

Agro-Techniques for Crop Production in Saline Soils

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Salts accumulation is the part of soil pedogenic processes and they are present in every soil. Their extent of accumulation however depends on nature of parent material and climate of the region. In irrigated and high rainfall regions their build up is controlled by the leaching through good quality irrigation water and rainfall. However, in arid and semi-arid regions, rainfall is scanty and it is insufficient to leach down the accumulated salts. Therefore, salts build-up continues year after year through capillary rise during summer season up to the extent which ultimately affecting crop production in these soils. Further, the irrigation with saline water aggravated the problem. The salinity is described based on quantity and nature of salts present. Soils dominated with soluble salts of sodium, calcium and magnesium as their sulphates and chlorides, termed as saline soils. On the other hand the soils having dominance of exchangeable Na as its carbonate and bicarbonate is categorized as sodic soils. To indicate the both types of problems broadly, soil salinity word is generally used. While to designate the saline and alkali irrigation water, the term poor quality irrigation water is used academically.

Globally salinity stress is affecting crop production in nearly 800 million hectare (mha) of agricultural land. In India, 6.73 mha of agricultural soils are facing problems of soil salinity at various extents. Soluble salts present in the saline soils increases the osmotic potential of soil water and plants incapable to uptake sufficient quantity of water for growth and faces water stress. Secondly, the excess amount of chlorides also causes injury to the plants. Saline areas generally confined with saline groundwater for irrigation. Then it becomes difficult to produce crops with dual stress of soil and water salinity. Under salt stress plant growth is affected through (i) reduced water availability, due to an osmotic effect from high concentrations of soluble salts in the root medium (ii) ion toxicity, as a result of the accumulation of Na^+ and Cl^- (iii) oxidative stress, resulting from an overproduction of reactive oxygen species (ROS) and (iv) acute K^+ deficiency as a result of massive K^+ leak from depolarized cells (Shabala, 2013). It is difficult to remove soluble salts from the soil through use of any chemical amendment. Only way to manage through agronomic practices so as to maintain lowest salt concentration in the root zone. Another way is to select the tolerant plant species for these soils and water. Adoption of appropriate agronomic techniques, crop selection along with other growth promoting and stress mitigation activities, sustainable crop production in saline environment can be achieved.

Agro-techniques for managing salt stress

The number of practices has been advocated to manage salt accumulation in the crop root zone. Seed priming with water or chemical substances augments germination and early growth of crop provides salt stress mitigation mechanism to the crop. Management practices such as night irrigation to reduce evaporation loss, pre-sowing seed treatments to enhance germination under saline conditions, land configuration such as sowing on raised bed, increased seed and fertilizer rates, and mulching etc. are found as good management practices for successful crop production in saline environment.

Seed priming: Salt stress adversely affects the physiological and biochemical processes of germinating seeds. It can affect the seed germination and stand establishment through osmotic stress, ion-specific effects and oxidative stress. The salinity delays or prevents the seed germination through various factors, such as a reduction in water availability, changes in the mobilization of stored reserves and affecting the structural organization of proteins. Seed priming is a pre-sowing treatment that exposes seeds to a certain solution for a certain period that allows partial hydration, but radicle emergence does not occur. The process of seed priming involves prior exposure to an abiotic stress, making a seed more resistant to future exposure. The inorganic salts like KH_2PO_4 , NaCl , KCl , CaCl_2 and are used as pre-hardening agents. When dry seeds are soaked in water or chemical solutions, the quiescent cells get hydrated and germination initiated. It also results in enhanced mitochondrial activity leading to the formation of high energy compounds and vital biomolecules. The latent embryo gets enlarged. When the imbibed seeds are dried again, triggered germination is halted. When such seeds are sown re-imbibition begins and the germination event continues from where it is stopped previously. Seed priming have various techniques for improving the performance of the growth, emergence, and yield of the crop. There are some techniques which are used i.e. hydro-priming, halopriming, osmopriming and hormonal priming. Hydro-priming involves soaking the seeds in water before sowing which may or may not be followed by air-drying of the seeds. Halo priming refers to soaking of seeds in solution of inorganic salts i.e. NaCl , KNO_3 , CaCl_2 , CaSO_4 , etc. A number of studies have shown a significant improvement in seed germination, seedling emergence and establishment and final crop yield in salt affected soils in response to halopriming. In osmopriming seeds are soaked for a certain period in solutions of sugar, polyethylene glycol (PEG), glycerol, sorbitol, or mannitol followed by air drying before sowing. Osmopriming not only improves seed germination but also enhances general crop performance under normal as well as saline conditions.

Sowing methods: Sowing or planting of crop in such a manner that root zone remains with low salt accumulation and diversion of salts away from root zone helps in minimizing the salt stress. Suitable land configuration like ridge and furrows and raised bed sowing found to save 20-30% irrigation water, increase water use efficiency and can provide opportunity to leach the salt from furrows. However, under saline conditions, increased salt accumulation on top of the beds has been reported by Choudhary *et al.* (2008) due to the upward movement of salts through capillary rise in response to evaporation gradients. Therefore, residue retention on raised beds is more effective than the effect of either of these practices alone for managing salts (Devkota *et al.*, 2015). They observed that when retaining crop residues, the soil salinity under permanent beds was reduced by 32% in the top 10 cm and by 22% over the top 90 cm soil profile compared to conventionally sown cotton without crop residue retention. To protect the crop from deposited salts, sowing should preferably be done on sides of the beds.

Furrow irrigation: Furrow irrigation is most commonly practiced in fine textured soils. In furrow irrigation, soil salinity varies widely from the base of the furrows to the tops of the ridges. There two ways to provide irrigation under furrow irrigation system like irrigation to every furrow and skip furrow irrigation. In furrow irrigation system if every furrow is irrigated then salt accumulation takes place on top of ridges of soil between the furrows (Fig. 9.1). So, under every furrow irrigation method, it is better to plant/sow crop either in furrows or on side of

the ridges. If alternate furrows are irrigated, the maximum zone of salt accumulation will be on the sides of the un-irrigated furrow (Fig. 9.2). In this situation, it is safe to place the seed or transplant seedlings away from the salt accumulation zone i.e. seed should be sown on side of the ridge towards irrigated furrow.

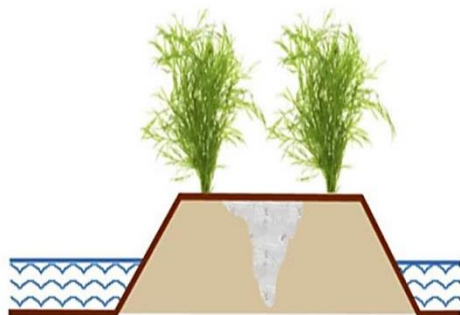


Fig. 9.1 Salt accumulation under every furrow irrigation method



Fig. 9.2 Salt accumulation under skip-furrow irrigation

Mulching: Mulching, among the other soil and water management approaches has potential to enhance soil quality over the long-term, as well as increase production. Crop residues placed on the soil surface shade the soil, serve as a water vapor barrier against evaporation losses, slow surface runoff, and increase infiltration (Mulumba and Lal, 2008) with reduction in salt build-up in the upper soil layer. Salinity buildup was 20% lower in crop residue mulched (1.5 t/ha) treatment compared with the non-mulching treatment in the upper 0.15 m depth after three cotton seasons.

Fertilizer management: In salt affected soils the availability of nutrients to the plants is low such as presence of salts, low soil moisture content, high soil pH, poor soil physical conditions, presence of toxic elements and ionic imbalances in soils and plants may be becoming limiting (Choudhary and Yaduvanshi, 2016). So, even the presence of sufficient total quantities of essential nutrients in salt-affected soil does not guarantee the availability of these nutrients to growing plants for optimum crop yields. Use of green manures and organics intensifies the reclamation process by increasing partial pressure of CO₂ and organic acids, improving soil physical conditions, mobilizing Fe and Mn and providing steady supply of nitrogen to the plants. Salt-affected soils are considered to be universally deficient in N and low availability of P and, therefore, crops grown thereon greatly respond to 20-25% higher levels of N and P than the commonly recommended rates. Saline soils often contain medium to high amounts of available K. Soil K application should be followed based on soil test. Saline soils are also deficient in micro nutrients based on their area of occurrence. So, need based micronutrient fertilization should be followed on the basis of deficiency.

Irrigation management: The poor quality of groundwater is a common problem in arid and semi-arid areas and it constitutes 32-84% of irrigation water surveyed in different Indian states. The poor quality water is grouped into two categories i.e saline water (with excess salt) and alkali water (with residual alkalinity) (Minhas, 1996). The use of this poor quality groundwater for irrigations purpose leads to development of root zone salinity (Rhoades et al., 1992). The removal of this root-zone salinity is very important to minimize the adverse impacts of poor quality ground waters in agriculture (Gideon *et al.*, 2002; Katerji *et al.*, 2003). Leaching of

excess salts with good quality waters is the effective approach to control the salinity. However, the limited availability of good quality waters restricts the leaching of excess salts. Therefore, it is indicated that use of deficit (drip) irrigation will be useful to minimize salt build up thereby adverse effects on crop growth can be minimized by lowering the salt load. The application of irrigation water through drip provides better soil moisture regime in the root zone and thus lowering the salinity under drip irrigation than conventional surface irrigation (Saggu and Kaushal 1990). According to Kang *et al.* (2004) the high frequency and low quantity applications of saline water through drip irrigation over a long period of time, can maintain high soil matric potential in root zone, compensating for the decrease of osmotic potential introduced by the saline water irrigation, and constant high water potential can be maintained for the crop growth. Besides this, in drip irrigation system crops tolerated higher level of irrigation water salinity, with lower salt accumulation in the crop root zone and lower leaching requirement as compared to surface irrigation system. Minhas (1996) regarded drip system as the most advantageous method for applying saline water to crops and also for maintaining well aerated conditions in the soil.

Salt tolerant crops and varieties: Crops plants have variable levels of tolerant to salinity. Selection of crops based on their threshold tolerant minimizes the crop failure risks to certain extent. The salt tolerant of important field crops has already discussed in chapter 2 (Table 2.3). The institute has released the 10 varieties of rice, 5 varieties of wheat, 5 varieties of Indian mustard and 1 variety of gram by central varietal release committee for salt affected areas of the country. Further, the intragenic variations are also exists in crop varieties and plant species in response to the salinity stress. This can also be utilized for selecting the crops, crop varieties, and plant species under various ranges of saline soils. Some of the promising tree species suitable for different categories of saline soils are given below.

Saline and waterlogged soils (EC_e, dS m⁻¹ below 0.3 m)	
20-30	<i>Acacia frnesiana</i> (pissi babul), <i>Prosopis juliflora</i> (mesquite, pahari kikar), <i>Parkinsonia aculeate</i> (Jerusalem thorn, parkinsonia), <i>Tamarix aphylla</i> (faransh)
14-20	<i>Acacia nilotica</i> (desi kikar), <i>A. Pennatula</i> (kikar), <i>A. tortilis</i> (Israeli kikar), <i>Callistemon lanceolatus</i> (bottle brush), <i>Casuarina glauca</i> (casuarina, saru), <i>C. obesa</i> , <i>C. equisetifolia</i> , <i>Eucalyptus camaldulensis</i> (river-red gum, safeda), <i>Feronia limonia</i> (kainth, kabit), <i>Leucaena leucocephala</i> (subabul), <i>Ziziphus jujube</i> (ber)
10-14	<i>Casuarina cunninghamiana</i> (casuarina, saru), <i>Eucalyptus tereticornis</i> (mysore gum, safeda), <i>Terminalia arjuna</i> (arjun)
5-10	<i>Albizia caribea</i> , <i>Dalbergia sissoo</i> (shisham), <i>Emblia officianalis</i> (amla), <i>Guazuma ulmifolia</i> , <i>Punica granatum</i> (anar), <i>Pongamia pinnata</i> (papri), <i>samanea saman</i>
<5	<i>Acacia auriculiformis</i> (Australian kikar, akash mono), <i>A. deamii</i> , <i>A. catechu</i> (khair), <i>Syzygium cumini</i> (zamun), <i>salix spp.</i> (willow, salix), <i>Tamarindus indica</i> (imli)
Saline water irrigation (EC_{iw} < 15 dS m⁻¹)	
Very Promising	<i>Acacia nilotica</i> (keekar), <i>Acacia tortilis</i> (Israeli kikar), <i>Acacia farnesiana</i> (pisi babul), <i>Azadirachta indica</i> (neem), <i>Capparis decidua</i> (kair), <i>Eucalyptus camaldulensis</i> (river-red gum, safeda), <i>Feronia Lemonia</i> (Kainth, kabit), <i>Melia azedarach</i> (bakain, dhake), <i>Prosopis juliflora</i> (pahari kikar), <i>P. cineraria</i> (khejri, jand), <i>Phoenix dactylifera</i> (datepalm, khajur), <i>Salvadora persica</i> (jaal), <i>S. oleoides</i> (jaal), <i>Tamarix articulate</i> (faransh), <i>T. troupe</i> , <i>T. eridoides</i>

Promising	<i>Cassia javanica</i> (cassia), <i>C. siamea</i> (kassod, Cassia), <i>Casuarina glauca</i> (casuarina, saru), <i>Dalbergia sissoo</i> (shisham), <i>Eucalyptus tereticornis</i> (mysore gum, safeda), <i>Jatropha curcas</i> (jamalghota), <i>Pithecellobium dulce</i> (jangal jalebi), <i>Punica granatum</i> (anar), <i>Tecomella undulate</i> (rohira, Rajasthani sal), <i>Zizyphus mauritiana</i> (ber), <i>Z. jujuba</i>
Poor	<i>Acacia auriculiformis</i> (Australian kikar, akash mono), <i>Bauhinia variegata</i> (kachanar), <i>Cassia glauca</i> (cassia), <i>Cassia fistula</i> (amaltas), <i>Crescentia alata</i> , <i>Pongamia pinnata</i> (papri), <i>Sizygium cumini</i> (jamun)

Conclusions

Salinity hinders the crop growth right from germination to maturity of crop plants by altering the water relations, nutrient balance, specific ion toxicity etc. Agronomic practices, though cannot reclaimed or remove the salts from the soil, but have potential role in managing the salt and water balance in the crop root zone and apart escaping and tolerance mechanism to the crop plants grown. Adoption of package of best agro-techniques like selection of appropriate crop and its varieties, priming of seed prior to sowing, sowing with appropriate methods, irrigation with minimized salt load in soil, balanced fertilization etc. can sustain the yield of salty soils.

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