AgroPedia
e - Publication for Agriculture Popular Articles
Volume: 03, Issue: 09 (September, 2026)
ISSN: 3048-6580
Available online at: https://www.agropedia.co.in

Crop Response and Management to Stress of Sodic Soil Situation

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The increase in population of both human and animals in the last century and intensification of agriculture with fast growing industrialization and urbanization in last few decades have overstrained the natural resources which have been degraded much faster than ever before. Soils are considered as the integral part of the landscape and their characteristics are largely governed by the landforms on which they have developed. In Maharashtra, salt affected soils are 606759 ha (saline: 177093 ha and sodic: 422670 ha and 6996 ha of coastal saline soils) (CSSRI, 2025), which are distributed in Sangli (Bank of river Krishna), Ahilyanagar (Pravara, Godavari, Mula river and command area), Pune (Nira command area), Solapur (Ujani command area) and Nashik (Godavri river and command area) districts as well as canal command areas of these rivers. Every year 10 % lands are deteriorating in canal command area.

The soil condition in irrigated areas of Maharashtra are fragile and especially the soils of canal command area are prone to degradation due to salinity and sodicity owing to injudicious management of canal irrigation water, very low hydraulic conductivity, slow permeability of smectite dominant shrink-swell clay soils, associated with semi-arid climate resulting in accumulation of salts. 'Salt affected' refers to soils with substantial enough salt concentration to affect plant health, soil properties, water quality and other land and soil resource uses. These soils can substantially reduce land value and productivity. Sodic soil is a major limiting factor of agricultural sustainability and recovery functional environments in irrigated agriculture. The low productivity in sugarcane due to injudicious use of irrigation on shrink-swell soils of Maharashtra. The severity of salinity and sodicity of these soils is being further aggregated by the semi arid climate, topography, indiscriminate use of irrigation water and restricted drainage.

Hiller and Pharande (2008) studied shrink-swell soils of irrigated and rainfed area of Maharashtra in which they reported that the presence of palygorskite in the irrigated soil is believed to be a direct consequence of irrigation and its effect on soil chemistry and moisture regimes which indicates that pedogenic palygorskite formation can be an extremely rapid process, the transformation of smectite to palygorskite has decreased the CEC of the soils and may have an impact on other soil properties that are clearly undesirable from a soil quality perspective.

Origin of salts in soil

The main source of all salts in the soil is the primary minerals in the exposed layer of the earth's crust. The released salts are transported away from their source of origin through surface or groundwater streams. The salts in the groundwater stream are gradually concentrated as the water with dissolved salts moves from the more humid to the less humid and relatively arid areas. The predominant ions near the site of weathering in the presence of carbon dioxide will be carbonates and hydrogen-carbonates of calcium, magnesium, potassium and sodium; their concentrations, however, are low. Salts released through weathering in the arid regions with limited rainfall are usually deposited at some depth in the soil profile, the depth depending on such factors as the water retention capacity of the soil, seasonal, annual and maximum rainfall, etc. If the salts are deposited beyond the rooting zone of most crops, say below 150 cm, they rarely affect the crops adversely unless they are redistributed and accumulate in the surface soil layers.

Important properties of salt affected shrink-swell soils of Maharashtra

Sodic soils

Soils which contain sufficient exchangeable sodium (ESP > 15 and pHe > 8.5) to cause soil dispersion. An increase in soil pH thereby adversely affects the both physical and nutritional properties of soil. A build up in exchangeable Na is caused by presence of Na_2CO_3 in measurable quantity. The important characteristics are presence of alkali salts (Na_2CO_3) and salt encrustation which is marked with black colour near organic matter spot. Most of the time water does not penetrate into soil solum, water stagnate for longer time due to poor physical properties of soil. Sodium forms the most soluble salts that stay longer in solution with decreasing soil water. Less soluble salts precipitate at deeper depth in the profile than Na salts. Sodium concentration increases in the soil solution and Na+ becomes the dominant cation.

The Na/Cl or Na/Cl + SO_4 ratio is > 1.0 and gypsum content is absent in these soil. The crop shows scorching and leaf burns symptoms typical of any toxicity or yellowing of leaves due to poor physical properties. Characteristic properties of sodic soil are: pHs > 8.5, ECe < 4 dSm^{-1} and ESP > 15.0. Chemistry of soil solution dominated mainly by HCO_3^- and CO_3^{2-} anions or both effect of electrolytes on soil particles leads to dispersion. Alkalinity of soil solution, geographical distribution associated mainly with arid and semi arid areas. Sodic soils are inherently low in organic matter (<0.1%), and available N, and are more responsive to N application. These soils are more prone to N losses due to higher N volatilization caused by high pH, further aggravating N deficiency. Microbial activity, which influences N mineralization, is restricted by salt stress.

Saline sodic soils

Soils which contains excessive soluble salts as well as higher exchangeable sodium percentage (ESP > 15) with variable paste extract pH (> 7.5).

Constraint in salt affected soils

1. Effective soil depth: Salts accumulated in upper surface layer in which osmotic potential

increased due to salt accumulation in rhizospheres which inhibits the uptake of water and nutrients in saline and saline-sodic soil. However, hard crustation in sodic soil developed due to dispersion of clay particles under strongly alkaline and ESP condition which inhibits the germination of seed and reduce infiltration rate and hydraulic conductivity of soil which leads to water lagged conditions.

2. The sodic soil have a high bulk density (upto 1.5 to 1.65 g cm^{-3}) resulting in poor root penetration and proliferation and also impended drainage.

3. Pore space distribution is low and little air space at field capacity. The sodic soils may have a non capillary porosity as low as 2 % at which the normal aeration of the plants is adversely affected.

4. Dispersion coefficient is high which causes in the low permeability of the sodic soils by sealing the surface pores under the impact of rainfall.

5. Infiltration rate of sodic soil is very low (below 0.1 cm hr^{-1}) due high pH, increase in ESP of sodic soil and prone to severe erosion.

6. Soil water availability to plant decrease in saline soil due to increase in the osmotic pressure of soil solution and in sodic soil due to high matrix potential of soil water which is not available for plant.

7. Saline soils are behaving as normal soil in respect of physical properties however, yield reduction is due to salt accumulation in rhizosphere leads to increase in osmotic pressure of soil water.

8. Sodic soils behaves high swell properties during rainy season due to imperfect drainage condition reflecting on reduction of yield of various crops.

9. Salt encrustation and salt mixed degraded soil structure inhibits the germination of seed of many salt sensitive crops e.g. pulse crops in saline and saline-sodic soil respectively.

10. Udic to aquic moisture regimes hinders the root growth of many salt sensitive crops.

11. High COLE value indicating high shrink-swell properties due to sodiumised clay reflects on low available water to crop in saline-sodic and sodic soil.

12. Compaction in subsurface layer due to high BD reflects the improper root growth of pulse crops in sodic soils resulting wilting of crops.

Reclamation and management of sodic soil

The reclamation is comparatively easy in saline soils. The main problem is to leach the salts below the root zone. Following two methods may be used for removal of salts

A. Mechanical control measures

a. Flooding and leaching of the soluble salts

The leaching can be done by ponding with good quality water on the land and allow it to stand for a week. Most of the soluble salts would leach down below the root zone. After a week standing water (dissolved with soluble salts) is allowed to escape through drain. Such 2 to 3 ponding treatments are require reclaiming highly saline soils.

b. Scraping of the salt crustation

In summer season the soluble salts accumulate on the soil surface, scraping helps to remove salts. This is a temporary cure, however, salinity again develops on such lands. The provision of surface drainage, subsurface drainage and tubewell drainage is the essential component before reclamation of soils.

c. Surface drainage

Open drains are advantageous for removing large volumes of either surface or subsurface water. They are also disposing of storm water. However, there are some disadvantages like unutilization of land for production and requires frequent maintenance due to growth of obnoxious weeds. Therefore, subsurface drainage techniques are useful which includes pipe drains and mole drains.

d. Subsurface drainage

If the soil is not free draining, artificial perforated pipe subsurface drains are opened or tile drains laid underground to help wash out the salts.

e. Mole drainage

Mole drainage is an inexpensive and effective method of drainage which is widely used in the clay soils. It is generally confined to soils having a minimum clay content of about 30-35 %. The mole channel is formed by pulling a bullet shaped steel plug of about 75 mm diameter through the soil at desired depth.

A mole drainage system can be created by pulling through the soil at the desired depth with the help of mole plough. A pointed cylindrical plug about 7-10 cm in diameter attached to a plough (like subsoiler).

The compressed wall channel thus, formed provides a mechanism for removal of excess water with salt. The mole drainage system with 4.0 m mole spacing and 0.60 m depth is recommended for effective drainage and to obtain higher crop yield from ill drained deep black soils.

f. Tubwell drainage

Under some conditions, pumping ground water to provide land drainage is an effective method of lowering a high water table and reducing salt hazards in irrigated area.

g. Bio drainage

Use of quick growing plants (exotic trees) has been utilized to improve marshy and waterlogged lands. It is because such plants draw water at a fast rate. This system of drainage requires through investigations on plant species to suit specific areas particularity in saline soils. The deep rooting characteristics of trees make them extremely efficient users of water. While shallow-rooted grasses and crops have limited access to underlying water tables, deep-rooted trees can access water tables down to several metres.

The most promising forest species identified for planting in highly alkali soils include; *Prosopis juliflora*, *Tamarix articulata*, *Acacia nilotica*, *Casuarina equisetifolia* and *Eucalyptus tereticornis*. A special site preparation technique called “auger hole planting technique” has been developed.

B. Cultural techniques

a. Ploughing and leveling of the land

Ploughing and leveling of the land increase the infiltration and percolation rate. Therefore, salts leach down to the lower horizons.

b. Use of good quality salt free irrigation water

The good quality of irrigation water should be used to reduce the salt load by using drip, sprinkler and subsurface irrigation systems except injudicious flood irrigation methods.

c. Proper use of irrigation water

It is known that as the quantity of water in the soil increases resulted in to decrease in the concentration of salts in the soil solution. Thus, moisture should be kept at optimum level or at field capacity.

d. Planting or sowing of seeds middle of the furrow

The salt concentration even in smaller amounts is most harmful to the germinating seeds and seedlings. Water generally evaporates from the highest surface by capillary and hence these points have maximum salt concentrations. If the seeds or seedlings are planted on middle of the furrows, they escape zone of maximum salt concentrations.

e. Use of organic manures

The organic manures *viz.*, Farm Yard Manure (FYM), Vermicompost (VC) and Press Mud Compost (PMC) are effective for improving physical properties and drainage condition of soil, water and nutrient holding capacity of soil. The addition of organic matter reduces the alkalinity. Organic matter is especially helpful where sulphur is added to correct the alkalinity. The organic matter supplies food for the bacteria that stimulates the oxidation of sulphur to the sulphate form. The combination of sulphur, organic matter and gypsum has also been used successfully.

Addition of PMC compost in soil decreases the pH of soil and improves the hydraulic conductivity of soil and structure. Hence, 5 t ha^{-1} PMC compost is generally recommended for reclamation of sodic soil.

f. Use of green manuring crops

The green manuring crops like dhaincha and sunhemp should be included in crop rotation for maintaining physical and biological health of salt affected soils.

g. Mulching

Mulching by using crop residue, polythene sheet and sugarcane trash management results into reduction in soil water loss through evaporation and capillary rise of ground water therefore, salt load remain in lower horizon. Soil moisture may be conserved by reducing the water evaporation. Thus, salts may remain in the lower horizon below root rhizosphere.

h. Growing of salt tolerant crops

a) High salt tolerant crops: Barley, sugar beet, cotton etc.

b) Moderately salt tolerant crops: Sugarcane, wheat, rice, sorghum, maize etc.

c) Low salt tolerant crops: Beans, radish, white clover, pulse crop etc.

C. Chemical methods

a. Application of gypsum: Effect of gypsum on yield and soil properties

Gypsum requirement of sodic soils can be determined in the laboratory. Moreover, it reduces pH, electrical conductivity and sodium adsorption ratio of soils which resulted in improving the drainability and other physico-chemical characteristics of soil. The gypsum required for the improvement of sodic soil should be incorporated before sowing of crops and mixed it thoroughly in upper 15 cm soil layer by harrowing. If there are lumps in gypsum, it should be applied in fine powder to increase its efficiency.

The different amendments are also available that can be used for reclamation of sodic soil considering their efficiency (Table 1).

Table 1. Estimated efficiencies of various materials used to reclaim soils compared to gypsum

Amendment	**Gypsum equivalent**
Gypsum ($CaSO_4 . 2H_2O$)	1.00
Sulphur (S)	0.18
Sulphuric acid (H_2SO_4)	0.57
Iron sulphate ($FeSO_4 . 7H_2O$)	1.62
Iron pyrite (FeS_2)	0.63

b. Organic amendments

Role of organic amendments like FYM, pressmud cake, molasses, green manuring, groundnut and safflower husk, wheat straw etc. is well known in improving the properties of soils. These organic amendments may be less effective in reclaiming the sodic soils but its synergistic effects can be exploited for reducing the doses of chemical amendments by improving their efficiency. When Gypsum @ 50 per cent GR was applied in combination with FYM @ 5 t ha^{-1} or PMC @ 2.5 t ha^{-1} to sodic soils, it enhanced the grain yield of crops and also improved the physical and chemical characteristics of soil over gypsum or FYM or PMC when applied alone.

c. Frequency of gypsum application

Considering the large quantity of gypsum requirement for improvement of sodic soil, frequency of gypsum incorporation is an important factor in relation to economics of gypsum application and favourable changes made in soil properties.

d. Agronomic practices

1. Proper leveling of land should be achieved before flooding or leaching.

2. Periodic soil testing for gypsum requirement and fertility status before and after reclamation.

3. Frequent light irrigation is better than heavy irrigation.

4. Dilution of saline water with good quality of water for irrigation.

5. Heavy textured soil and salt tolerant crops, the maximum permissible limit for EC of water is 1.5 dSm^{-1} while light textured soil, water with EC up to 8 dSm^{-1} could be used for tolerant crop.

6. Use of green manuring crops like Dhaincha which tolerant to flooding and salts.

7. Use of bulky organic manures, rice husk and crop residue management is essential to keep good physical condition of soil.

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