

Management of salt affected soils for crop production

Dipak Kumar Gupta¹, Kamla K. Choudhary² and A.K. Shukla³

Regional Research Station, Central Arid Zone Research Institute, Pali-Marwar (Rajasthan) 306 401

Salinity and alkalinity of soil is one of the most severe abiotic factors limiting agricultural production in arid and semi-arid regions of the world. In India, under different agro-ecological regions about 6.74 million ha area is salt affected (saline, saline-sodic and sodic soils) which is severely affecting crop yield. Saline and sodic soils have different characteristics and thus require different strategies for management. There is need for use of efficient technologies for managing these problematic soils for enhancing crop yield especially in arid and semi-arid regions. Among different technologies, growing of salt-tolerant crops; application of amendments (gypsum, organic manure and green manuring) and surface- and sub-surface drainage is most effective in managing sodic as well as saline soils in arid and semi-arid regions.

Key words: Arid region, Crop, Management, Production, Saline irrigation, *Sesbania aculata*, Sodic soil, Water

DRY areas specially arid and semi-arid regions are characterized by harsh climatic condition with limited natural resources. Soil which is most important component for agricultural production is low in fertility and also problematic in this region due to high salt content. Further, these regions is facing dual water problems: very low rainfall and poor quality of available water. Most of the available groundwater in these areas has high salt content, which further enhances salt content in soil after irrigation with this water. Salinity and alkalinity of soil is one of the most severe abiotic factors limiting agricultural production in arid and semi-arid regions of the world. Excessive soluble salts in the saline soil limit the ability of plant roots to absorb soil water even under wet soil conditions, while high sodium (Na) content in sodic soil reduce the availability of Ca, Mg, and other micronutrients, and finally deteriorate physical condition of soil. Poor physical structure of soil results difficulty in tilling, poor seed germination owing to soil crusting

and restricted plant root growth. Owing to poor physical structure, sodic soils are susceptible to wind and water erosion than saline soils. All these negative impact of salt accumulation on the soil finally affect growth and yield of the crops. Further more, the area under this category is rising due to faulty management of irrigation water, seepage loss, impeded drainage, rapid rise of water-table causing water-logging due to secondary salinization. Therefore, management of salt affected soil becomes necessary for ameliorating negative impact and enhancing agricultural production in these regions. Each type of salt-affected soil has different characteristics and thus required different strategies for management. The selection of appropriate technology for reclamation of salt affected soil is necessary for enhancing crop production and farmers income.

Extent of salt affected soil

According to Food and Agricultural Organisation (FAO), globally the total area of saline

soils are 397 million ha (3.1%) and that of sodic soils 434 million ha (3.4%). Highest salt affected soils are present in Asia and Pacific, and Australia. It accounts for 6.3 % and 8% of total area of this zone affected by soil respectively in India. According to Central Soil Salinity Research Institute, Karnal in 6.74 million ha area is salt affected under different agro-ecological regions, out of which 3.79 million ha is alkaline soil while 1.71 and 1.24 million ha is saline and coastal saline area respectively. According to the available estimates, almost 15% of the total cultivated lands in India are influenced by salinity. About 80% sodic lands in the country are found in Uttar Pradesh, Gujarat, Maharashtra, Tamil Nadu, Haryana and Punjab. Gujarat (1.22 Mha) followed by Rajasthan (0.2 Mha) and Maharashtra (0.18 Mha) has thus highest area under saline soil, whereas Uttar Pradesh (1.35 Mha) followed by Gujarat (0.54 Mha) and Maharashtra (0.42 Mha) has largest area under sodic soil. According to Rajasthan Agriculture Department, about 0.42 and 0.45 million ha of

land are saline and sodic respectively. In Rajasthan, Jaipur (74,224 ha) followed by Sikar (59,936 ha), Bharatpur (32,613 ha), Bhilwara (27,950 ha) and Pali (26,374 ha) have highest saline soil while Alwar (97,625 ha), Pali (57,662 ha), Bharatpur (45,217 ha), Dausa (38,437 ha) and Sikar (30,036 ha) districts has highest sodic soil.

Salt affected soil and their impacts on plants

To enhance crop production and income from salt affected soil, it is necessary to identify type and severity of problem followed by suitable technology intervention. This requires expertise and chemical analysis of soil. Salt affected soils can be visually identified; however, chemical analysis is required for the quantification of severity of problem and designing strategies for management. Visually this salt-affected soil can be identified by presence of white layer of salt deposition on soil surface (Fig. 1a). Chemically, soil having electrical conductivity greater than 4 dSm^{-1} at 25°C , exchangeable sodium percentage (ESP) less than 15 and pH lower than 8.5 is characterized as saline soil. In contrast to saline soils, sodic soils have excessive levels of sodium (Na^+), high concentration of carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) and very low Ca^{2+} and Mg^{2+} adsorbed at the cation exchange sites leading to soil dispersion, poor soil structure, soil crusting and poor soil aeration and water infiltration. All these affect plant germination, root growth, crop development and yield negatively. Sodic soils are chemically characterized with Electrical Conductivity (EC) less than 4 dSm^{-1} , ESP and soil pH greater than 15 and 8.5 respectively. Visually this type of soil can be identified by soil crusting and presence of black color powder on soil due to dispersion of organic matter (Fig. 1b). Saline-sodic soil has EC greater than 4 dSm^{-1} and ESP greater than 15, while, soil pH can be above or below 8.5.

Factors responsible for development of salt affected soil

In arid and semi-arid climates, there is not enough rainfall to leach

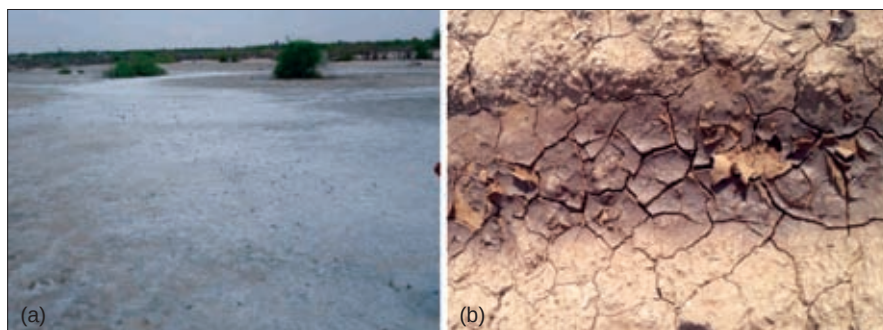


Fig.1. (a) Saline soil (b) Sodic soil

soluble salts which originates from parent material.

An additional factor in causing salt-affected soils is the high potential evapotranspiration in these areas, which increases the concentration of salts in both soils and surface water. Indira Gandhi Canal command area in Rajasthan has resulted into expansion of area under cultivated and crop production due to assured irrigation facility. It has also resulted into rise in water-table, waterlogging, soil salinity and alkalinity in canal command area and adjoining Ghaggar basin in Ganganagar district. Irrigation of non-saline soils with saline water can also cause salinity problems. One of the major problems in irrigated areas of arid region is that the irrigation water has high salinity, and when the soils are irrigated with this water, salts accumulate unless they are leached out due to low rainfall and high evapo-transpiration.

Management of salt affected soil

The main strategies adopted for managing salt affected soil for better crop production is removal of excess soluble salts from crop root zone. This can be achieved by: (i) reclamation of sodic soils by chemical amendments, (ii) reclamation of saline soils by leaching and surface and sub-surface drainage, (iii) use of salt-tolerant crops and plant varieties, and (iv) management of saline and sodic irrigation water.

Reclamation of sodic soils: Strategy for reclaiming sodic soil is first to replace the excessive sodium (Na^{+2}) from the cation exchange sites and its replacement by more favorable calcium (Ca^{+2}) ions in the root zone. Various chemical compounds with appreciable soluble calcium content

[gypsum, calcium chloride, press mud, acids, acid formers (sulphur), pyrites, fly ash and organic materials] were tried in varying agro-ecological situations in India. Among these, gypsum is easily available, low-cost and efficient amendment. The technology is very simple and consisted of land levelling and bunding (for rainwater storage and uniform distribution of irrigation water), determination of gypsum requirement, uniform application of gypsum followed by mixing in surface (10 cm) soil, ponding water for minimum 7 days before sowing or transplanting. The quantity of the gypsum to be added depends on the soil analysis and can simply be determined by soil pH and texture of the soil. The Government of Rajasthan provides 50% subsidy to farmer on district-wise rate of gypsum for maximum area of 2 ha for its wider adoptability and reclamation of sodic soil. Use of gypsum in sodic soils is more effective when applied in combination with farmyard manure. The application of gypsum @ full gypsum requirement (GR) + farmyard manure 10 tonne/ha⁻¹ proved useful in lowering down the pH (9.38 to 8.15) and ESP (61.67 to 41.08) as well as increasing seed and stover yield of Taramira. Research at RRS, CAZRI, Pali showed that application of 8 tonne/ha farmyard manure and gypsum @ 50% gypsum requirement is effective to ameliorate the adverse influence of soil sodicity on pearl millet production. Application of farmyard manure @ 10 tonne/ha or *dhaincha* as green manure crop is helpful in minimizing the effects of sodicity in pearl millet. *Dhaincha* (*Sesbania aculata*) best green manuring crop

Table 2. Performance of wheat varieties under saline and sodic condition at Pali

Wheat varieties		Yield (kg ha ⁻¹)	Net Return (₹ ha ⁻¹)	B:C Ratio	% Yield Increase
Farmers' practice	Local cv.	2,020	14,120	2.1	-
Recommended	Raj 3077	2,360	18,260	2.5	11.4
Intervention	KRL-19	2,630	21,720	2.7	30.2

for alkali soils, showed potential to withstand alkalinity (9.5 pH), waterlogging (1.5 to 1.8 mm) and good ratability.

Reclamation of saline soils: Saline soils can be reclaimed by scraping or flushing out the accumulated salt on the soil surface, however, these are less effective and costly. Leaching with good quality (low EC) water along with surface and sub-surface drainage is most effective for removing salt from root zone. For successful reclamation, salinity should be reduced in the top 45 to 60 cm of the soil to below the threshold values for the particular crop being grown. A thumb rule is that a unit depth of water will remove nearly 80% of salts from a unit soil depth. Thus, 30 cm water passing through the soil will remove approximately 80% of the salts present in the upper 30 cm of soil. However, in this method, reclamation can be hampered by restricted drainage in area of high watertable, low soil hydraulic conductivity due to restrictive soil layers and lack of good-quality water. Therefore, adequate drainage facility should be created before leaching and period of leaching should be selected when watertable is low and is better just preceding monsoon season to utilize rainfall effectively.

Surface drainage is used to remove excess water from surface of the soil. It is achieved normally by opening of shallow ditches/open drains which is directed to discharge into larger and deeper collector drains by creating artificial slope. Subsurface drainage had remarkable impact on crop yield, farm income and employment. It helped in reducing watertable and salinity level by 25% and 50% respectively and enhancing yield of rice, cotton, sugarcane and wheat by 69%, 64%, 54% and 136% respectively in waterlogged saline soil of canal irrigated area in arid and semi-arid region of India. A composite pipe sub-surface drainage

system with drain spacing of 150 m and a drain depth of 1.20 m, in combination with a geotextile envelope was recommended for the sandy soils in the arid lands of Rajasthan for enhancing crop yield in waterlogged canal irrigated saline area. Despite all the positive points associated with sub-surface drainage of salt affected areas, the drainage technology could gain momentum only with the support from Government, mainly due to high costs. The technology initially got impetus in Haryana, followed by widely adopted in Rajasthan, Gujarat, Punjab, Andhra Pradesh, including Telengana, Maharashtra and Karnataka. About 15,000 ha in Chambal command area of Rajasthan was treated successfully by subsurface drainage technology.

Selection of salt tolerant plants and varieties: Plants differ a great deal in their ability to survive and yield satisfactorily when grown in saline soils. To get good crop yield from saline soil, it is necessary to select crop and variety which are relatively salt-tolerant. Crops like barley, sugarbeet, cotton etc. are classified as salt-tolerant. While wheat, oats, sorghum, maize, sunflower, potato and soybean are classified as moderately salt-tolerant and corn, alfalfa, pulses, many clovers, citrus, grape and most vegetables and fruit trees are sensitive varieties to salt. However, grape and citrus can be grown on salt-tolerant rootstock. Further, salt-tolerant varieties of important crops are CSR-10, CSR-13, CSR-23, CSR-27, CSR-30, CSR-36, Sumati and Bhutnath of rice, KRL-1-4, KRL-19, KRL-210 and KRL-213 of wheat, and CS-52 and CS-54 of mustard. These varieties are grown widely in salt affected areas of Punjab, Haryana, Rajasthan, Uttar Pradesh, Gujarat, Maharashtra, West Bengal etc. and are contributing immensely to the food basket of salt affected areas. One farm trial on

**Fig. 2.** Performance of wheat variety KRL-19 at farmers' field, Pali

farmers' field at district Pali (villages Rampura and Denda), Rajasthan, showed that performance of wheat (KRL-19 variety) under saline irrigation water (pH 7.7 to 8.1 and ECe 5.12-9.0) and sodic soil (pH 8.9 to 9.4 and ECe 0.98 to 2.4) conditions was far better than local and recommended variety. It improved the grain yield by 30.2% and 11.4% over local and recommended variety, respectively (Table 2, Fig. 2). This demonstration led to widespread adoption of wheat variety KRL-19 by farmers of villages Rampura and Denda. At RRS, CAZRI, Pali, cultivars NH-419, ST-89, Soneten-2-22, Kuran-42 and Mundra- 89 of pearl millet, SPV-678 of sorghum, HD-1152 and kharchia of wheat and DIRA-337 of mustard produced better yield under saline water irrigation.

SUMMARY

Salinity and sodicity of soil is major problem in arid and semi-arid regions of India. This constraint limits the agricultural production in these regions. The knowledge of extent and type of problematic soil is necessary for proper management and enhancing crop yield in this region. For enhancing crop production on sodic soil the most effective technologies are: application of gypsum, organic manure, green manure (*Sesbania*) and their combination in sodic soil, while, leaching with provision of sub-surface drainage, use of drip irrigation system and salt-tolerant crop and varieties in saline soil.

^{1,2} Scientist, ³Head RRS, CAZRI, Pali. Corresponding authors' e mail: anilciah@gmail.com