Gypsum Technology: A Cost-Effective Strategy to Recoup Alkali Soils on a Sustainable Basis

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OPEN ACCESS

Keywords

Soil, Gypsum, Sustainability, Alkali

How to cite this article

Reddy, M. B., Kumar, M., Mahapatra, A., Sravani, P. and Sravani, S. 2022. Gypsum Technology: A Cost-Effective Strategy to Recoup Alkali Soils on a Sustainable Basis. *Vigyan Varta* 3(9): 39-41.

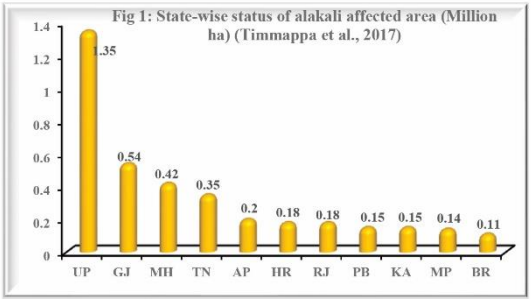
ABSTRACT

In India, nearly 6.73 million ha of land has been classified as salt-affected, with alkali and saline soils accounting for 3.70 and 2.96 million ha, respectively, threatening the farming community's livelihood security. Reclamation of salt-affected soil is a priority in current policies in India in order to meet the demands of a growing population for food, feed, fiber and bioenergy. For reclaiming alkali soils and making them productive, it is necessary to remove or replace exchangeable sodium (Na^+) on soil colloids with divalent cation calcium (Ca^{2+}). Among the various strategies tested, gypsum technology proved to be a cost-effective method for reclaiming alkali soils on a long-term basis.

INTRODUCTION

The soil naturally contains a certain amount of salts. These salts have no effect on plant growth at small concentrations. Moreover, increasing the amount of soluble and precipitated salt to a greater extent causes the formation of saline and alkali soils, which inhibit plant growth and reduce agricultural crop productivity. In India, nearly 6.73 million ha of land has been classified as salt-affected, with alkali and saline soils accounting for 3.70 and 2.96 million ha, respectively, threatening the farming community's livelihood security. Uttar Pradesh (UP) has the largest alkali area (Fig. 1) of about 1.35 million hectares (shares nearly 35.75 % of the total alkali-affected area), which is followed by Gujarat (14.36 %), Maharashtra (11.21 %), Tamil Nadu (9.41 %), Haryana (4.86 %), and Punjab (4.02 %). These six states account for roughly 80% of India's

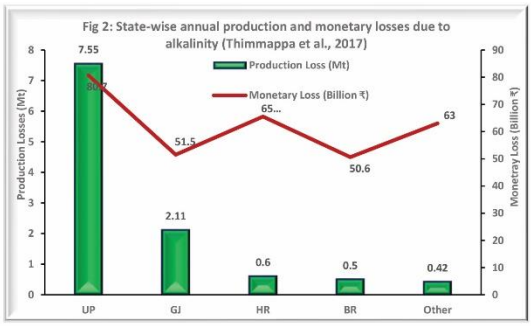
total alkali soils (Thimmappa *et al.*, 2017). Reclamation of salt-affected soil is a priority in current policies in India in order to meet the demands of a growing population for food, feed, fiber and bioenergy. For reclaiming alkali soils and making them productive, it is necessary to remove or replace exchangeable sodium (Na^+) on soil colloids with divalent cation calcium (Ca^{2+}). Gypsum is the most efficient and economic source of Ca containing 28 % Ca and capable of reacting with soluble carbonates to precipitate Ca as $CaCO_3$ and reducing soil pH to a safe range to permit crop cultivation.



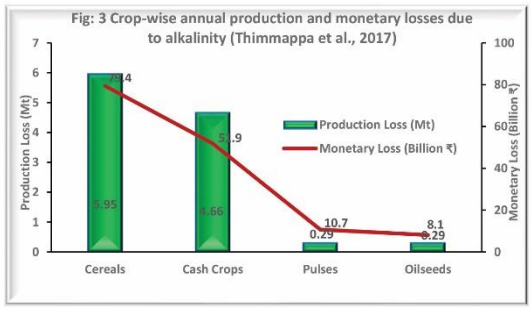
Production and economic loss by soil alkalinity: Indian context

As per estimates by ICAR-CSSRI, every year, India loses 11.18 million tonnes (Mt) of cereal, oilseeds, pulses, and cash crops annually from 3.77 million ha alkali area, equating to a monetary loss of approximately $150,000 million. State-by-state crop production losses (Fig. 2) revealed that UP alone lasted nearly 7.55 Mt (that equal to 68 % of national crop yield losses), while Gujarat suffered production losses of 2.11 M t. In monetary terms (Fig. 2), UP lost ₹ 80,750 million, followed by Gujarat (₹ 51,490 million), Haryana (₹ 6,550 million), Bihar (₹ 5,060 million), Andhra Pradesh (₹ 2,640 million), and Tamil Nadu (₹ 1,060 million).

Among different groups, cereals recorded the greatest production and monetary loss of 5.95 M t (53 %) and ₹ 79,000 million (nearly 53% of total monetary losses), respectively (Fig. 3), followed by cash crops of about 4.66 M t (42 %). The share of monetary losses for oilseeds is ₹ 11,000 million (7%) and pulses shares ₹ 8,000 million (5%) as reported by Thimmappa *et al.* (2017).



This clearly demonstrates the urgent need for alkali soil reclamation to safeguard soil productivity and enhance crop production in order to cater to rising food demand. Among the various strategies tested, gypsum technology proved to be a cost-effective method for reclaiming alkali soils on a long-term basis.



Technology in brief:

To reclaim alkali soils, the following steps must be taken.

1. Collection of soil samples: in general Gypsum recommendation is made based on soil pH. For this purpose, collect the soil samples from the plough sole layer (top 15 cm depth of soil) and get test them from laboratories.

2. Gypsum requirement (GR): Even Gypsum is recommended based on soil analysis as a rule of thumb nearly 12-15 tonnes of gypsum per hectare (50 % GR of 0-15 cm soil as determined by soil analysis) is sufficient to reclaim the upper 15 cm soil having a pH as high as 10.7.

3. Land development: proper land levelling and bunding of field is a must in order to check the ingress of water from adjoining un-reclaimed places. So, various on-farm development work, including farm layout with irrigation and drainage channels, should be completed by early summer before the rains arrive.

4. Gypsum application and leaching: The amendment is applied uniformly throughout the field and thoroughly mixed within the 10 cm topsoil layer, followed by irrigation/rainwater ponding for 7-10 days to promote leaching and create a conducive environment for ionic reactions at the soil exchange complex.

5. Crop cultivation and management: The land is properly cultivated and fertilized after the excess water has been leached. During *kharif* season, rice is a highly suitable crop immediately after reclamation. Salt tolerant cultivars developed by ICAR-CSSRI can be used for cultivation. Plant 3 to 4 seedlings per hill at a spacing of 15 to 20 cm distance between hills. The submerged condition is to be maintained throughout the rice crop. During rabi season, wheat or berseem is the best option for continuing the reclamation process. In summer, it is preferable to plant a green manure crop.

6. Nutrient Management: Efficient, balanced, and integrated nutrient management is an essential component of alkali land reclamation. Thus, it is necessary to adopt the recommended nutrient management practices based on soil test values in order to sustain soil productivity during and after reclamation.

- During initial years of reclamation use 25% more Nitrogen. Nitrogen should be applied in three parts: $1/3^{rd}$ as basal application and $1/3^{rd}$ at 21 and 45 days of crop growth. To reduce ammonia volatilization losses and increase nitrogen use efficiency in rice, a basal dose of urea should be applied under pre-submerged conditions.
- For the first few years, apply 25 to 40 kg Zinc Sulphate per hectare to rice, and then apply on a soil test basis.
- Farmyard manure, organic residues, and green manures all contribute to increased productivity. It is critical to use organic resources alongside chemical amendments.
- After three to four years of reclamation P supplementation at a rate of 22 kg P ha^{-1} is necessary to maintain productivity and soil fertility as available phosphorus in soil decreases.

Economics of technology:

As per Thimmappa *et al.* (2017) estimates, reclaiming alkali lands will require a capital investment of roughly ₹ 76,000 per ha. Out of total expenses, gypsum alone shares 57 % followed by farm development costs (27%). Labor costs account for approximately 16%. When the economic feasibility analysis assumed a 12% opportunity cost of capital, the benefit-to-cost ratio ranged from 1.34 to 2.47. Whereas, the internal rates of return extended from 18 % to 67 %, with payback periods ranging from 2 to 3 years.

CONCLUSION:

From the discussion, it is clear that Gypsum technology by far, the most effective and low-cost strategy to restore the productivity of sodic soils on a sustainable basis. As per the estimations of ICAR-CSSRI, the reclaimed area contributes around 16.60 Mt of food

grains to the national food basket. Farmers produced 4 tonnes of rice and 2 tonnes of

wheat per ha of reclaimed alkali soils (Thimmappa *et al.*, 2022). Further, Gypsum application improves soil health, soil productivity, input use efficiency (water and nutrients), and farm income and thereby reducing inequity and poverty in the country on a sustainable basis.

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