Ecofarming
e-Magazine for Agriculture and Allied Sciences
http://www.ecofarming.rdagriculture.in
e-ISSN: 2583-0791

Aromatic Plants

A Tool for Phytoremediation of Salt Affected Soils

1. **Rameshwar Choudhary**
Department of soil science Punjab Agricultural University, Ludhiana, Punjab 141004, India
Email: rameshwarchoudhary96100@gmail.com
2. **Sunil Kumar Prajapati**
Division of Agronomy, ICAR-Indian Agricultural Research Institute, Pusa Campus, New Delhi-110012, India

Received: November, 2023; Accepted: November, 2023; Published: January, 2024

Abstract

Soil, a non-renewable resource, plays a pivotal role in primary production systems, and salt-affected soils pose a significant challenge to sustainable agriculture. These soils, containing soluble salts or exchangeable sodium, limit plant growth and crop development, leading to reduced yields. Salt-affected soils are prevalent in arid and semi-arid regions, but also in humid climates, particularly in countries like India facing extreme pressure on agricultural lands. Approximately 6.74 million hectares of Indian land are affected by salinity and alkalinity issues. This study explores the potential of aromatic plants, such as Vetiver, Palmarosa, Lemongrass, and Java citronella, for phytoremediation of salt-affected soils. The chemical properties of salt-affected soils are categorized into saline, sodic, and saline-sodic based on pH, electrical conductivity (EC), exchangeable sodium percentage

(ESP), and sodium adsorption ratio (SAR). Soil degradation processes, including salinization and alkalization, are discussed, emphasizing the impact of climate, rainfall, and evapotranspiration on soil salinity. Traditional methods of soil remediation often involve chemical amendments, but this study focuses on phytoremediation, a plant-assisted approach using aromatic plants. Aromatic plants, abundant in India, are known for essential oil production and exhibit tolerance to salt-affected soils. Palmarosa, Vetiver, Lemongrass, Citronella, and Basil are identified as promising candidates for phytoremediation, demonstrating the potential to improve soil properties and fertility.

Keyword: *Agriculture, Land restoration, saline, sodic soil, phytoremediation*

Introduction

Soil, a non-renewable resource, is central to all primary production system. 'Salt-affected' is a general term used for soils which contain soluble salts or exchangeable sodium and/or both, in such amounts that can retard growth and development of plants. Such soils cause reduction in crop yield and are required to be managed and remediated for sustainable agriculture. Mostly, salt-affected soils exist in arid and semi-arid regions but are also found in some humid to sub-humid climatic areas, where conditions are favourable for their development. Over the years, in countries like India, due to high population rate, the landmass has suffered from different types of extreme pressure on crop lands and also from degradations. In arid and semi-arid region, indiscriminate use of canal water for irrigation often causes accumulation of harmful salts in soil which limits crop productivity. Salt affected soils are distributed in 120 countries covering 1074 M ha and it reduced crop productivity to 7–8% at the global scale. In India 6.74 m ha of area has been characterized as salt affected (salinity and alkalinity), out of which 3.77 m ha is alkali and remaining 2.96 m ha is saline (Prajapati *et al*., 2023), state wise distribution of saline soil in India reveals that soil salinity is a serious problem across 13 state of the country with Gujarat having largest area of 1.68 m ha (viz., 56.84 % of total saline soil) fallowed by west Bengal (14.92%), Rajasthan (6.61%) and Maharashtra (6.23%). India is endowed with natural abundance of diverse flora including enormously large number of aromatic plants which have the potential to grow in wide range of soil including salt affected soil and uncultivable waste land. As a result of research and development carried out by various laboratories under Council of Scientific and Industrial Research (CSIR), Indian Council of Agricultural Research (ICAR) and the state and central universities, India has made significant progress in the production and processing of aromatic plants. Evidence from research being carried out in recent past reveals that some of these aromatic plants are well suited to saline and alkaline soils than the traditional agricultural crops because of their tolerance to salts and high benefit cost ratio. Some aromatic grasses, Vetiver (*Vetiveria zizanioides* (Linn) Nash), Palmarosa (*Cymbopogon martinii* var. motia), Lemongrass (*Cymbopogon Àexuosus*) and Java citronella (*Cymbopogon winterianus*), appear suited for growth in salt affected soils, able to withstand salinity in soil and irrigation

water to a great extent than traditional agriculture crops.

Salt affected soils

Salt affected soils are designated as problematic soils. Salt affected soils are unproductive unless excess salts are reduced or removed. These soils are most extensively found in arid climates, but these soils are also found in coastal areas where soils are inundated by ocean or sea water. Such salt affected soils are categorized into various groups as hereunder.

Soil	Saline	Sodic	Saline-sodic
pH	<8.5	>8.5	<8.5
EC (dSm^{-1})	>4	<4	>4
ESP	<15	>15	>15
SAR	<13	>13	>13

Table-1 Basic chemical properties of different salt affected soils (Choudhary *et. al.* 2018).

Soil degradation processes

1 Salinization of soil: The sources of salts in soil are from the soil itself or also from ground water, irrigation water, canal water and tide water. The primary source of salts in soil is from rock weathering. During the process of rock weathering and soil formation, soluble salts are formed. Solute movement in the water is the determining factor in the soil salinization process. In the humid and sub humid regions with adequate rainfall, most of the soluble salts are leached down either at some depth below the surface or into the ground water. If the rainfall is not adequate and the evapotranspiration exceeds rainfall, leaching is not adequate to remove the soluble salts. Soil salinization is quite common in the arid and semi-arid regions having an annual rainfall of less than 55 cm. Further, incrustation of salts on the land surface also occurs.

2 Alkalization of soil: Formation of carbonates of Na and alkalization in the soil take place as a result of carbonation of alumino-silicate minerals in the presence of water. Sodium carbonate is highly soluble and its hydrolysis results in high alkalinity (pH up to 12).

In the presence of CO2, the pH is lowered because of the formation of bicarbonates of Na, according to the reaction

$$Na_2CO_3 + H_2O + CO_2 \rightarrow 2NaHCO_3$$

The release of CO2 with decomposition of organic matter in soil accentuates the process of $NaHCO_3$ formation in soil. In arid region, these reactions go on indefinitely, resulting in excessive accumulation of Na_2CO_3 and $NaHCO_3$ in the soil. With excessive evaporation and extreme arid conditions, carbonates and bicarbonates of sodium may accumulate in the soil as double salt crystals.

Phytoremediation of salt affected soils

Generally, chemical amendments are used to ameliorate sodic and saline-sodic soil by supplying readily available source of Ca^{2+} to replace excess Na^+ on the cation exchange complex. In this respect, amendments such as gypsum ($CaSO_4.2H_2O$) supply soluble sources Ca^{2+} to the soil solution, which then replace excess Na^+ on the exchange complex. Application of chemical amendments, particularly gypsum and dolomite, for management of sodic soil is a century-old practice. However, there are some constraints with chemical amelioration of sodic soils in

several developing countries because of (1) low quality of amendments containing a large fraction of impurities; (2) restricted availability of amendments; and (3) increased costs due to competing demand. On the other hand, scientific research and farmer's practices have demonstrated that sodic and saline-sodic soils can ameliorate through organic and plant based materials. The organic materials and the action of plant roots improve biological activity in the soil. The plant-assisted approach of amelioration of sodic and saline-sodic soils is also known as phytoremediation. The synonymous terminology of phytoremediation includes vegetative bioremediation, phytoamelioration, and biological reclamation.

Aromatic plant species used for phytoremediation of salt affected soil

Aromatic plants are those which produce essential oils having aromatic compounds and are widely used in cosmetics, toiletries, agarbattis, tooth paste, food products like confectionary, chocolate, ice cream, medicine, pharmaceuticals, etc. India is having unique advantage of growing majority of aromatic plant species due to diversity in its climate, soil, rainfall and geographical conditions. The growth rate of demand is 9% in domestic and 25% for export market. At present, India produces about 16,000–18,000 tons of essential oil out of 80,000 tons of world's production which is about 20–25% of total world's production. Most of the oil that have a good demand in the present market are: mints, lemongrass, rose oil, citronella oil, basil, geranium, palmarosa, eucalyptus, vetiver, jasmine, sandal wood, lavender, ginger oil, cinnamon, etc.

Figure Some important aromatic plants : (a) Lemongrass (*Cymbopogon Àexuosus*), (b) Palmarosa (*Cymbopogon martini* var. motia), (c) Citronella (*Cymbopogon winterianus*), (d) Sweet wormwood (*Artemisia annua*), (e) Vetiver (*Vetiveria zizanioides*), (f) Tulasi (*Ocimum tenuiÀorum*), (g) Japanese mint (*Mentha arvensis*), (h) Sweet Basil (*Ocimum basilicum*), (i) Pathcouli (*Pogostemon cablin*), (j) Galangal (*Alpinia galangal*) (Samarth *et. al.* 2017)

Aromatic plants	Soil category	Potential benefits
Palmarosa (*Cymbopogon martini* var. *motia*)	Sodic soil	Palmarosa crop has ameliorative potential and in the long term it may reclaim the sodic soil by reducing the pH and ESP and produce good amount of oil yield and income.
	Salt affected soil	Palmarosa improves the salt affected soil by decreasing the pH and SAR. Improves the physicochemical properties and fertility of salt affected soil.
Vetiver grass (*Vetiveria zizanioides*)	Saline water irrigation	Vetiver was well survived (93–95%) and remained unaffected by saline irrigation.
	Sodic soil	Vetiver could withstand soil alkalinity up to pH 9.5. Herb and oil yield of vetiver was not significantly affected up to pH 9.5.
Lemon grass (*Cymbopogon Àexuous*)	Calcareous soil and saline water irrigation	Results indicated the possibilities of raising lemon grass on degraded calcareous soil using saline water up to EC 8.6 dSm^{-1}.
	Salinity stress	Successfully grown with salinity upto 15 dSm^{-1} .
Citronella (*Cymbopogon winterianus*)	Saline soil	Citronella can tolerate salinity up to 5 dSm^{-1} and reduction in yield moderately up to 10 dSm^{-1}.
Basil (*Ocimum Basilicum*)	Sodicity stress	Basil is highly tolerant to soil sodicity stress of ESP up to 36.

Table-2 Ameliorative potential of aromatic plants in degraded and marginal lands. (Basak *et. al*. 2022)

Future Prospective

Aromatic grasses were found to be promising for phytoremediation of sodic and saline-sodic soils. A relative performance of amelioration with that of chemical amendments highlights the effective role of aromatic grass in amelioration of sodic and saline-sodic soils. Phytoremediation has been found to be beneficial in several aspects: (1) no financial liabilities for chemical amendments, (2) financial benefits from aromatic crops during amelioration, (3) more uniform and greater zone of amelioration (4) improvement in soil properties and (5) environmental benefits in terms of C sequestration. However, phytoremediation approach is effective only when used on moderately sodic and saline-sodic soils. Moreover, the amelioration process through phytoremediation is very slow and it requires calcite to be present in the soil. So, the feasibility of phytoremediation is limited when soil is highly saline or sodic. Considering the challenge associated with amelioration of sodic and saline-sodic soils and environmental consequences, it is high time to consider the soil as a useful natural resource rather than environmental burden. In this context, phytoremediation through cultivation of aromatic crops is a cost effective intervention for amelioration of these soils. The economic importance of aromatic crops as a candidate for phytoremediation of sodic and salinesodic soils of resource poor farmers are also realized. So, phytoremediation can be more effective if selected plants have economic value or local utilization at the farm level. However, in future, we need to

consider the economic value of improved soils.

Conclusion

The study concludes that aromatic plants offer a viable and sustainable solution for the phytoremediation of salt-affected soils. Unlike traditional chemical amendments, phytoremediation using aromatic plants has advantages such as no financial liabilities, financial benefits from crop yields, broader and more uniform amelioration zones, improved soil properties, and environmental benefits through carbon sequestration. However, the effectiveness of phytoremediation is limited to moderately sodic and saline-sodic soils, and the process is relatively slow, requiring the presence of calcite in the soil. Considering the challenges associated with soil amelioration and the environmental consequences, it is recommended to view soil as a valuable natural resource rather than a burden. Aromatic crops, with their economic importance and local utilization, prove to be a cost-effective intervention for the phytoremediation of salt-affected soils. Future efforts should focus on assessing the economic value of improved soils, thereby ensuring the sustainability and long-term success of phytoremediation practices for the benefit of resource-poor farmers.

References

1. Akhter, J., Mahmood, K., Malik, K.A., Ahmed, S. and Murray, R. (2003). Amelioration of a saline sodic soil through cultivation of a salt-tolerant grass *Leptochloa fusca*. *Environ. Conservation* **30**(2): 168-174.
2. Basak, B. B., Saha, A., Sowmya, N., Sarkar, R., and Trivedi, A. P. (2022). Prospect of Medicinal Plant Cultivation in Marginal and Degraded Lands. *Biotica Research Today*, **4**(1), 003-006.
3. Chauhan, N., and K, Dheeraj. (2014). Effect of salinity stress on growth performance of *Citronella java*. Int. J. of Geology, *Agriculture and Environ. Sci.* **2**(6): 11-14.
4. Choudhary, O. P., and Kharche, V. K. (2018). Soil salinity and sodicity. *Soil science: an introduction*, **12**, 353-384.
5. Prajapati, S. K., Soni, R. L., Diwakar, A. K., and Verma, S. (2023). Integrated Methodologies for the Management and Reclamation of Saline Soils *Agrospheres:e- Newsletter* **4**(3):7-12
6. Prasad, A., Kumar, D., and Singh, D.V. (2001). Effect of residual sodium carbonate in irrigation water on the soil sodication and yield of palmarosa (*Cymbopogon martini*) and lemongrass (*Cymbopogon Àexuosus*). Agricultural Water Manage. **50**(3): 161-172.
7. Samarth, R. M., Samarth, M., and Matsumoto, Y. (2017). Medicinally important aromatic plants with radioprotective activity. *Future science OA*, **3**(4), FSO247.