ranged 13.07 to 14.05 kg/ha. Similarly, P content and P uptake significantly ($p<0.05$) affected by mycorrhizal application in wheat and sorghum crops. Significantly ($p<0.05$) greater effect of mycorrhizal application was observed in salt tolerant variety i.e. KRL 210 in comparison to salt sensitive wheat variety HD2967 (Fig 6).

Response on soil properties

- The AMF inoculation caused a significant increase in soil Olsen's–P content compared to the un-inoculated control. The increase in Olsen's–P was greater in sodic compared to saline soils. The contents of the glomalin related soil protein (GRSPs) were greater in AMF inoculated soils. Saline and sodic soils recorded greater values for DE–GRSP and EE–GRSP, respectively. Sodic soils showed a maximum 15–35 fold increase in the EE–GRSP and DE–GRSP because of AMF inoculation ($P \leq 0.05$). The AMF inoculated soils had greater *($p<0.05$)* bacteria, actinomycetes, and fungi count in all the soil types. Similarly, mycorrhiza caused a significant *($p<0.05$)* increase in microbial enzymes (Dehydrogenase and phosphatase enzymes).
- AMF affected different form of phosphorus in soil and calcium bound P was found to be most abundant in both normal and saline soil. Effect of treatment was highest on calcium bound P as compared to other forms (Fig. 9). Among other inorganic P fractions, saloid-bound P recorded the lowest value. While other forms, aluminum bound P (Al–P), iron phosphorus fraction (Fe–P) and occluded P remained unaffected by the treatments (Fig. 9).

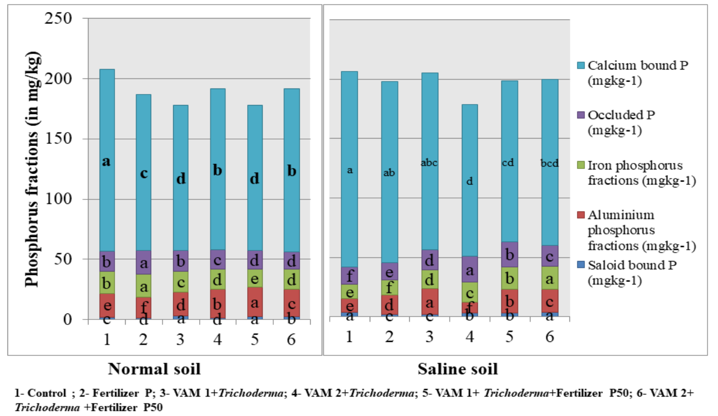


Fig. 9. Results demonstrating the effect of AMF and Trichoderma on different fractions of phosphorus in (a) normal soil (b) saline soil. 1- Control ; 2- recommended dose of Fertilizer; 3- AMF 1+Trichoderma; 4 - AMF 2+Trichoderma; 5- AMF 1+ Trichoderma+Fertilizer P50; 6- AMF 2+ Trichoderma +Fertilizer P50

Mycorrhizal responsiveness

- Crops responded positively to AMF inoculation (Table 1). Mycorrhizal responsiveness for arbuscular abundance, K^+/Na^+ ratio, and P uptake was greater for saline compared

Table 1. Mycorrhizal responsiveness in different types of soil; NSIM: normal soil inoculated with AMF; SAIM: saline soil inoculated with AMF; SOIM: sodic soil inoculated with AMF; EE: easily extractable glomalin related soil protein; DE: Difficultly extractable glomalin related soil protein; TG: total glomalin related soil protein.

	NSIM	SAIM	SOIM
Mycorrhizal colonization	84.3^{A}	81.3^{A}	80.0^{A}
Arbuscules abundance	67.0^{B}	90.0^{A}	$80.^{AB}$
EE	84.37^{AB}	79.34^{B}	91.87^{A}
DE	94.2^{A}	93.1^{A}	97.1^{A}
TG	90.9^{A}	89.1^{A}	95.7^{A}
Root shoot ratio	56.1^{A}	39.5^{AB}	26.3^{B}
K^+ / Na^+ ratio	42.4^{B}	57.6^{A}	41.3^{B}
P-uptake	26.16^{C}	37.0^{A}	31.37^{B}
P-concentration	9.72^{B}	7.76^{B}	13.07^{A}
Olsens-P	10.5^{A}	3.34^{B}	3.51^{B}

to sodic soils. While, EE, TG, and P concentrations were greater for sodic soils *($p<0.05$)*. Mycorrhizal responsiveness for Olsen's–P and root: shoot ratio were significantly *($p<0.05$)* greater in normal soil.

Application

This mycorrhizal based biostimulant for salt affected soils can complement with available technologies and integrate with existing crop management practices through seed bio priming or soil application:

- For seed bio priming, 250 g of seeds were mixed with 50 g AMF inoculum and 80 mL of carboxymethyl cellulose (1 % w/v) solution.
- Soil application: Mix 10 kg of AMF biostimulant in 50 kg of well decomposed FYM, compost, vermi-compost or field soil. Spread the mixture uniformly in 1 hectare of land. For better results the biostimulant can be applied in furrow in proximity of seed.
- The recommended doses of fertilizers should be applied.

View of the experiment at experimental farm Nain, Haryana

Acknowledgement: The financial support from Science and Engineering Research Board, Department of Science & Technology, Government of India is highly acknowledged.

Grant no. EEQ/2021/000369

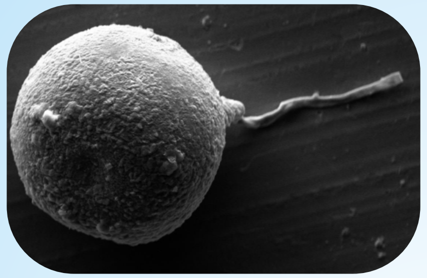
Design and Technical Support
Yudhvir Singh Ahlawat

For further information, please contact
Director
ICAR-Central Soil Salinity Research Institute, Karnal 132001, Haryana
Email: director.cssri@icar.gov.in;
Website: www.cssri.org

Citation: Chandra, P., Rai, A.K., Basak, N., Sundha, P., Prajapat K., Yadav, R.K.2023. Mycorrhizal Biostimulant for improved productivity in Salt Affected Soils. ICAR-CSSRI/Karnal/ Technical Folder/2023/08, ICAR–Central Soil Salinity research Institute, Karnal – 132001, Haryana, India.

ICAR-CSSRI/Karnal/ Technical Folder/2023/08

Mycorrhizal Biostimulant for Improved Productivity in Salt Affected Soils



ICAR–Central Soil Salinity Research Institute
Karnal 132 001, Haryana, India

INTRODUCTION

Nearly 112.5 million hectare (M ha) of agricultural landscape is salt affected; of which North and Central Asia, including India accounts for ~20 % of affected area. In India, about 6.74 M ha (~4.2 % of total arable lands) area is affected by salinity, sodicity or their combination. If current trends continue unabated, simple extrapolation suggests expansion of salt–induced land degradation to 16.2 M ha by 2050 (CSSRI Vision 2050). Presence of excess salts (soluble or exchangeable Na^+) in the soil affects all aspects of crop growth and development, including germination, vegetative growth and reproduction.

Arbuscular mycorrhizal fungi (AMF) are the obligate biotrophs that establish mutualistic associations with roots of most terrestrial plants, including many crops. Root colonization by AMF improves the uptake of mineral nutrients in the host plant, mainly phosphorus and nitrogen, in exchange for photosynthetically fixed carbon, ultimately helping plant growth and development. AM symbiosis is also one of the most widespread plant strategies to cope with abiotic and biotic stresses. The symbiosis with AMF can ameliorate plant's response to salt stress and have beneficial effects on their growth and yield, which made AMF suitable candidates to bio-ameliorate salt stress.

Role of AMF in salt stress mitigation:

- AMF enhance the uptake of essential nutrients
- AMF forms arbuscules, which assist in exchange of minerals, carbon and phosphorus, ultimately improving plant vigor
- AMF reduces the adverse effect of salt stress by increasing antioxidant defense mechanism in crop plants
- AMF mitigates the salt-induced deleterious effects by maintaining the osmotic balance through regulating Na^+/K^+ ratio. AM symbiosis reduces Na^+ uptake and translocation while favouring the uptake of essential cations such as K^+, Ca^{2+} and Mg^{2+}

AMF inoculum

The two morphological sets named (i) type 1 AMF spore, and (ii) type 2 AMF spore were trapped from sodic soil under rice-wheat cropping. The sequence of the amplified DNA suggested AMF spores to be the *Funneliformis mosseae* and *Funneliformis geosporum*. Their NCBI GenBank accession number are OM510280 and OM510281, respectively. The spores of *Funneliformis mosseae* were yellowish-brown and globose to subglobose shape. The spore size varied in the range of 150–210 µm. The shape of subtending hypha attached to spores was straight to somewhat recurved. The spores of the *Funneliformis geosporum* were yellowish-brown with a globose to subglobose shape. The

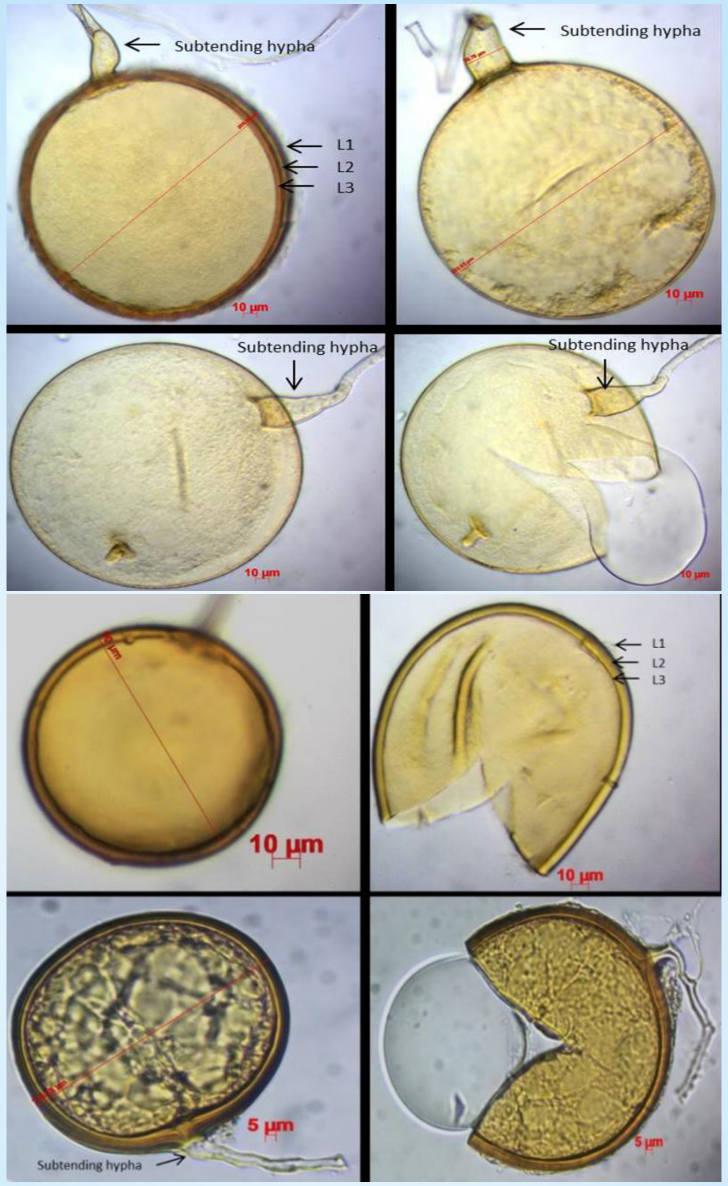


Fig.1. Morphology of AMF spores isolated from rice-wheat cropping system of sodic soil (a) Funneliformis mosseae (b) Funneliformis geosporum

spore size varied in the range of 80–170 µm. The spore wall layer of both the AMF consists of three layers (L1, L2, and L3). Similarly, the shape of subtending hypha of *F. geosporum* was also straight to somewhat recurved (Fig. 1).

Propagation techniques

Two different host *viz.* Sorghum and maize were studied for AMF propagation. Mycorrhizal association and colonization increased with time in both the cycles. AMF colonization was greater in maize compared to sorghum in both cycles of inoculation. The rate of colonization in both the crops was more in the initial stage, about 61–81 % colonization and arbuscular abundance was achieved within 30 days of growth. The remaining 19–39 % VAM colonization and arbuscular abundance were attained in the next 30 days. The rate of

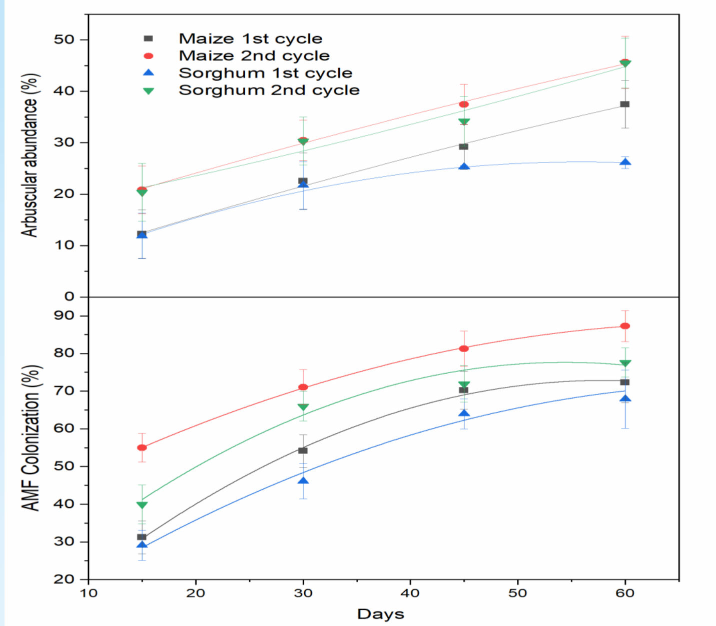


Fig. 2. (a) Mycorrhizal colonization and (b) arbuscular abundance in roots of maize and sorghum in first and second cycle of trap culture

colonization was more in the second cycle of inoculation compared to the first cycle (Fig. 2).

Response in salt affected soils

- The AMF inoculation caused a significant *($p<0.05$)* improvement in growth in comparison to uninoculated control. Microscopic observations revealed the presence of different growth stages of mycorrhizal development in the roots of plants, such as intra and extra–radical hyphae, arbuscules, and vesicles (Fig. 3).
- The SEM analysis study also revealed the mycorrhizal colonization as well as the presence of hyphae on the root surface of plants inoculated with AMF in comparison to non-inoculated controls (Fig. 4).
- The AMF colonization and arbuscular abundance were greater for sodic and normal soil, respectively (Fig. 5). The impact of AMF inoculation on plant height, fresh and dry

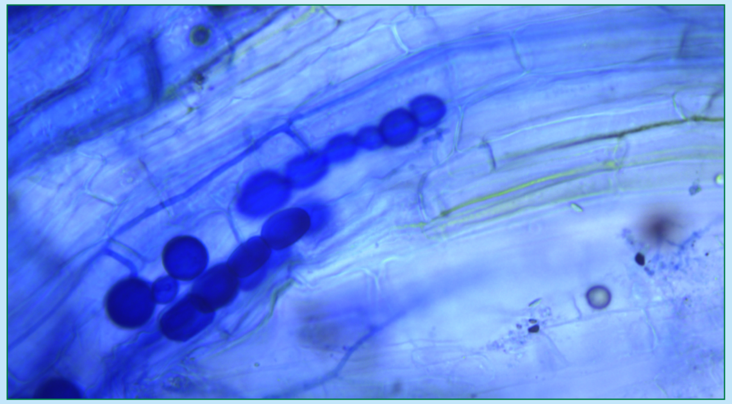


Fig. 3. The roots of AMF-inoculated sorghum plants demonstrated AMF colonization and abundance as their typical fungal structures were found under microscope

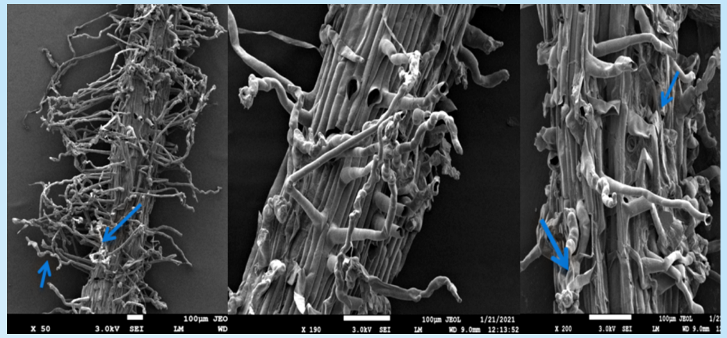


Fig. 4. Electron micrograph of root with visualization of mycorrhizal hyphae coiling the root hairs

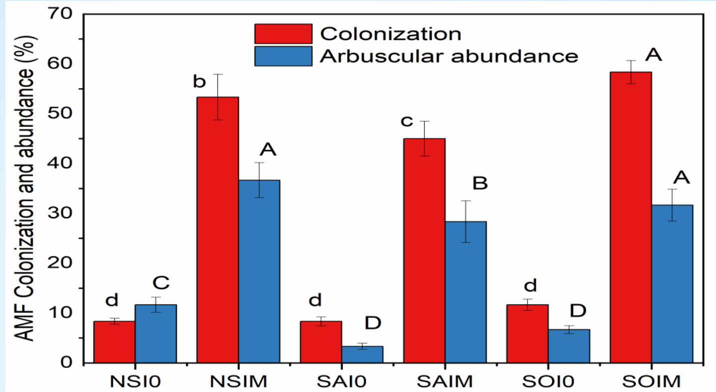


Fig. 5. Effect of inoculation with mixed culture of F. mosseae and F. geosporum on colonization and arbuscules abundance in different soil types; NSI0: normal soil uninoculated; NSIM: normal soil inoculated with AMF; SAI0: saline soil uninoculated; SAIM: saline soil inoculated with AMF; SOI0: sodic soil uninoculated; SOIM: sodic soil inoculated with AMF.

biomass was greater in sodic followed by saline soils. Below-ground biomass responded to inoculation, and saline soils showed a maximum increase (51 %) followed by normal (44.5 %) and sodic (28.8 %) soils. The root and shoot ratio also increased because of AMF inoculation. Sodic soil showed a greater increase in root to shoot ratio compared to saline soils. The P content in sorghum biomass and P uptake was greater in AMF inoculated soils. Although different soils showed varied P uptake under uninoculated conditions. The AMF inoculation effect of soil type was not evident in P nutrition. The AMF inoculation affected the drastic reduction in the Na^+/K^+ ratio in saline and sodic soil.

- In field experiment at Nain Farm Panipat, the available phosphorus significantly varied in different treatments and

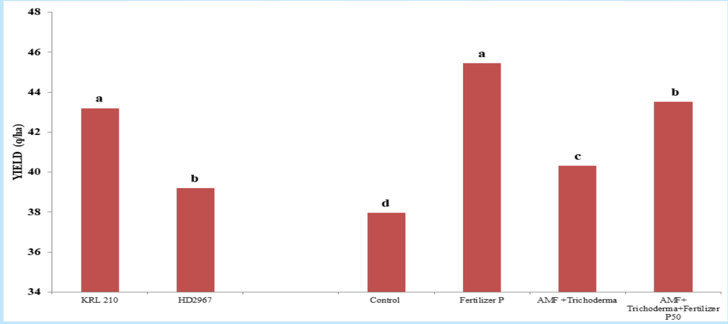


Fig 6. Yield of salt sensitive and salt tolerant wheat varieties at Nain Farm