Lime-sulphur (calcium polysulphide)

$$CaS_5 + 8O_2 + 4H_2O \rightleftharpoons CaSO_4 + 4H_2SO_4$$

$$+ CaCO_3 \rightleftharpoons + CO_2 + H_2O$$

$$10Na\Box + 4H_2SO_4 + CaSO_4 \rightleftharpoons 8H\Box + Ca\Box + 5Na_2SO_4$$

Iron sulphate

$$FeSO_4 + H_2O \rightleftharpoons H_2SO_4 + FeO$$

$$2Na\Box + H_2SO_4 \rightleftharpoons 2H\Box + Na_2SO_4$$

Sulphuric acid

$$2Na\Box + H_2SO_4 \rightleftharpoons 2H\Box + Na_2SO_4$$

Hydrochloric acid

$$Na\Box + HCl \rightleftharpoons H\Box + NaCl$$

Nitric acid

$$Na\Box + HNO_3 \rightleftharpoons H\Box + NaNO_3$$

The results reported from time to time on the effectiveness of various chemical amendments for the reclamation of sodic/saline-sodic soils show a variety of response. Generally, H_2SO_4 among the acidulents and gypsum from other amendments were found to be the most effective reclaimants. Because of its comparatively low price and freight, general availability and easy application than other amendments, gypsum is the most commonly used source of Ca^{2+} for the reclamation of both calcareous and non-calcareous sodic/saline-sodic soils.

Biological methods

The term "biological reclamation" is used to describe the reclamation of a salt-affected soil by growing crops on the affected area. Sometimes, addition of organic matter to the salt-affected soils as farm-yard/green manure is also included under the same heading. Use of manures/other organic materials for the reclamation of salt-affected soils should preferably be treated separately to avoid confusion between the organic and the biological amendments.

The soil being host for crops is influenced by both the below- and above-ground plant parts. The below-ground parts comprising roots can modify conditions within the root-soil interface (rhizosphere) in many ways. Roots tend to change the soil pH, lower oxygen concentration, release organic compounds and complex energy sources such as exudates, secretions, and mucilages, produce chelating and/or reducing substances, increase CO_2 partial pressure, provide channels for soil solution movement, increase microbial activity and influence numerous physical and chemical properties. The above-ground plant parts provide shade to the host soil, lower soil temperature, have a mulching effect, decrease evaporation from the soil surface and thus check upward movement of salts through capillaries. After harvest of the crops, the remains of the below-ground parts, e.g. large and small roots, rhizomes, etc. plus the plant litter/trash all add organic matter to the soil.

The possible mechanism of biological reclamation may be associated with a long chain of reactions. This involves 1) release of CO_2 in the root zone as a result of root and microbial respiration, 2) formation of carbonic acid (H_2CO_3) via CO_2 dissolution in water, 3) reaction of H_2CO_3 with the native $CaCO_3$ to form relatively more soluble $Ca(HCO_3)_2$, 4) release of Ca^{2+} ions from $Ca(HCO_3)_2$, and 5) displacement of exchangeable Na^+ by the Ca^{2+}.

Plants growing in saline/sodic environment may face certain limitations particularly in terms of biomass production. Soil salinity may reduce crop yields by upsetting the water and nutritional balance of plants while sodicity affects plant growth by deteriorating the physical condition of soils or by disturbing the plant nutrition due to excess Na^+ in the root medium. The judicious selection of plant species capable of producing satisfactory biomass under inhospitable soil conditions during the reclamation of sodic/saline-sodic soils is vital. The efficiency of various plant species in soil reclamation is highly variable because of differences in their tolerance to soil salinity/sodicity and irrigation requirement. Generally, high water-requirement crops get the benefit of salt dilution, because of heavy irrigations, while salt tolerant crops enjoy the facility of their natural as well as adaptive mechanisms of salt tolerance when planted in a saline environment.

Stage of vegetative growth and kind of vegetation play an important role in modifying the environment of the host soil. At early stages of growth, crop roots occupy some of the soil macropores that would otherwise be available for infiltration. The amount of root mass, its rate of decay as well as ability to form root channels can markedly be different among crops.

Regarding kind of vegetation, plants which are able to colonize salt-affected soils are important for stabilization and reclamation of the growth medium. The ability of some plant species to grow in a wide range of stress conditions could render them in an expanded range of adaptability and utility compared to others. Some research workers favoured the inclusion of kallar grass, sesbania or sordan as the first crop to start and speed-up the reclamation of sodic/saline-sodic soils. The salt tolerant plant species generally perform more efficiently in calcareous saline-sodic/sodic soils than the non-calcareous soils. In calcareous soils, their roots act as Ca^{2+} mobilizers via dissolution of the native $CaCO_3$. In some experiments, the levels of soluble Ca^{2+} in calcareous sodic soils grown with the salt tolerant crops were found to be sufficient to cause a marked decrease in the salinity and sodicity levels.

Although cultivation of certain salt tolerant plant species for the improvement of salt-affected soils is an age old practice, yet little work has been reported to evaluate the role of these species in terms of soil amelioration over a certain period of time and at different growth stages. Many workers have simply correlated a good stand and harvest of certain salt tolerant forage plants from the salt-affected areas with the decrease in salinity/sodicity hazard without analyzing the soil characteristics. Very few studies give the requisite information on actual changes in EC_e and SAR/ESP of saline-sodic/sodic soils during reclamation through biological means. generally, reclamation of saline-sodic/sodic soils through biological means is considered a slower than the application of inorganic amendments. However biological reclamation can be started at a relatively low initial cost.

Hydro-technical method

This method initially makes use of the effect of the high electrolyte concentration of saline water on soil permeability and subsequently, in successive dilutions, of the "valence-dilution" effect.

The "valence dilution" effect was demonstrated by Eaton and Sokoloff (1935) for reclaiming sodic soils. In a soil-water system where monovalent and divalent cations in solution are in equilibrium with the adsorbed cations, the addition of water to the system (dilution) alters the equilibrium condition. This dilution of the soil solution favours the adsorption of divalent cations, like Ca^{2+} at the cost of monovalent cations, like Na^{+}. The reverse is true when the soil solution is concentrated due to evapotranspiration.

The ratio of divalent to total cations (with concentrations expressed in $mmol_c\ L^{-1}$) of the water should be at least 0.3, and the greater it is the less the depth of water required for effective reclamation. Some natural waters meet this ratio, but in many cases some additional Ca^{2+} is required. The additional Ca^{2+} can be introduced by 1) applying gypsum to the soil and followed by leaching with high-salt water or 2) by placing gypsum stones in the water channels to add Ca^{2+} in the salty water through gypsum stone dissolution.

The major problems with this method are the facilities required to collect, convey, and treat the saline water.

Electro-reclamation method

Electro-reclamation refers to the amelioration of saline-sodic/sodic soils through electrodialysis. Laboratory and field investigations have shown that treatment with electric current may simulate reclamation of saline-sodic/sodic soils, although it can not replace the conventional procedures of soil reclamation. This method of soil reclamation has shown some encouraging results which indicate increased solubility of $CaCO_3$ to supply more Ca^{2+} to replace the exchangeable Na^{+}. Moreover, this method created an environment which was effective for leaching of soluble salts and exchangeable Na^{+}. It is too early to recommend this method for practical use in agriculture of Pakistan and elsewhere in the world.

Synergistic approach (combination of reclamation methods)

Under certain conditions, reclamation can be speeded up by combining the various reclamation methods, e.g. a saline-sodic soil having an impermeable layer of 15 cm width at a soil depth. In this case, a combination of physical and chemical methods may be better than the use of either chemical or physical method alone. In most of the cases, this approach is practiced for the reclamation of saline-sodic/sodic soils at farmers' level.

As already discussed, gypsum is the most commonly used amendment for the reclamation of sodic and saline-sodic soils. However, in a developing country like Pakistan, although gypsum is available in abundance yet its potential use is limited because of the fact that an amount of more than Rs.7000 per hectare (considering an average gypsum requirement of sodic soils = 14 Mg ha^{-1}) is needed to purchase the amendment only. This price is high to be incurred by the small farmers occupying the greater part of the affected soils. This is one of the major reasons for somewhat low progress of sodic soil reclamation in the country. It is imperative to sort out some materials capable of reclaiming sodic soils particularly at relatively low initial costs.

Leaching:- Removal of materials in solution from the soil by percolating waters is called leaching.

LR:- Leaching fraction of irrigation water necessary to keep soil salinity from exceeding a tolerance level of the crop to be grown is called.