induced inhibition of Ca uptake and transport limits shoot growth. Increasing salinity inhibits nitrate reductase activity, decreases chlorophyll content and photosynthetic rate, and increases the respiration rate and N content in the plant. Plant K and Ca contents decrease but the concentrations of NO_3^- –N, Na, S, and Cl in shoot tissue increase.

D. Secondary nutrients

Calcium plays a vital nutritional and physiological role in plant metabolism. Calcium, which like K also is an essential mineral nutrient, helps in maintaining membrane integrity, is important in senescence processes, and is known to counteract the harmful effects of Na on crops (Lahaye and Epstein, 1971). Plant growth is dependent on Ca^{2+}, and both cell division and cell elongation processes are affected by the Ca^{2+} ion concentration.

The presence of Ca^{2+} as the dominant cation in agricultural soils generally ensures that the absolute Ca^{2+} level is not a primary growth-limiting factor. As salinity increases, the requirement of plants for Ca^{2+} increases. The uptake of Ca^{2+} from the soil solution may decrease because of ion interactions, precipitation, and increases in ionic strength that reduce the activity of Ca^{2+}. In citrus, Ca was found to be effective in reducing the transport of both Na and Cl from the roots to leaves. Maintaining an adequate supply of Ca^{2+} in the soil solution is an important factor in controlling the severity of specific ion toxicities.

The magnesium content of the leaves of saline-treated bean plants increased, whereas it decreased in the root. Hodson et al. (1982) found potentially toxic concentrations of Mg in salt-marsh soil solution samples and demonstrated that a salt-marsh clone, *Agrostis stolonifera,* was considerably more tolerant to Mg^{2+} than was an inland clone. Magnesium concentration of avocado leaves was decreased with an increase in the exchangeable Na in the soil. In rice, Mg transport to the tops was suppressed by Na compared with Mg uptake (Song and Fujiwara, 1996). The Mg content in the roots revealed the competition between Mg and Na uptake and transport to the tops (Alam, 1999, Alfocea et al., 1993).

E. Micronutrients

The concentrations of micronutrients in the soil solutions, with the exception of Cl, seem to be low and depend on the physical and chemical characteristics of the soil bodies. The availability of most micronutrients depends on the pH of the soil solution as well as the nature of binding sites on organic and inorganic particle surfaces. In saline soils, the solubility of micronutrients such as Fe, Mn, Zn and Cl is particularly low and plants grown in these soils often experience deficiencies in these elements (Alam, 1999, Page et al., 1990). Nevertheless, the micronutrient concentration in plant shoots may increase, decrease, or have no effect depending on the type of plant tissue, salt tolerance of plant species, salinity, micronutrient concentration, environmental conditions, and/ or abrupt changes in the permeability of the crop cell membranes.

Work done so far on the role of micronutrients in coastal saline soils is meagre. The soils are generally rich in micronutrients, such as Fe, Mn, Zn, Cu, B and Mo. In the coastal sands of Andhra Pradesh in India the soils are deficient in Zn as well as in N, P and K. Iron chlorosis is common to crops like sugarcane (Saccharum officinarum L), jowar (Sorghum bicolor L. Moench), rainfed rice (Oryza sativa L.), etc. In Andhra Pradesh salinity accentuated the zinc deficiency. In coastal saline soils, it was found that the amount of Zn available to the plants decreased with submergence (Maji and Bandyopadhyay, 1990). High amount of $CaCO_3$ (up to 15%) is congenial to Zn and Fe deficiency disorders. High dose of Zn application is recommended in rice as foliar spray. Zn deficiency was noted from various laterite and lateritic soils in other coastal states in India. Besides, Al and Fe toxicities too have been reported from a few acid lateritic soils along the coast. Both Fe and Mn contents were reported to increase in all parts of the salt-treated peanut plants (Chavan and Karadge, 1980). The increase in Fe contents was more prominent than that of Mn. Salinity increased the Fe concentration in the shoots of pea and rice and decreased its concentration in the shoots of barley and corn (Hassan et al., 1970).

Alleviation of nutrient deficiency in cyclone affected coastal areas

Additions of N and P generally increase the growth of plants grown in N- and P-deficient environments, provided that the plant is not experiencing severe salt stress. When both salinity and nutrient deficiency are responsible for limiting growth, relief of the most limiting factor will promote growth more than the relief of the less limiting factor. Therefore, addition of a limiting nutrient can either increase, decrease, or have no effect on relative plant tolerance to salinity, depending on the level of salt stress. Failure to account for the severity of salt stress when interpreting salinity and nutrient interactions has caused considerable confusion among researchers in the past.

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).

Long term field experiment in coastal saline soils in India showed that rice and wheat yield could be maintained with 50% NPK used in conjunction with FYM or green manure (DARE, 2003-04). In another detailed long term experiment conducted (CSSRI, 1990) 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. In Sri Lanka addition of Gliricidia muculata in combination with phosphate and a small dose of inorganic fertilizer was effective to secure high rice yields (Deturckl et al., http://www2.alterra.wur.nl/Internet/webdocs/ilri-publicaties/publicaties/Pub53/pub53-h8.pdf). In India, for the coastal acid sulphate soils of Sundarbans, application of lime, superphosphate and rock phosphate have been found beneficial in improving the soil properties and rice growth (Bandyopadhyay, 1989). Application of Ca-rich oystershell, 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. Effect of salinity on the microbial and biochemical parameters of the salt-affected soils in Sundarbans (India) was studied at nine different sites. The study revealed that the average microbial biomass C (MBC), average basal soil respiration (BSR), and average fluorescein diacetate hydrolyzing activity (FDHA) were lowest during the summer season, indicating the adverse effect of soil salinity (Tripathi et al., 2006). It was suggested that integrated nutrient management should be very effective for increasing its use efficiency for higher and sustainable yield of crops (Bandyopadhyay et al., 2006, Tripathi et al., 2007). Bandyopadhyay and Rao (2001) were of the opinion to introduce systems approach involving organic, inorganic and biofertlizers compatible with the farmers' practice. In coastal soil at Tamil Nadu (India), application of agro-industrial wastes significantly improved soil organic carbon, pH, EC and soil bacteria, fungus and actinomycetes population and enhanced the soil fertility status (macro and micro nutrients) and improved the crop productivity of finger millet. Application of pressmud @12.5 t ha^{-1} recorded better growth and yield of finger millet followed by composted coirpith @ 12.5 t ha^{-1} (Rangaraj et al., 2007).

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