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Application of Gypsum for Reclamation of Sodic Soils

([*]Ravi Saini[1], Siyaram Meena[1] and Bhanu Verma[2])

[1]Ph.D. Scholar, Division of Soil Science and Agricultural Chemistry, ICAR-IARI, New Delhi-110012

[2]Ph.D. Scholar, Division of Seed Science and Technology, ICAR-IARI, New Delhi-110012

[*] ravisaini09121998@gmail.com

All soils contain some quantity of salts, which is required for a healthy growth of the plants. Such soils, which contain excess soluble salts and adversely affect the plant growth, are called salt affected soils. Saline soils develop under the influence of chloride and sulphate whereas, alkali soils, formed under the influence of sodium ions capable of alkaline hydrolysis. The salt affected soils account for 6.727 Mha equivalent to 2.1 % of the geographical area of India (Dagar *et al.*, 2019). Out of which, 2.956 million ha are saline and the rest 3.771 million ha are sodic. In Rajasthan, salt affected soils account for 374,942 ha out of which 195,571 ha is saline and 179,371 ha area is sodic. The US Salinity Laboratory Staff in 1954, originally proposed the three categories of salt-affected soils *i.e.*, saline, saline-alkali and alkali soils based on soil pH, EC and ESP of the soil.

Table - 1 USDA system for classification of salt affected soils

Class	ECe (dS m^{-1})	pH	ESP (%)
Saline	**>4**	**<8.5**	**<15**
Sodic	**<4**	**>8.5**	**>15**
Saline sodic	**>4**	**>8.5**	**>15**

Alkalization in Soil

The major sources of salts are weathering of rock which causes alkalization of soils by hydrolysis of either the exchangeable cations or of such salts as Na_3CO_3, $CaCO_3$, $MgCO_3$, 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 and Mg. In absence of Ca and Mg the exchangeable Na is replaced by H^+ ions and surface soils 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.

$$Na\,[clay + H_2O = H\,[clay + NaOH$$
(Acid soils on surface horizons)

$$2NaOH + CO_2 = Na_2CO_3 + H_2O$$
(Alkali soils in subsurface horizon)

Soil Alkalinity and Plant Growth

With increasing ESP (or pH), the soil physical properties are adversely affected and cause various problems for plant growth including:

- Restricted entry of air and water in the soil due to dispersion of soil particles
- Restricted internal drainage is causing water logging.
- Formation of surface soil crust affecting seedling emergence.
- Compaction of soil creating problems for root penetration and soil tillage.
- 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 Soils using Gypsum

Gypsum is the most widely used chemical amendment for the reclamation of saline-sodic soils because of its low cost, general availability, and rich supply of Ca^{2+} followed by leaching can ameliorate saline-sodic soils (Murtaza *et al.*, 2009).

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

1) 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,
- Crops intended to be grown, and
- Soil depth up to which excess adsorbed sodium must be replaced.

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 using the following equation,

GR (cmol/kg) = (Initial level of exchangeable Na- Final level of exchangeable Na) × CEC

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 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.

2) Method of Gypsum Application

The effectiveness of the amendment depends on the application method. Gypsum is normally applied broadcast and then incorporated with 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, the finer the gypsum particles the more effective they are likely to be for the reclamation of sodic 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.

3) 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 soil reclamation besides their role as fertilizer. Organic amendments release certain organic acids and carbon dioxide during decomposition which enhance solubility of native $CaCO_3$ and thus provide Ca 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.

In wheat-based cropping system gypsum applied at a rate of 12- 15 ton/ha (50% GR of 0-15 cm soil) is sufficient to initiate the reclamation process. Field studies have shown that gypsum dose could be reduced from 50 to 25 % when FYM @ 20 ton/ha was applied (Yadav and Chhipa, 2007).

Conclusions

At present, gypsum is the most commonly used chemical amendment used for sodic soils reclamation. Chemical methods for sodic soil reclamation are not cost-effective because shortage of fresh water for leaching of salts, and 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.

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