Short Research Article

Evaluation of Arbuscular Mycorrhiza Fungi Species for Their Efficiency Towards Nutrient Acquisition in Rhizospheric Soil of Maize

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Abstract

An investigation was carried out to evaluate the response of selected species of mycorrhizae for nutrient acquisition and phosphorus uptake by maize in an alluvial soils of Bihar. The study was undertaken during 2013 wet season (July to December) in a net-house at Bihar Agricultural University. Six treatments along with a control treatment were maintained with three replications for the experiment. Five species of AM fungi collected from TERI (The Energy and Resources Institute) along with a local species from long term litchi orchard (Muzaffarpur), were evaluated on the basis of nutrient acquisition in the soil rhizospeheric region for maize crop. The results obtained clearly show that of all the species of mycorrhizae taken under consideration, *Glomus mosseae* was found to perform better in terms of nutrient acquisition and uptake of P to plant. The maximum P concentration (7.65 mg kg^{-1}), organic carbon (0.60%) and Zn Concentration (6.48 mg kg^{-1}) and P uptake (was also found with the application of *G. mosseae*. The AM (Arbuscular Mycorrhiza) species significantly increased the released of P and micronutrients in the soil of rhizospheric region of maize plant. The beneficial effect was more pronounced for the treatment in case of *Glomus mossae* among all the other species used. This may be due to the higher solubilization power of *Glomus mossae* for soil nutrients than other species.

1. Introduction

Now-a-days maize is one of the valuable crops in Bihar. Phosphorus is known to be one of the most essential elements for plant growth and development after nitrogen for the said crop. Effective nutrient management particularly for phosphorus and micronutrients is important to optimize crop yield potential, reduce production costs and decrease the risk of environmental damage. Arbuscular Mychorriza (AM) fungi are one of the sustainable options for increasing the nutrient availability in rhizospheric region of crops. The beneficial effects of AM and other microorganisms on plant performance and soil health can be very important for the sustainable management of agricultural ecosystems (Smith and Smith, 2011 and Gianinazzi et al., 2010). Almost all higher plants in the terrestrial ecosystem are known to be associated with mycorrhizal fungi (Smith et al., 1997; Hata et al., 2010). Perhaps AM fungi synthesize and secrete organic substances (siderophores) which increase the desorption of P in labile soil P pools. With organic acids, AM fungi can solubilize low-soluble and insoluble P sources which are a part of the crystalline structure of minerals in the soil (Anonymous, 2005).

In many ecosystems, these symbiotic fungi play an important role in sustaining plant productivity by increasing its nutrients and water uptake from the soil (Anup et al., 2014 and Mobasser and Moradgholi, 2012) Roots and rhizosphere are the regions of interest for their symbiotic efficiency. By colonizing the roots, they bring about several changes in the metabolic activity of the plants, resulting in stimulation of various enzymes. This leads to the modification of the rhizosphere, wherein plenty of micro-organisms survive with their mutual interactions. Mycorrhizosphere may bring about the changes in microbial population and can also contribute for the enhanced growth and nutrition of crop plants. Soil nutrients are highly activated under mycorrhizosphere and yield several positive responses. Hence, it is essential to study the understanding of the AM induced changes in the rhizosphere. The role of AM in the acquisition of nutrients from the soil has been long recognized and well documented. It has been reported that plant dependency to mycorrhizal fungi depends on the level of soil fertility and receptivity of soil to inoculants (Covacevich and Echeverria, 2008).With this background, the present study was undertaken to evaluate different AM species for their efficiency

towards nutrient acquisition in rhizospheric soil in maize crop.

2. Materials and Methods

The present study was undertaken to screen the AM fungi for maize crop during the *rabi* season of 2013-14 with a promising var. DHM-117, at Bihar Agricultural University, Sabour, Bhagalpur, India. Inoculums of the five AM species viz., *Glomus mosseae, Glomus coronatum, Glomus intraradices, Gigaspora decipiens* and *Gigaspora margarita* were commercial products of The Energy Resource Institute (TERI), New Delhi, India. The products consisted of fragments of colonized roots and spores of AM fungi in a vermiculite substrate. One uncharacterized local inoculum (control) was collected from the maize and litchi farm of Bihar Agricultural University, Sabour. The substrate used for the experiment consisted of soil from the Bihar Agricultural University, research farm and river bed sand of the Ganges (w/w, 3:1). The soil was collected from the surface (0–15 cm) and passed through a 2.00 mm aperture sieve to remove roots and debris. The river bed sand was thoroughly washed with tap water to remove salt. The substrate mixture was completely sterilized by autoclaving over 1 hr with stepwise increase in temperature till the center reached 120 °C (kept for 30 minutes). The substrate used for the pot experiment was loamy sand in texture, having a pH of 7.2 and EC of 0.22 dS m^{-1}. The organic carbon content of the substrate was 0.56%, and the available nitrogen, phosphorus and potassium content was found 180.77, 25.89 and 220.66 kg ha^{-1}, respectively.

Seeds were surface-sterilized by treatment with a 1:1 mixture of H$_2$O$_2$ and absolute ethanol for 2 minutes followed by a treatment with 0.05% HgCl$_2$ for 1 minute. The sterilizing agents were drained aseptically, and the seeds were washed for 10-12 times in sterile distilled water to remove all traces of the chemicals. Earthen pots of 15 cm height and 30 cm diameter were filled with 10 kg of sterilized substrate. All AM species were maintained in the pots with five replications each. The following treatment structure was formulated for the study: T$_1$-*G. mosseae,* T$_2$-*G. coronatum,* T$_3$-*G. intraradices,* T$_4$-*G. decipiens,* T$_5$-*G. margarita,* T$_6$-Local (uncharacterized inoculum) and T$_7$-control (without inoculum). About 5 g of the AM inoculum source (containing and 8-10 spores g^{-1}) was mixed with the upper 4 cm of the substrate in each pot. In each pot, 4 sterile seeds of maize (var. DHM 117) were planted. Once in every 15 days, each pot was treated with 20 ml of Hoagland solution minus phosphate (Hoagland and Arnon, 1938). One plant from each pot was uprooted after 75 days of sowing. After measuring the shoot height they were kept in a hot air oven to dry at 105 °C for 72 hours until they attained a constant weight. The experiment was laid out in a completely randomized block design with three replications.

The cultivated soil was collected from Bihar Agricultural University Farm. The soil used in the pot experiment was air-dried, ground and sieved through a 2 mm sieve, and then stored in plastic bags. An initial soil sample was analyzed for different physico-chemical parameters following the standard protocol. The pH and electrical conductivity of the soil was determined by Glass electrode pH meter and Conductivity meter (Jackson, 1973) respectively. The textural class was determined by (Bouyoucos, 1962). Rhizospheric soil samples were analyzed for mineral-N by (Subbiah and Asija, 1956), available P by (Olsen et al., 1957), available-K by (Black, 1965), Organic Carbon by (Walkley and Black, 1934) and available cationic micronutrients by (Lindsay and Norvell, 1978) after the harvesting of maize crop. Analysis of variance (ANOVA) was performed as described by Gomez and Gomez (1984) to determine the effects of various treatments. Critical difference (CD) at 5% level of probability and P values was used to examine differences among treatment means.

3. Results and Discussion

3.1. Physico-chemical characterization of the experimental soil

The chemical properties and texture of the soil before starting of the experiment were shown in Table 1. The soil was neutral to slightly alkaline in reaction. EC of soil was 0.257 dSm^{-1}. The experimental soil was silty clay loam in texture. The soil was characterized with a low organic matter content of 0.56%, having low available N, P and K of 104, 6.1 and 88.3 mg kg^{-1}, respectively. The DTPA extractable cationic micronutrients were found out to be 4.51, 0.78, 16.13 and 13.91 mg kg^{-1} for Zn, Cu, Fe and Mn, respectively.

Figure 1 showed that the pH values of the studied soil were affected by the application of AM species indicating that the inoculation of AM had a favorable effect on lowering the soil

Table 1: Physico-chemical properties of initial experimental soil

Parameters	Value	Parameters	Value
Soil texture	Silty clay loam	Organic carbon (%)	0.56
pHw (1:2.5)	7.66	Bulk density (g cc^{-1})	1.45
Electrical conductivity (dSm^{-1})	0.257	Zn (mg kg^{-1})	4.51
Available nitrogen (mg kg^{-1})	104	Cu(mg kg^{-1})	0.78
Available phosphorus (mg kg^{-1})	6.1	Fe (mg kg^{-1})	16.13
Available potassium (mg kg^{-1})	88.3	Mn (mg kg^{-1})	13.91

pH in rhizospheric region. The pH was at its lowest value in case of *Glomus* mosseae (7.49). This finding might be due to the beneficial effect of organic acids produced by the root exudates and AM species during its life cycle. The similar results were also obtained by Rai et al., 2013; El-Fayoumy and Ramadan, 2002.

Data in Table 2 showed that addition of AM inoculation increased soil P concentration which was significantly higher over control. Available P was increased by 41.4% under *Glomus mosseae* over *control* treatment (Table 2). *Glomus* mosseae had pronounced effect for phosphorus acquisition in soil. A parallel trend was also seen in case of available N, K and organic carbon status of soil (Hodge and Fitter, 2010 and Olsson et al., 2010). The increasing root length value and
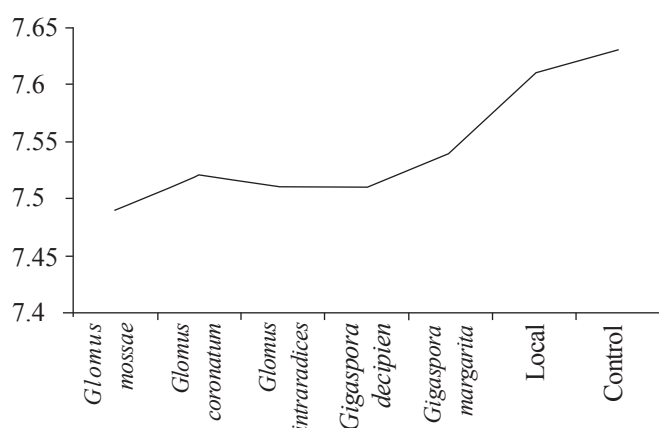
root biomass observed in the study resulted in greater root exudates and readily metabolizable C. These results were also in accordance with the findings of Rakshit and Bhadoria, 2010 and Chu et al., 2013. *Glomus mosseae* was found to be as much compatible strain than other AM strains used for maize crop. The similar results were also reported by Tanwar and Aggarwal, 2013 and Parewa et al., 2010.

Data in Table 3 also indicated that the concentrations of Fe, Mn, Zn and Cu were significantly increased in case of applied AM species over control treatment. DTPA extractable Fe and Mn were slightly affected by mycorrizal inoculation than non-inoculated control. But the DTPA extractable Zn and Cu were increased in the soil treated with AM fungi. Higher root biomass mediated exudation and this was perhaps the most important reason for the increase. Among all the AM species, *Glomus* mosseae had pronounced effect for cationic micronutrient acquisition in soil. This result was in consonance with the findings of Archana et al., 2012; Balakrishnan and Subramanian, 2012; Habasy and Abo-Zaid, 2005. *Glomus mossae* showed the highest acquisition of cationic micronutrients in soil rhizosphere among all the other species.

3.2. P uptake

P uptake was found to be higher with the application of *G. mosseae*, than *G. coronatum* and *G. decipiens* (Figure 2). AMF induced enhancement in phosphatase activity could possibly mediate the release of organically bound phosphorous and hence increasing transport and uptake of phosphorous in AMF inoculated plants. Increased activity of phosphatases has direct bearing with the phosphorus metabolism. Bhadraiah
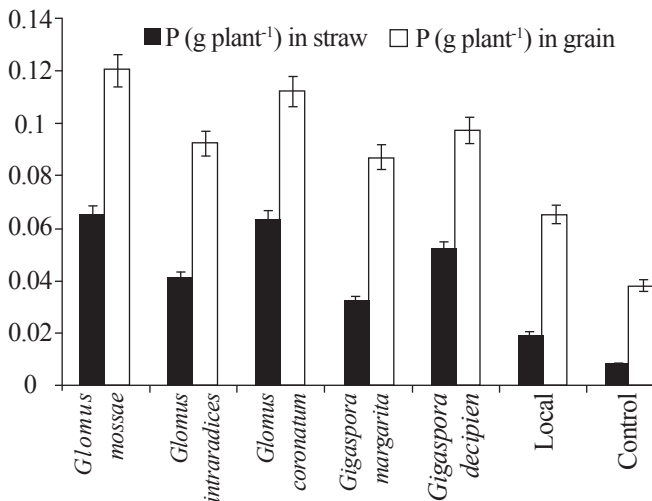

Figure 1: pH of the post harvest soil

Table 2: Macronutrient concentration and organic carbon status of soil

AM Species	Available N (mg kg^{-1})	Available P (mg kg^{-1})	Available K (mg kg^{-1})	Organic Carbon (%)
Glomus mossae	99.32	7.65	101.33	0.60
Glomus coronatum	98.32	7.1	97.83	0.59
Glomus intraradices	95.47	6.93	96.93	0.59
Gigaspora decipien	93.28	6.75	94.04	0.58
Gigaspora margarita	91.00	6.57	90.53	0.58
Local	88.0	5.6	87.3	0.57
Control	86.33	5.41	76.24	0.51
CD (*p*=0.05)	NS	0.36	2.44	NS

Table 3: DTPA extractable cationic micronutrient concentration of soil

AM Species	Zinc (mg kg^{-1})	Copper (mg kg^{-1})	Iron (mg kg^{-1})	Manganese (mg kg^{-1})
Glomus mossae	6.48	0.93	18.18	15.32
Glomus coronatum	5.37	0.85	17.98	15.11
Glomus intraradices	4.98	0.83	17.82	14.43
Gigaspora decipien	4.74	0.77	17.53	14.38
Gigaspora margarita	4.56	0.76	16.86	13.98
Local	4.2	0.74	16.77	13.23
Control	3.61	0.61	16.02	13.15
CD (*p*=0.05)	0.58	0.086	0.015	0.12

et al. (1999) observed a high degree of correlation between phosphorous uptake and activity of phosphatases. Earlier studies by Bethlenfalvay (1993) also show that different species and strains of AMF differ in their effectiveness in increasing nutrient uptake and plant growth. The pattern of extra-and intra-radical forms of AMF hyphae can also justify the difference in phosphorus acquisition among the AMF isolates. Hence, the level of development of extra-radical mycelium in the soil is a major determinant of the efficiency of AMF for phosphorus uptake (Rakshit and Bhadoria, 2010). Similar results indicating that phosphorus uptake by mycorrhizal plants fluctuate with fungal isolates and genetic variability; have also been found on soybean cultivars (Diop et al., 2003). The nitrogen and phosphorus transfer to the maize plants may also be a consequence of the competitive demand for the nutrients, with both host plant and fungus evolving transporters to take advantage of the localized increase in nutrients.

3.3. P content in straw and grain

Phosphorus content in straw and grain was found to be highest under *G. mosseae* inoculation (Figure 3). It might be due to the solubilization of unavailable phosphorus and increase in phosphorus uptake through plants root since mycorrhiza is responsible for increase in the surface area of roots. About 95-99% of the total P in soil exists in insoluble form unavailable to plants. The remaining soluble P is mostly present on exchangeable sites in equilibrium with the small amount of P in the soil solution. Therefore any solubilization of insoluble P by AM fungi significantly adds to the available pool. These results corroborate with the results of Gui et al. (2011) who reported that inoculation of *G. mosseae* significantly increased plant P concentration over un-inoculated maize plants.

3.4. Correlation of estimated soil parameters

The relationships of soil pH, organic C, Available N, P, K and DTPA extractable cationic micronutrients were determined. All the other parameters showed a significant negative association with soil pH, thereby indicating that there was a reciprocal relationship between pH and all other attributes. The organic carbon content exhibited significant positive correlation with
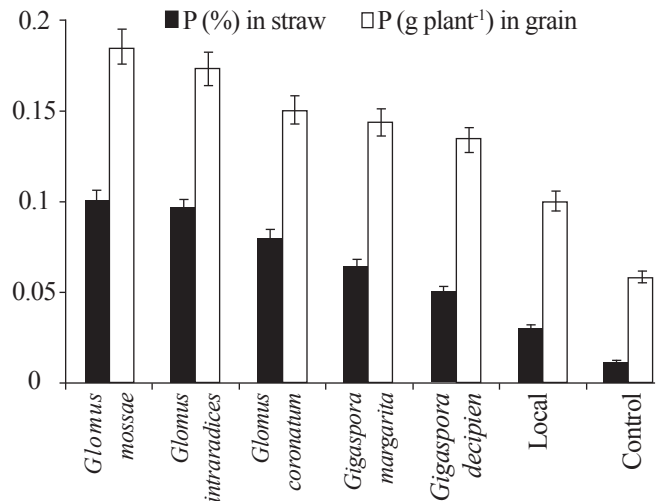
Figure 2: Effect of AM fungi on P uptake by straw and grain

Figure 3: Effect of AM fungi on Phosphorus (P) concentration

Table 4: Correlation between different parameters

	Available N	Available P	Available K	Organic C	Available Zn	Available Cu	Available Fe	Available Mn	pH
Available N	1	0.965**	0.938**	0.814**	0.936**	0.938**	0.969**	0.989**	-0.905**
Available P	0.965**	1	0.941**	0.840**	0.936**	0.927**	0.935**	0.974**	-0.968**
Available K	0.938**	0.941**	1	0.960**	0.907**	0.973**	0.978**	0.913**	-0.933**
Organic C	0.814**	0.840**	0.960**	1	0.808**	0.923**	0.889**	0.782**	-0.857**
Available Zn	0.936**	0.936**	0.907**	0.808**	1	0.964**	0.908**	0.934**	-0.842**
Available Cu	0.938**	0.927**	0.973**	0.923**	0.964**	1	0.954**	0.909**	-0.867**
Available Fe	0.969**	0.935**	0.978**	0.889**	0.908**	0.954**	1	0.941**	-0.916**
Available Mn	0.989**	0.974**	0.913**	0.782*	0.934**	0.909**	0.941**	1	-0.914**
pH	-0.905**	-0.968**	-0.933**	-0.857**	-0.842**	-0.867**	-0.916**	-0.914**	1

soil available macronutrient and cationic micronutrients content. This positive correlation with organic carbon indicated that cationic micronutrients formed complexes with organic matter and consequentially remained in the forms, easily available to the plants. The significant coefficient of correlation between macronutrients and organic matter content was in accordance with the findings of El-Fayoumy and Ramadan, 2002.

4. Conclusion

Inoculation of AM would be more attributed to nutrient availability in soil rhizosphere. It also contributed to relative better plant growth and higher uptake of phosphorus. As evident from the results, the AM fungal inoculation can effectively increase the solubility of micronutrients and plant phosphorus uptake. In the present experiment, the mycorrhizal inoculum, *Glomus mosseae* was found to cater important role in nutrient acquisition in rhizospheric soil of maize plant.

5. Acknowledgment

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