

Bio-remediation and health management of salt affected soils

Sanjay Arora¹

ICAR-CSSRI, Regional Research Station, Lucknow, Uttar Pradesh 226 002

In present situation where irrigated agriculture has attained optimum yield levels, there is scope to harness the marginal salt affected soils to enhance crop production to feed the burgeoning population of the country. The soils of vast areas of Indo-Gangetic plains are sodic or saline sodic. The halophilic plant growth promoting microbes have potential to ameliorate these soils. The halophilic bacterial strains can help in recovery of salt affected soils by directly supporting the growth of vegetation thus indirectly increasing crop yields in salt affected soils and enhancing productivity of crops especially paddy and wheat.

Key words: Bio-remediation, Saline sodic, Sodic soil, Soil health management

OUT of the total 6.727 million ha of salt affected soils, 2.956 million ha are saline and the rest 3.771 million ha are sodic. Out of the total 2.347 million ha salt affected soils in the Indo-Gangetic Plains, 0.56 million ha are saline and 1.787 million ha are sodic. Also there are reports of emerging salt affected soils from Jammu and Kashmir, mainly due to excessive use of irrigation water, chemicals and/or canal seepage. The state wise extent of salt affected soils in India is given in Table 1.

Excess accumulation of salts hampers the growth and activity of soil microflora. It affects the growth of N_2 fixing and phosphate solubilising bacteria which reduces fertility of soils. Sodic soils are generally reclaimed using gypsum along with organic amendments/manures. The availability of mineral gypsum and manures is scarce these days. Also the estimation of gypsum requirement of sodic soil is tedious so a model was developed to estimate gypsum requirements based on soil pH value. The mobile application “GypCal” was developed to promote judicious use of chemical amendment

gypsum for reclamation of sodic soil using soil pH as input and this application is available for free download through google play store.

Both physical and chemical methods for reclamation of saline and sodic soils are not cost-effective and on the other hand, organic crop production is being promoted. The microbial strains available as bio-fertilizers for different crops do not perform effectively under salt stress and their activity decreases when

used in salt affected soils due to osmolysis.

Microbes for promoting organic farming

Organic agriculture is holistic food production management system, which emphasizes the use of management practices in preference to the use of off-farm inputs, taking into account that regional conditions require locally adapted systems. This is accomplished by using, agronomic, biological and mechanical methods,

Table 1. Extent of salt affected soils in India (ha)

State	Saline	Sodic	Total
Andhra Pradesh	77598	196609	274207
Andaman & Nicobar Islands	77000	0	77000
Bihar	47301	105852	153153
Gujarat	1680570	541430	2222000
Haryana	49157	183399	232556
Karnataka	1893	148136	150029
Kerala	20000	0	20000
Madhya Pradesh	0	139720	139720
Maharashtra	184089	422670	606759
Odisha	147138	0	147138
Punjab	0	151717	151717
Rajasthan	195571	179371	374942
Tamil Nadu	13231	354784	368015
Uttar Pradesh	21989	1346971	1368960
West Bengal	441272	0	441272
Total	2956809	3770659	6727468

Source: NRSA & Associates (1996).





Sodic soil of Indo-Gangetic Plain

as opposed to using synthetic materials. For organic farming, beneficial microbes are essentially required to improve soil health and enhance crop growth and yield. Microbial inoculants are carrier-based preparations containing beneficial microorganisms in a viable state, intended for seed and soil application. These are designed to improve soil fertility or biocontrol agents that not only manage the plant diseases with ecological balance, but also promote production of safe food. A bio-inoculant is a substance which contains living microorganisms, when applied to seed, plant surfaces, or soil, colonizes the rhizosphere or the interior of the plant and promotes growth by increasing the supply or availability of primary nutrients to the host plant.

Since bioformulation is a living

products in the market. In developing countries, the insufficient knowledge, lack of adequate machinery, and improper distribution and importation laws for live inoculants can lead to loss of their viability and effectiveness. Inoculation of plants with target microorganisms at a much higher concentration than those normally found in soil is necessary to take advantage of their beneficial properties for plant yield enhancement. The erratic performances of bioinoculants under field conditions have raised concerns about the practical potential offered by microbial releases into soil. Soil is an unpredictable environment and an intended result is sometimes difficult to obtain. The immediate response to soil inoculation with plant growth promoting (PGP) bioformulations varies considerably depending on the

product, utmost care is needed at all the steps beginning from the production till the end use to maintain the microbial load and vigor. Production technology of bioformulations requires proper care and aid of sophisticated equipments to ensure availability of quality

one region may not perform in the same way in the other soil and climatic conditions. Thus salt tolerant halophilic bacteria are needed for their application in salt affected soils.

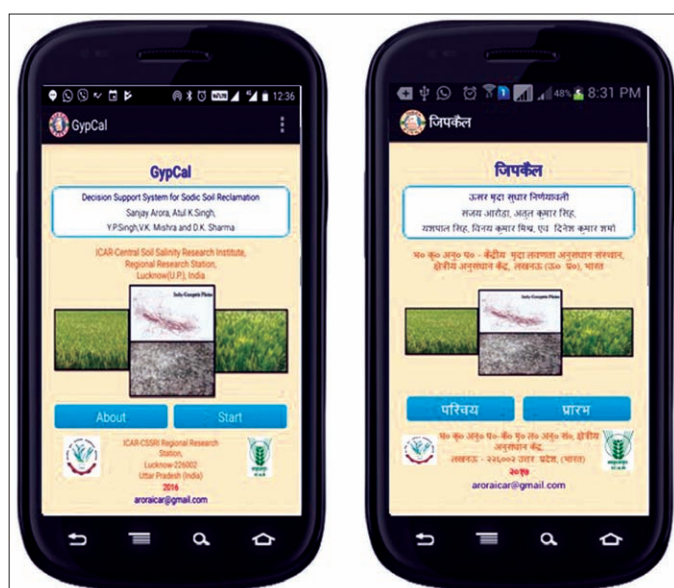
Halophilic bacteria

The existence of high osmotic pressure, ion toxicity, unfavourable soil physical conditions and/or soil flooding, are serious constraints to many organisms and therefore salt-affected ecosystems are specialised ecotones. The organisms found over there have developed mechanisms to survive in such adverse media, and many endemisms. The halophilic microorganisms or salt-loving microorganisms live in environments with high salt concentration that would kill most other microbes. Halotolerant and halophilic microorganisms can grow in hypersaline environments, but only halophiles specifically require at least 0.2 M of salt for their growth. Halotolerant microorganisms can only tolerate media containing <0.2 M of salt. Distinctions between different kinds of halophilic microorganisms are made on the basis of their level of salt requirement and salt tolerance. The halotolerant grow best in media containing <0.2 M (~1%) salt and also can tolerate high salt concentrations.

Bacteria inhabiting soil play a role in conservation and restoration biology of higher organisms. The domain bacteria contain many types of halophilic and halotolerant microorganisms, spread over a large number of phylogenetic groups. Most halophiles within the domain bacteria are moderate rather than extreme halophiles in general. It was reported that halotolerant Gram-positive endospore forming rods from saline soils and sediments of salterns located in different areas were assigned to the genus *Bacillus*, and the majority of them were classified as extremely halotolerant microorganisms, being able to grow in most cases in up to 20 or 25% salts.

Vesicular arbuscular mycorrhiza (VAM)

Vesicular arbuscular mycorrhizal fungi commonly called as VAM occur naturally in saline environment.



Several researchers investigated the relationship between soil salinity and occurrence of mycorrhizae on halophytes. VA mycorrhizal fungi most commonly observed in saline soils are *Glomus* spp., and this suggests that this may be adapted to grow in saline conditions, but ecological specificity has not been demonstrated. There is evidence that VAM species distribution is markedly changed with increased salinity. Some reports indicate that mycorrhizal fungi can increase growth of plants growing in saline habitats. VA mycorrhizal fungi may have the ability to protect plants from salt stress, but the mechanism is not fully understood.

Applications of halophilic bacteria

Halophilic bacteria provide a high potential for biotechnological applications for at least two reasons: (i) their activities in natural environments with regard to their participation in biogeochemical processes of C, N, S, and P, the formation and dissolution of carbonates, the immobilization of phosphate, and the production of growth factors and nutrients, and (ii) their nutritional requirements are simple. The majority can use a large range of compounds as their sole carbon and energy source. Most of them can grow at high salt concentrations, minimizing the risk of contamination.

Halophilic bacteria have the ability to produce compatible solutes, which are useful for the biotechnological production of these osmolytes. Some compatible solutes, especially glycine, betaines and ectoines, may be used as stress protectants (against high salinity, thermal denaturation, desiccation and freezing) and stabilizers of enzymes, nucleic acids, membranes and whole cells. The industrial applications of these compounds in enzyme technology are most promising. The other compatible solutes such as trehalose, glycerol, proline, ectoines, sugars and hydroxyectoine from halophilic bacteria showed the highest efficiency of protection of lactate dehydrogenase against freeze-thaw treatment and heat stress.

Also, halophilic bacteria produce a number of extra- and intra-cellular enzymes. Halophilic bacteria can produce enzymes that have optimal activity at high salinity, which is advantageous for harsh industrial processes.

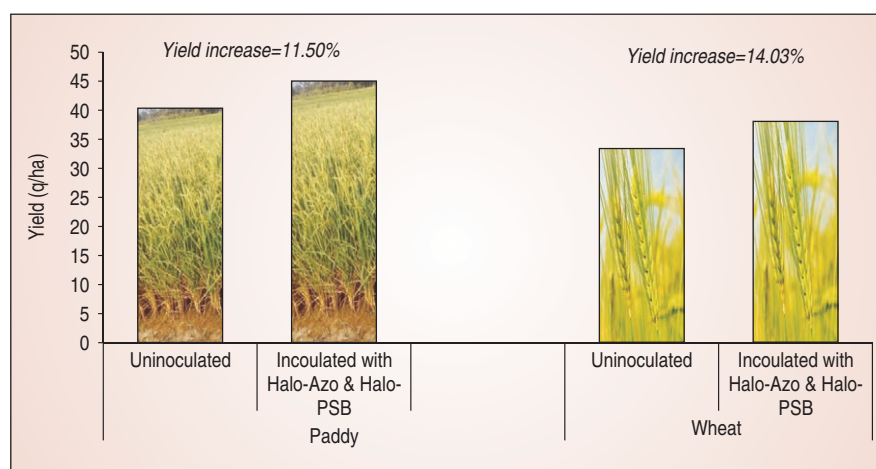
The application of halophilic bacteria in environmental biotechnology is possible for (i) the recovery of saline soil, (ii) the decontamination of saline or alkaline industrial wastewater, and (iii) the degradation of toxic compounds in hypersaline environments. The use of halophilic bacteria in the recovery of saline soils is based on the following hypotheses: microbial activities in saline soil may favour the growth of plants resistant to soil salinity. The second hypothesis is based on the utilization of these bacteria as bio-indicators in saline wells. Indicator microorganisms can be selected by their abilities to grow at different salt concentrations. These organisms could indicate that well water could be used with producing low saline contamination of plants or soils which could be alleviated by the desertification of soil. The last hypothesis is the application of halophilic bacterium genes using a genetic manipulation technique to assist wild-type plants to adapt to grow in saline soil by giving them the genes for crucial enzymes that are taken from halophiles.

Liquid bio-formulations for enhancing crop production in salt affected soils

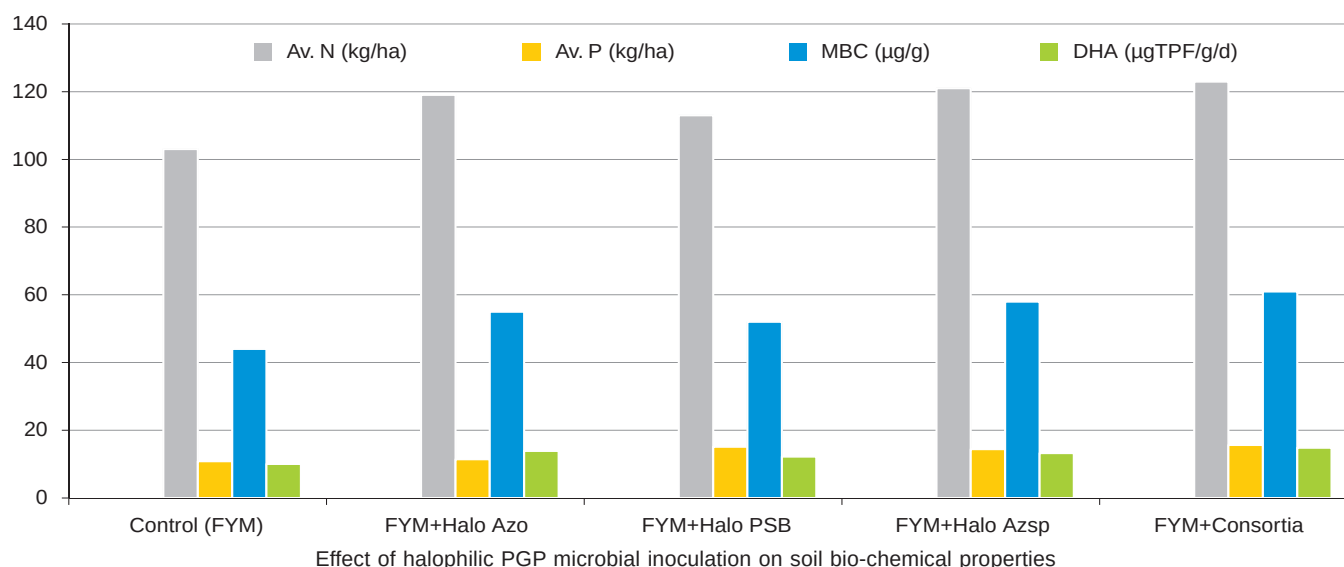
Salt tolerant (halophilic) bacterial strains of N-fixers and phosphate

solubilization bacteria (PSB) were isolated from the salt affected soils at ICAR-CSSRI, RRS, Lucknow. These strains were characterized for plant growth promotion and tested for their efficacy under different levels of salt stress. To enable the seed application of these promising selected strains of beneficial soil microorganisms, these were cultured in laboratory and prepared in suitable standardized media as liquid bioformulations viz. Halo-Azo and Halo-PSB. These can be used either for seed/seedling root treatment or soil application. Application of these bioformulations helps to generate plant nutrients like nitrogen and phosphorus through their activities in the soil or rhizosphere and make available to plants in a gradual manner under salt stress. Also liquid formulations 'Halo-Zinc' and 'Halo-Mix' having salt tolerant strains of zinc solubilizers and consortia of species, respectively, were developed and found to be effective under salt stress. These shall also help in maintenance of soil health, minimize environmental pollution and cut down on the use of chemicals in agriculture. They are affordable for most of the farmers who are small and marginal. Bioformulations are also ideal input for reducing the cost of cultivation and for promoting organic farming on salt affected soils.

Under sodic and saline-sodic soils, the bioformulation has been tested at farm, validated at different farmers' fields in 5 districts of salt affected areas. The seedling dip or seed inoculation with the bioformulation



Efficacy of liquid bio-formulations of halophilic PGP strains on wheat and rice on sodic soils



resulted in enhanced crop yields, management of soil health and stress regulation.

These liquid bio-formulations are very beneficial for enhancing production of cereal crops mainly rice and wheat as well as vegetable crops. These can be easily used as seed treatment, seedling dip and soil application with FYM/manure. The packing of 100 ml bottle is sufficient for treating seeds of 1 acre land or root dip. It has been found to be very effective in sodic soil. There was increase in rice and wheat yield by 11.5 to 14% under salt stress conditions in Indo-Gangetic plains. This is a low cost and eco-friendly approach for bio-remediating salt affected soils and optimizing crop yields in the degraded lands.

The application of liquid bio-formulations have the potential to improve growth and yield of crops under salt stress and they also play role in soil health improvement as observed in soil after harvest of the crop. There was substantial improvement in soil pH and exchangeable sodium content. Build up of organic C and N apart from improvement in microbial biomass C and dehydrogenase activity was observed with application of liquid bioformulations.

SUMMARY

In view of the fact that both physical and chemical methods for reclamation of saline and sodic soils are not cost-effective and the halophilic plant growth promoting

microbes have potential to ameliorate these soils. The halophilic bacterial strains can help in recovery of salt affected soils by directly supporting the growth of vegetation thus indirectly increasing crop yields in salt affected soils. Halophilic plant growth promoting bacteria have high potential for remediation of salt affected soils and enhancing productivity of crops especially paddy and wheat. The use of liquid bioformulations of halophilic plant growth promoters have not only helped in enhancing crop yields under salt stress but also have role in maintaining soil health.

¹Principal Scientist. Corresponding author's e-mail: aroraicar@gmail.com.

Halophilic plant growth promoters

Application of liquid bio-formulations 'Halo-Azo' and 'Halo-PSB' on growth and yield of wheat and rice under sodic soils (pH 9.4) were tested. In wheat, seed inoculation with halophilic nitrogen fixers (Halo-Azo, and Halo-Azsp) and P solubilizers (Halo-PSB) resulted in ~21% increase in plant height and ~17–25% increase in root length over control. Wheat grain yield increased by 14.2, 10.9 and 17.9% in Halo-Azo, Halo-PSB and Halo-Azsp treatments, respectively, over control. However, consortia of halophilic strains resulted in an increase of 21.8% in grain yield over control. In case of rice, grain and straw yields increased by 18.6 and 24.9% respectively in consortia treated pots over control.

Source: DARE-ICAR Annual Report 2018-19

Effect of CO₂ and temperature elevation on plant nutrition and water use in wheat

A field experiment in wheat crop (var. HI 1544) was conducted in the Open Top Chamber facility at the research farm of the institute during *rabi* 2016–17 to study the effect of climate change parameters on plant growth, nutrient uptake and water use. The studied climate parameters at the required level were maintained through an automated control facility connected to data loggers. Results indicated that with recommended crop fertilization, elevation in atmospheric CO₂ concentration by about 150 ppm increased the grain yield by 12%, whereas increased temperature showed a decline in the yield by about 6%. The positive effect from CO₂ elevation showed a tendency of getting neutralized with rise in growing temperature by about 2.5°C.

Source: DARE-ICAR Annual Report 2018-19

