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Reclamation of Sodic/Alkali Soils by using Gypsum

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All soils and natural waters contain soluble salts. The amount of salts in the root zone (or the salt concentration in the soil solution) determines whether the soil is “normal” or "salt-affected" when an "excessive" amount or concentration of soluble salts occurs in the soil and it adversely affects crop growth. Saline soils develop under the influence of chloride and sulphate ions whereas, sodic/alkali soils formed under the influence of sodium ions. The salt affected soils account for 6.72 Mha equivalent to 2.1 % of the geographical area of India. Out of which, 2.95 Mha are saline and the rest 3.77 Mha are sodic/alkali.

In Rajasthan, salt affected soils account for 374,942 ha out of which 195,571 ha is saline soil and 179,371 ha area is sodic soil. Based on soil pH, EC and ESP of soil, the US Salinity Laboratory Staff in 1954, originally proposed the three categories of salt-affected soils *i.e.*, saline, saline-alkali and sodic/alkali soils.

Table - 1 Classification of salt affected soils according to USDA system

Classes	ECe (dS m^{-1})	pH	SAR	ESP (%)
Saline	>4	<8.5	<13	<15
Sodic/Alkali	<4	>8.5	>13	>15
Saline-sodic	>4	>8.5	>13	>15

Process of Soil Alkalization

Addition of sodium-containing salts particularly its carbonates to the soil may result in saturating the soils exchange complex with Na. As the salt concentration increases, calcium and magnesium may precipitate as their respective carbonates. It causes calcium carbonate to accumulate in the soils and results in a gradual increase in proportion of sodium in solution and thereby the proportion of the sodium adsorbed on soil colloids also increases. The process of progressively increasing the Na saturation on the soils exchange complex is called sodication. Sodication induces deterioration in physical properties and the soils so formed are called sodic soil, solods, solonetz or black alkali soils. If these soils occur only in small areas (in small localized spots), are often called slick spots. The major sources of salt are weathering of rock which causes alkalization of soils by hydrolysis of either the exchangeable cations or of salts such as Na_3CO_3, $CaCO_3$ and $MgCO_3$, etc. Hydrolysis of the exchangeable cations takes place according to the following reactions-

$$Na_2CO_3 + 2HOH = 2Na^+ + 2OH^- + H_2CO_3$$

Calcareous soils having a significant amount of calcium carbonate which on hydrolysis produce alkalinity, as given in the following equation-

$CaCO_3 + H_2O = Ca^{2+} + HCO_3^- + OH^-$

Degraded alkali soils develop as a result of leaching of saline-alkali soils in the absence of any soluble sources of Ca^{2+} and Mg^{2+}. In absence of Ca^{2+} and Mg^{2+}, the exchangeable Na^+ is replaced by H^+ ions and surface soil become slightly acidic, due to high concentration of H^+ on soil exchange complex and Na_2CO_3 deposited in sub surface soils and cause alkalinity.

Na [clay + H_2O = H [clay + NaOH (Development of acid soils on surface horizons)

$2NaOH + CO_2 = Na_2CO_3 + H_2O$ (Development of alkali soils in subsurface horizon)

Effect of Soil Alkalinity on Plant Growth

The physical properties of soil are adversely affected by increasing the ESP (or pH) and cause various problems for plant growth such as:

- Formation of surface soil crust which affect the emergence of seedling.
- Soil compaction creating problems for root penetration and soil tillage.
- Due to dispersion of soil particles, entry of air and water in soil is restricted.
- Restricted internal drainage is causing water logging.
- Adverse crop growth is due to direct toxic effects of sodium. The adverse effects of soil alkalinity may appear as a result of a combination of more than one factor.

Reclamation of Sodic/Alkali Soils by using Gypsum

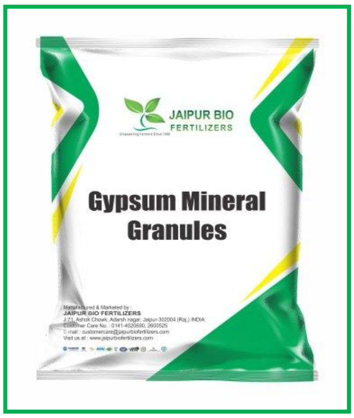
Mined gypsum is the most commonly used chemical amendment for sodic soil reclamation because of its abundant availability and low cost. Chemically gypsum is $CaSO_4.2H_2O$ and occurs extensively as the natural deposits. In India, gypsum deposits have been estimated to be more than 1000 Mt. It must be ground before it is applied to the soil. Gypsum has been used successfully to reclaim the sodic soils and enhance crop productivity of barren lands.

$2Na - X + CaSO_4 = Ca - X + Na_2SO_4$ (leachable)

Gypsum Requirement of Soil-

The gypsum requirement for amelioration of alkali/sodic soil depends upon exchangeable sodium to be replaced, exchange efficiency and depth of soil to be reclaimed. The gypsum requirement of a soil depends upon the following factors-

- Soil texture and mineralogical make-up of the clay,
- Extent of ESP value of the soils,
- SAR of irrigation water,
- Soil depth up to which excess adsorbed sodium must be replaced and
- Crops intended to be grown.



Gypsum requirement depending upon initial level of exchangeable sodium and its reduction to a desired level of exchangeable sodium per unit area and per unit depth of soil, can be calculated by using the following equation-

$$\textbf{GR}\ (\text{cmol/kg}) = \frac{[\text{Ex. Na}_{Initial} - \text{Ex. Na}_{Final}]}{100} \times \text{CEC}$$

Whereas, Ex. $Na_{Initial}$- Initial level of exchangeable Na,

Ex. Na_{Final}- Final level of exchangeable Na

CEC- Cation Exchange Capacity (cmol/kg)

Since, one cmol/kg gypsum is equal to 860 kg gypsum/10^6 kg soil, for one hectare to a depth of 0-15 cm (2×10^6 kg soil), the GR (kg/ha) can be calculated by the following equation-

GR (kg/ha) = GR (cmol/kg) × 1720

Because of the presence in some sodic soils of free soda, the actual efficiency is lower. Thus, it is recommended that the amount of applied gypsum be increased in accordance with equivalents of free sodium carbonate and bicarbonate.

Method of Gypsum Application

The effectiveness of amendment depends on the application method. Gypsum is normally applied through broadcasting method and then incorporated in the soil by disking or ploughing. The depth of mixing gypsum depends on the depth up to which excess adsorbed sodium must be replaced for satisfactory crop growth. Usually, gypsum is incorporated in the surface 0-10 cm soil. However, finer the gypsum particles more effective they are likely to be for the reclamation of sodic/alkali soils. The size to which gypsum must be ground is a matter of economic consideration. Mined gypsum ground to pass through 2 mm sieve has been found to be cost effective and efficient. Under field conditions, one irrigation prior to application of an amendment would further ensure leaching of soluble carbonate, eliminate the need for additional quantities of gypsum for neutralizing the free sodium carbonate.

Application of Gypsum with Organic Amendments

Various organic amendments, such as farmyard manure, pressmud and municipal solid waste, compost alone or in combination with chemical amendments, have been investigated for their effectiveness in sodic/alkali soil reclamation besides their role as a fertilizer. Organic amendments release certain organic acids and carbon dioxide during decomposition which enhance solubility of native $CaCO_3$ and thus provide Ca^{2+} for the removal of exchangeable Na^+. Organic manure improves soil structure and improves aggregate formation and soil permeability particularly in sandy soils, and increases the cation exchange capacity of the soil and thus enhance removal of salts through leaching.

Conclusion

At present, gypsum is the most commonly used chemical amendment used for reclamation of sodic/alkali soils. Chemical methods for sodic/alkali soil reclamation are not cost-effective because shortage of fresh water for leaching of salts, high costs of construction and maintenance of drainage systems. Application of organic manures in combination with gypsum can help to reduce the gypsum dose to half of that needed.