Plant Succession-A Key to the Utilisation of Saline Soils

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Abstract: *The paper describes the extent of salinity in the Indus Plain and mentions some of the methods employed for reclaiming the salt affected soils. The rationale of a biological approach consisting of introduction of a plant succession on calcareous saline-sodic soils has been described which has given encouraging results in the preliminary experiments carried out by the authors.*

Pakistan has a total land area of 199 million acres out of which 73 million acres are suitable for agriculture. The area under the command of irrigation canals is 37.37 million acres. Of the total river diversions of 95.7 million acre feet, the net field delivery is of the order of 48.0 m.a.f. Farm deliveries are thus estimated at 1.6 acre feet against a requirement of about 2.7 acre feet per cropped acre (7th NESA Irrigation Practices Seminar, Lahore, Pakistan, 1968). Due to the shortage of irrigation water, high salinity of the sub-soil water, presence of salts in the surface irrigation water and undesirable redistribution of the initial salt content of the soils of the Indus Basin, large areas have developed saline conditions.

According to a recent estimate about 25 million acres of land in Pakistan have been severely affected by salts, whereas moderately saline area is estimated to be about 15 million acres (Pakistan Times, 2nd June, 1973; Dawn, Karachi, 8th June, 1973). Because of the magnitude of the problem and the rate at which the scourge of soil salinity is spreading, the government have recently launched a large project costing 5, 350 million of rupees to combat this problem. Although over the last 50 years or so, different methods have been tried to keep the spread of water-logging and salinity under control but no noticeable success seems to have been achieved. In nearly all the remedial measures advocated so far, emphasis has been mainly on the hydrological aspects of the problem. With the launching of SCARPs it is claimed that some success has been achieved as regards the lowering of the level of sub-soil water and the supply of much needed irrigation water. However, very little attention has been paid to the ecological conditions and agronomic practices in the affected areas. Without going into the merits and demerits of the different reclamation methods tried so far it must be acknowledged that unless the soil is treated as a living system and not merely as a mixture of dead chemicals, the productivity of the saline soils cannot be increased satisfactorily.

It is well-known that most of the affected soils are saline-sodic in nature. It is also known that of the 95.7 million acre feet of the diverted river water, only 48.0 million acre feet are delivered to the fields to irrigate nearly as many million acres of land. Under-irrigation of the land has adversely affected the distribution of salts in the top soil. Irrigation with canal water of the naked sodic or saline-sodic soil also does not always improve it because, firstly, the permeability of such soils is usually very low and secondly the washing of salts from the saline-sodic soils may lead to the development of sodic conditions, thus further impeding the passage of water and hence decreasing the rate of leaching of the salts. Again the tube-well water in most areas is known to be sodic (high SAR waters) due to the presence of appreciable amounts of residual sodium carbonate. The use of this water has resulted in further deterioration of the soil and, at many places, tube-wells have had to be closed at the request of the farmers. Even when such water is mixed with the canal water, as originally recommended (Revelle *et al*, 1964), it seldom falls within the recommended limits for good irrigation water. As no proper drainage has been provided to carry away the drainage water, the whole of it practically evaporates off leaving the salts behind in the same area.

It is true that saline-sodic and sodic soils can be reclaimed very quickly using chemical amendments like gypsum, sulphur and calcium chloride (Hussain, 1969). Of these, gypsum is the cheapest but even then it costs more than 200 rupees per ton and the poor farmers cannot afford to invest so heavily on soil which does not give any returns. Again the solubility of gypsum is much lowered in the presence of soda due to the formation of a coating of calcium carbonate and gel films on the surface of gypsum particles (ElGabaly, 1971). Due to the upward movement of mineralized water, frequent additions of gypsum will also be needed. The scientists at Mona Reclamation Project have clearly shown that gypsum is a very expensive soil amendment and have recommended the use of farm-yard manure as the most economic amendment (Mona Reclamation Project Report No. 16, 1972, WAPDA, Lahore), but it is the shortage of farm-yard manure which presents a serious problem. With the decrease of cattle population and burning away of cow-dung by villagers, the supply of farm-yard manure has decreased heavily. The other agricultural waste products like rice and wheat straw are being used as cattle feed or converted into card-board and other useful products and thereby very little is available for the preparation of fertilizer by composting. It simply means that efforts should be made to find an alternative solution of the problem which should be easy to accomplish and be within the means of the average farmer in the country.

BIOLOGICAL APPROACH

Biological Desalination

Many authors (Kovda, 1947; Bernstein, 1959, 1962; Chaudhry *et al*, 1964; Boyko and Boyko, 1966) have recommended the use of plants that take up salts from the soil and can then be removed, thus reducing the salt content of the top layers. For example, Kovda (1947) suggested that if 5 tons of plants of the Atriplex species were harvested per acre it corresponded to 1 ton of salt taken out of soil. But the problem is that the salts in the plants removed go back to the soil after the decomposition of these plants. Besides, it is quite a laborious job to remove these plants when millions of acres are involved and hence is not practicable.

Organic Amendments

As pointed out earlier, organic amendments, especially the farm yard manure, are very beneficial for ameliorating saline soil conditions because the organic matter affects the soil in many ways:—

(1) Organic matter on decomposition increases the cation exchange capacity of the soil.

(2) It promotes the stable aggregation of the soil particles.

(3) It decreases the bulk density of the soil leading to better plant respiration and root stimulation.

(4) It stimulates the growth of soil micro-organisms which:

  (a) release acidic products of decay that have solvent effect on the inorganic parts of soil thus yielding new supply of plant nutrients from the soil minerals and also decompose calcium carbonate present in the soil releasing soluble calcium which goes on the soil complex replacing sodium.

  (b) the release of the intermediate organic substances made available by the activity of soil microbes markedly increases soil aggregation.

(5) The presence of organic matter provides, through metabolic processes, the necessary energy required by the plant growing in saline environments for the acquisition of water against high osmotic pressure and the selective absorption of ions such as potassium, calcium and magnesium in the presence of a great excess of sodium (Heiman, 1966).

(6) The organic matter also serves as a direct source of important plant nutrients.

Reclamation through cropping

Some authors have recommended the use of rice as a reclamation crop (McNeal *et al.*, 1966; Pearson and Ayers, 1960; Hussain, 1969). It is based on the fact that washing out salts from the soil necessitates ponding water on the surface and because rice can tolerate prolonged submergence, it can often be grown with profit on soil that is under going leaching. But it has also been observed that:

(a) growth of rice on such soils is quite poor in majority of cases.

(b) it is essential to irrigate rice with large amounts of good quality water. It is estimated that the quantity of water applied to one acre of rice is sufficient for growing 3 to 4 acres of other crops (Yadav, 1972). Under the present conditions of supply of irrigation water, it appears a shear wastage to put large areas under rice crop as a means of reclamation of the saline soils.

The other likely source of organic matter are the crops like *Sesbania aculeata* (Dhancha) for green manuring. This crop can only grow in reasonably good soil and hence can not be used as primary colonizer of saline and barren soils (Kausar and Muhammad, 1972).

Plant Succession

From the above discussion it appears logical that something must be grown on the saline and barren soils in order to:—

(1) reduce evaporation.

(2) to give a green coverage on the barren fields boosting up the morale of the farmers and provide some financial benefit at the same time.

(3) to help in improved leaching of salts due to root action.

(4) to render help in the aggregation of soil particles through the agency of root exudates, and

(5) to support the growth of important soil microflora through the provision of organic matter by leaf litter, decaying roots and other excretion products.

For the purpose out-lined above, the ideal crop for use as a primary colonizer should be able to tolerate high salinity and sodicity, produce green fodder or grain to give the farmers some financial return and should not require excessive amounts of good irrigation water. No single crop appears to fulfil these conditions but *Diplachne fusca* locally known as kallar-grass which has been known to our farmers and agriculturists for some time, can be considered as a strong candidate. It has been wrongly believed that this grass eats up the salts from the soil (biological desalination) and after the reclamation of the soil has taken place it automatically dies away. This notion has been found to be fallacious as the grass does not accumulate excessive amounts of salts and grows equally well on good soils. In fact, it has the property of tolerating high salinity and sodicity and will grow even with water of bad quality. It is for this reason that it serves as an ideal primary colonizer of saline-sodic and sodic soils. The help rendered by the grass roots in enhanced leaching of salts and addition of organic matter through leaf litter, decaying roots, root exudates, growth of microbes of different types including nitrogen fixing bacteria and blue-green algae, makes it possible later on to bring in a leguminous crop like *Sesbania aculeata* (locally bnown as Dhancha). Dhancha is an ideal green manuring crop as its roots are profusely nodulated, fixing extensive amounts of atmospheric nitrogen. It has a deeper root system which opens up the soil further and it is an easily decomposable plant having acidic cell sap. This leguminous crop when ploughed under and allowed to decompose, either as such with the addition of some phosphatic fertilizer or by inoculating with a mixture of cellulose decomposing fungi to desirably modify the process of decomposition, improves the soil a great deal and renders it fit for cultivation of an economic crop. Such a plant succession appears to be the most economic method of reclaiming saline-sodic and sodic soils as it does not involve any expenditure in terms of amendments like gypsum. Another advantage is that initial leaching of soil and growth of kallar-grass can be carried out with bad quality tube-well water and when it comes to the sowing of Sesbania crop which has a much lower requirement for water, canal water or amended tube-well waters can be used for the growth of this crop and the following economic crops like wheat and rice. It is recommended that extensive and intensive research should be carried out to select better primary colonizers for different ecological conditions, breeding for salt tolerance of different economic crops should be vigorously pur-