Comparative efficacy of different arbuscular-mycorrhizal fungal spp. (AMF) on tomato (*Lycopersicon esculentum* Mill.)

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Abstract

Mycorrhizal fungi have been a paramount source of biological agent by which damages inflicted by soil-borne pathogens/microbes can be checked. A pot study was conducted to screen and to select potential arbuscular mycorrhizal fungi (AMF) for tomato (*Lycopersicon esculentum* Mill.) var. Pusa Ruby in sandy clay loam soil of Aligarh. Six different AMF were evaluated for their efficacy in term of growth characteristics, nutrient status and mycorrhization. Interaction with AMF species resulted in higher plant growth parameters such as root and shoot biomass and nutrient contents (N, P and K). Measurements of plants, harvested at 20, 40 and 60 days of sampling stages after inoculation showed per cent increase in external and internal colonization, per cent arbuscules in roots and number of chlamydospores per kg rhizosphere soil. Tomato responded to its best to inoculation with *Glomus mosseae*, followed by *G. constrictum*, *G. fasciculatum*, *G. aggregatum*, *Acaulospora scrobiculata* and *Gigaspora gigantea* in terms of plant fresh and dry weight, mycorrhizal colonization, sporulation and nitrogen, phosphorus and potassium content. Out of the six AM fungi screened, *G. mosseae* was found to be the most efficacious AM fungi for tomato var. Pusa Ruby which can be used as biofertilizer and potential biocontrol agent.

Keywords: Tomato, biocontrol, AMF and mycorrhiza.

Introduction

Arbuscular mycorrhizal (AM) association is known to improve plant growth through better uptake of nutrients and increased resistance or tolerance to drought and root pathogens in many species of leguminous and other crop plants (Singh, 1994; Mosse, 1973). AM fungi vary in their physiological interaction with different hosts and hence, in their effect on plant growth. Species and strains of AM fungi have been shown to differ in the extent to which they increase nutrient uptake and plant growth (Powell et al., 1980). These observations have led to introduction of the term "efficient" or effective strains (Abbot and Robson, 1981). Generally those fungi that infest and colonize the root system more rapidly are considered to be "efficient" strain (Mums and Mosse, 1980). The usefulness of mycorrhizae is especially appropriate in the development of sustainable system of agriculture (Mosse, 1986), so as to produce desirable effect of improving plant growth and inducing resistance to pathogen in given environmental conditions (Bali et al., 1987). Tomato is one of the important vegetable plants, used in different forms viz., juice, paste, ketchup, soup and powder. The information to select efficient AM fungi for inoculating tomato (var. Pusa Ruby) to achieve better growth and drought resistance is still meager. Hence, there is need to identify specific host -endomycorrhizal association and to define conditions under which these association function efficiently. The present study is a step in this direction to identify the efficient AM fungi for tomato crop.

Materials and methods

Starter culture of AM fungus (inoculum production)

Collection of soil sample

Morphologically different types of spores recovered from the rhizosphere soils were collected separately. In order to collect spores of AM fungi from each sites, fifty soil samples were collected from the crop fields in Aligarh and adjoining areas with the help of soil auger upto a depth of 15 cm from the rhizosphere ofthe plants.

Isolation of spores

Spores of AM fungi present in the soil samples were isolated by wet sieving and decanting method described by Gerdemann and Nicolson (1963). Samples of 100 g dry soil was taken in 1000 ml of water thoroughly shaked and left for a minute to settle down the heavier particles. The soil solution was passed through coarse sieve first and then decanted on to a series of sieves of varied size i.e. 80, 150, 250 and 300 mesh. The spores obtained on sieves were collected with water in separate beakers. The spore suspensions were repeatedly washed by Ringers' Solution in order to remove the adhered soil particles from the spores. The following species were found to be of common occurrence in the agricultural fields ofthe Aligarh district.

Glomus mosseae
Glomus fasciculatum
Glomus aggregatum
Glomus constrictum
Acaulospora scrobiculata
Gigaspora gigantea

All the above mentioned species were evaluated for their potential as effective AM inoculent for tomato (var. Pusa Ruby). The spores of AM fungi were identified under a dissecting microscope with the help of the synoptic keys suggested by Trappe (1982). The spores of AM fungal species were separated by picking and used for pot culture. Spores were separated with a microspatula and picked up by a Pasteur pipette fitted with a rubber bulb. These tools were surface sterilized for 2 minutes in a solution containing chloroamine T 20 g/l, streptomycin 300 mg /l and Tween 80 in trace amount/l of distilled water.

Maintenance of AM fungi culture

Pure cultures of six AM fungi viz., *Glomus mosseae*, Gerde and Trappe (Nicol and Gerd), *Glomus fasciculatum* (Thaxter Sensu Gerd) *Glomus aggregatum* (Schenck and Smith emend Koske), *Glomus constrictum* (Trappe), *Acaulospora scrobiculata* (Trappe), *Gigaspora gigantea* Nicol. & Gerd (Gerdemann and Trappe) collected during the survey were raised on Rhode's grass (*Chloris gayana* Kunth) grown in pots under glasshouse conditions. To raise Rhode's grass, seeds were surface sterilized with 0.1 per cent solution of HgCl3 and sown (5 seeds per pot) in 9 cm clay pots, containing sterilized soil (66% sand, 24% silt, 8% clay, OM 2%, pH 7.5). Fifty spores of each AM fungal species per pot were layered at 6 and 2 cm depth in 50 clay pots. After emergence, seedlings were thinned and one seedling was maintained in each pot. After 125 days. the plants were uprooted and the spores were isolated by wet sieving and decanting method from the pot soil and the roots were stained and examined for the AM colonization. The spores, hyphal fragments and small plant root segments were then used for further experiments. The population of different AM fungi in the inoculum was assessed by the most probable number method (Porter, 1979). In order to select efficient AM inoculant for tomato, the AM fungirecovered

from agricultural fields were evaluated for their efficiency in improving the performance of the crop (tomato: var. Pusa Ruby). The following AM fungi were used in this experiment *Glomus mosseae, G. fasciculatum, G. aggregatum, G. constrictum, Acaulospora scrobiculata* and *Gigaspora gigantean* Seedlings of tomato (*Lycopersicon esculentum* Mill.) cv. Pusa Ruby were raised in clay pots (25 cm diam.) from seeds surface sterilized with - 0.01% mercuric chloride. The surface sterilized seeds were sown in the pots filled with autoclaved sandy loam soil (66% sand , 24% silt, 8% clay, 2%OM, pH 7.7) and one - week - old seedling were transplanted in 15 cm diam. pots. In each pot filled with 920 g sterilized soil; 8og soil with AM inoculum was added later to make the amount of soil 1 l<g/pot. Before transplantation of seedlings, the mycorrhizal inoculum of different AM fungi was separately placed below the seedling by the layering method (Menge et al., 1977). The inoculum was spread as a layer at a depth of 3-5 cm in the pm at the time of planting. The seedlings were recovered with a layer of soil to ensure the development of an efficient host fungus association. The inoculum consisted ofa mixture of infected root segments and soil with extramatrical hyphae and spores (1000 spores /pot) from cultures of different AM fungi maintained on Rhode's grass, as described earlier. For each treatment 15 replicates were maintained. A control series was also maintained where no inoculum of AM fungi was added to the soil. Pots were watered appropriately and maintained in a glass house bench with air temperature ranging from 30 °C The plants were examined 20, 40 and 60 days after the transplantation for determining the plant growth, mycorrhization and nutrient status of the plants. Mycorrhization was recorded in terms of mycorrhizal intensity in roots i.e., external colonization percentage, internal colonization percentage, percent arbuscules, average number of chlamydospores in 1 cm root segment and number of spores recovered from 100 g dry rhizosphere soil. All the data related to growth of shoots and roots, root infection, spore population and nutrient contents were analyzed statistically by the method of Panse and Sukhatme (1985). Minimum difference required for significance (C.D) at 5% level was calculated by the ANOVA model. y The performance of the crop raised with added inoculum of selected AM fungal species was compared with that of control and the AM fungus causing maximum improvement in the performance over control was selected as efficient AM inoculent for the tomato var. Pusa A Ruby.

Parameters studied

During experimentation the following parameters were determined for each treatment of the experiments at different growth periods such as shoot and root lengths fresh and dry weights of shoot and root Per cent nitrogen, phosphorous and potassium content of plant. Mycorrhization in term of: External and internal colonization percentage, per cent arbuscules, average number of spores in one cm root segment and number of spores recovered from 100 g dry rhizosphere soil. Plant growth parameters Length, fresh weight as well as dry weight of shoots and roots at different stages of growth were recorded for each treatment. Plants of each treatment were taken out from the pots and soil particles adhering to roots were removed by washing in tap water and properly labelled. Lengths of shoot and root were measured by measuring tape and fresh weights of shoot and root were determined with the help of a physical balance. For determining dry weights of root and shoot, plants from each treatment were wrapped in blotting paper sheets, labelled and dried in a hot air oven running at 60 °C for 24-48 h till a constant weight is obtained.

Root colonization and the spore estimation

At the termination of the experiments root colonization in terms of percentage external and internal colonization, per cent arbuscules, average number of spores (in one cm root segment) of the plants by AM fungus and estimation of spores (in 100 g rhizosphere soil) in the same soil samples were used for assessment of the root colonization.

Estimation of N, P and K in plant

Nitrogen content in plants was determined according to the IITA (1975) procedure. Phosphate and potash contents from plants were estimated by the method of Lindner (1944).

Results

Growth characteristics

Plant length

The effect of different AM fungi at the different intervals on plant length was examined in terms of shoot, root and total length of the tomato plants (Tablel 1). Shoot length increased as the time intervals after inoculation increased from 20 to 60 days. *Glomus mosseae* treated plants, showed increase in shoot at each interval, compared to the control as well as to those inoculated with *Acaulospora scrobiculata* and *Gigaspora gigantea*. Shoot lengths of plants inoculated with either *A. scrobiculaza* or *G. gigantea* did not differ from control. Inoculation of tomato plants with *G. fasciculatum* or *G. constrictum* showed a better performance at 40 days interval than *G. mosseae* but at 20 and 60 days of growth intervals, all ofthem promoted almost the same amount of growth. The root length was also promoted by *G. mosseae* at all the growth intervals. Treatment of *G. mosseae* improved the root length to the same extent as that of *G. constrictum* at 40 and 60 days intervals but to a lesser extent at 20 days old seedlings compared to the plants inoculated with *G. constrictum* or *G. fasciculatum. G. aggregatum, A. scrobiculata* and *G. gigantea* treatments also increased root lengths to a higher level compared to control in 60 days old plants, but not in 20 days old seedlings. The growth effects due to treatment with AM fungi on total plant length are given in Table . Total plant length in control as well as in plants inoculated with either *A. scrobiculata* or *G. gigantea* were similar and significantly lower compared to the ones treated with *G. mosseae*. No significant difference in plant length could be observed in plants inoculated with *A. scrobiculata* or *G. gigantea* compared to control as well as to those inoculated with *G. aggregatum* at 20 days interval, but they significantly differed from control at 60 days interval. However, their total length was much less than those treated with the other three AM fungi namely *G. mosseae*, *G. fasciculatum* and *G. constrictum*. The extent of growth promoted by *G. mosseae* and *G. constriclum* 1 did not differ significantly at 20 days interval but later the differences 1 were significant. The highest (33%) growth promotion was recorded in it case of G. mosseae and it was closely followed by *G. fasciculatum* (32%) at 60 days interval. However. on 40 days old plants *G. constrictum* promoted the highest level of growth (27%) followed by *G. fasciculatum* (25%) and *G. mosseae* (24%)

Plant fresh weight

At all the growth intervals *G. mosseae* promoted the highest value of shoot fresh weight, compared to those treated with the other five AM fungi and control, but it was apparently at par with *G. constrictum* inoculated plants. Inoculation of *A. scrobiculata*

and *G. gigantea*.. However, resulted in no significant increase in the shoot fresh weight over the control at 20 days interval. The fresh weight of plants inoculated with *G. gigantea* did not differ from control at 40 days interval but significantly increase in shoot fresh weight occurred at 60 days interval compared to control. Inoculation of *G. constrictum* resulted in higher increase in shoot 5 fresh weight than those inoculated with *G. aggregatum* at 20 and 60 days intervals, but not at 40 days. The inoculation of plants with *G. constrictum* and *G. fasciculatum* resulted in almost similar increase in fresh weight upto 40 days, but the former supported a significantly higher if increase in shoot weight than the latter at the final stage (Table 2). At 40 days interval the plants treated with *G. mosseae* showed if higher root fresh weight than all the other AM fungi, but it was almost equivalent to those plants inoculated with *G. constrictum* and *G. aggregatum*. At 60 days interval, the root fresh weight was the highest in if the plants treated with *G. mosseae*. At 20 days interval, the control plants showed root fresh weight equal to those inoculated with *G. aggregatum* and *G. gigantea*, and at 20 days interval, it was at par with *G. fasciculatum* and *A. scrobiculata* but significantly superior to *G. gigantea*. Again at 60 days interval, control was apparently equal to those *G. aggregatum, G. constrictum* and *G. gigantea* (Table 2). Total fresh weight of tomato plants was improved by inoculation with *G. mosseae*, although it was at par with *G. aggregatum* and *G. constrictum* treated plants at 40 days interval. At the final stage of growth *A. scrobiculata* and *G. gigantea* treatments resulted in significantly higher plant fresh weight than control but significantly lower than that of *G. mosseae* inoculated plants. At all the three intervals *G. fasciculatum* and *G. constrictum* supported the same value of fresh weight. Inoculation of *G. mosseae* resulted in significant increase in total fresh weight percentage ofthe plants over the control as well as the other five AM fungi viz. *G. fasciculatum, G. aggregatum, G. consrrictum, A. scrobiculata*, and *G. gigantea* at all growth intervals.

Plant dry weight

At 60 days interval, *G. mosseae* inoculation resulted insignificantly superior shoot dry weight than all others. The inoculation of *G. mosseae*, *G. fasciculatum* and *G. constrictum* resulted in almost the same amount of shoot dry weight at 40 days interval although G. mosseae supported almost the same amount of dry weight in plants inoculated with *G. fasciculatum* at 20 days interval (Table 3). No significant difference in shoot dry weight was recorded in plants inoculated with *A. scrobiculata* or *G. gigantea* compared to control at 40 and 60 days intervals as well as to those treated with *G. aggregatum* at 20 days growth period. However, at all the three stages of growth the values of shoot dry i weight remained minimum in control. As in all the other cases, *G. mosseae* supported significantly high root dry weight at 60 days interval. The extent of root dry weight supported by *G. mosseae* and *G. fasciculatum* did not vary to any significant level at 40 days interval. Root dry weight in the control plants was found to be at par with those inoculated with *G. gigantea* at 20 days interval and also happened to be the same with those inoculated with *G. aggregatum, A. scrobiculata* and *G. constrictum* at 40 days interval. The dry weights of plants inoculated with *A. scrobiculata* and those of control were same at 60 days interval. The total dry weight of tomato plants inoculated with *G. mosseae* proved to be significantly high at 60 days growth interval compared to other treatments (Figure 2a). No significant difference in total dry weight was observed in the plants inoculated with *G. mosseae* and G. *fasciculatum* at 20 and 40 days intervals. Plants inoculated with *G. constrictum* resulted in significantly high dry weight over that of *G. fasciculatum* and *G. aggregatum* at 60 days time interval. Apparently equal values of

plant dry weight was recorded in plants treated with *G. constrictum, G. fasciculatum* and *G. aggregatum* at 20 and 40 days intervals. Plant dry weight in *A. scrobiculata* and *G. gigantea* inoculated 3 plants proved to be equivalent to each other and to control at the final stage of growth. The highest total plant dry weight was supported by *G. mosseae* at all the three intervals, which was closely followed by *G. fasciculatum* and *G. constrictum* at 20 and 40 days intervals. However, at 60 days old plants, the dry weight of the plants inoculated with *G. mosseae* was followed by *G. constrictum* and *G. fasciculatum* (Table 3).

Nutrient status

No significant difference in N contents was noted in plants inoculated with *G. constrictum* (1.75%), *A. scrobiculata* (1.64%) and *G. gigantea* (1.67%) compared to control (1.60%) at 20 days interval but there values dropped to significant levels compared to *G. mosseae* (1.92%) *G. fasciculatum* (1.86%) and *G. aggregatum* (1.80%). At 40 days interval, N contents in plants inoculated with *G. aggregatum* (1.90%) *A. scrobiculata* (1.98%) and *G. gigantea* (2.00%) were found to be almost the same (Table 4). The highest N content was observed in the plants inoculated with *G. constrictum* (2.49%) followed by the *G. mosseae* (2.31%) *G. fasciculatum* (2.29%) and *G. aggregatum* (2.10%) at 40 days interval. There was no significant difference in the N contents of the plants inoculated with *G. aggregatum*(2.00%) *A. scrobiculata* (1.88%) and *G. gigantea (1.97%)* compared to control (1.87%) at 60 days interval but the values increased in the plants inoculated with the other three AM fungi compared to control. Maximum N content was obtained in plants treated with *G. constrictum* (2.23%) but the difference being insignificant to those obtained with *G. mosseae* (2.18%) and *G. fasciculatum* (2.15%) inoculated plants. At the final stage of growth, all the three AM fungi proved to be equally efficient in this regard (Table 4). The P contents of the plants inoculated with *G. mosseae* was the maximum (0.389, 0.4l9 and 0.366%) in all the three intervals of growth. Inoculation of *G. mosseae* and *G. fasciculatum* resulted almost in the same amount of P content (0.4l9and 0.391%) in the plants after 40 days, but at the 60 days interval, *G. mosseae* (0.366%) proved to be at par with *G. constrictum* (0.35l%) in terms of P content values of the plants. The P content in the plants treated either with *G. fasciculatum* (0.344%) or *G. aggregatum* (0.363%) were significantly high compared to the plants inoculated with *G. constrictum* (0.252%), *A. scrobiculata* (0.389%) and *G. gigantea* (0.286%) but were significantly lower to those inoculated with *G. mosseae* (0.389%) at 20 days interval. No significant difference was 2 recorded in P contents of the plants treated with *G. constrictum* (O.252%) and *G. gigantea* (0.286%) compared to control (0.276%) at 20 days 9 interval but it was significantly low against *A. scrobiculata* treatment (0.309%). Phosphorus contents in the plants treated with *G. constrictum* (0.388%), *A. scrobiculata* (0.352%) and *G. gigantea* (0.325%) did not differ significantly from that of control (O.322%) at 40 days interval. At the 60 days old plants P content in plants with *G. aggregatum* (O.322%). *G. fasciculatum* (0.289%) *A. scrobiculata* (0.324%) and *G. gigantean* (0.303%) was same but it was significantly lower than those inoculated with *G. mosseae* (0.366%) or *G. constrictum* (0.351%) (Tabke. 4). 2 At 20 days interval, K content of *G. mosseae* (2.21%) treated plant i was at par with *G. fasciculatum* but proved significantly inferior to those inoculated with others. No significant difference occurred in K contents of *G. mosseae* inoculated plants (2.30%) and those inoculated with *G. constrictum* (2.26%) at 40 days interval. Similarly no significant difference was recorded in K contents of the plants inoculated with *G. mosseae* (2.05%) or *G. constrictum* (2.10%) at 60 days interval (Table 4). The K

contents of the plants inoculated with either *A. scrobiculata* (1.68°/o and 1.96 °/o) or *G. gigantea* (l.55% and 1.95%) did not differ to any significant level compared to control (l.52% and 1.95%) at 20 and 40 days intervals and it was, however, significantly lower to all the others. At the final stage the control (1.54%) and the plants treated with *A. scrobiculata* (1.58%) did not show any significant difference in their K content (Table 4).

Mycorrhization

The mycorrhization of AM fungi was estimated by using five parameters as given in the table 15. The values for all the parameters in plants inoculated with *G. mosseae* was higher than all the other treatments except the number of chlamydospores (352/100 g soil) at 20 days interval and per cent arbuscules (33.00) at 60 days interval. The values of mycorrhization in case of *A. scrobiculata* and *G. gigantea* were lesser than the other AM fungi viz. *G. mosseae, G. fasciculatum, G. aggregatum, G. constrictum*. The values in case of mycorrhization in *G. fasciculatum, G. aggregatum*, and *G. constrictum* treated plants fluctuated between *G. gigantea* and *G. mosseae* treatments (Table 5). The highest percentage of outer colonization (80.4%), internal colonization, (68.4%), arbuscules (55.4%) and the average number of spores in one cm root segment (42.8) was recorded in plants treated with G. mosseae which was followed by *G. constrictum* 70.0, 48.0 and 35.6% respectively at 40 days interval. Almost similar pattern of mycorrhization was observed in *G. mosseae* and *G. constrictum* inoculated plants at 20 and 60 days intervals. *G. mosseae* inoculated plants also resulted in the highest spore population in 1oog soil/pot (352, 336 and 925) compared to all the other AM fungi at all the three intervals, and it was closely followed by *G. constrictum* (227, 316 and 788).

Discussion

In the present study, it has been found that the mycorrhizal status and growth responses are considerably high in all the treatments compared to the control and the different strains of AM fungi differ in their capacity to promote plant growth and N P and K levels. There are wide variations in the growth promoting efficiency of different AM fungi and their ability to stimulate plant growth and P uptake on soybean (Carling and Brown, 1980) and pearl millet (Krishna and Dart, 1984). Better plant growth in AMF infected plants could be due to enhanced nutrient contents of the plant. Enhanced absorption and accumulation of several nutrients such as N, P, K, Zn Mn, Fe. Ca and S infected plants have been reported (Bowen et al., 1975; Powell, 1975; Selvaraj et al., 1986 and Dhillion, 1992). AM fungi also enhance the concentration of different organic compounds in root and can improve the productivity of the host plant (Selvaraj et al., 1995). Out of the six different AM fungi experimented, *G. mosseae* caused highest increase in dry weight over the control, followed by *G. constrictum* at all the three sampling stages. The results of the present study are in agreement with those of Jeffries (1987) who found that AM fungi are known to improve plant growth mainly through increased P uptake and other nutrients. Growth yield and dry matter increase by mycorrhizal fungi have been reported for many crops such as barley, onion, soybean, rice and blackgram (Owusu and Mosse, 1979; Bagyaraj et al., 1979; Kuo and Hung, 1982; Luis and Brown 1986; Sanni 1976; Umadevi and Sitaramaiah, 1990). Sundaram and Arangarasan (1995) recently reported that out of four cultures of AM fungi, *G. fasciculatum* gave the highest fruit yield in tomato plants. Bagyaraj et a1. (1989) reported that different

strains of AM fungi have different capability to increase the nutrient uptake and plant growth and therefore there is a need for selecting the efficient ones. The extent of extra and intramatrical mycelia, arbuscules formation and chlamydospore population in soil vary with different AM fungal species studied. They also vary in their specificity with the host. Root colonization has been found to 'facilitate more host-fungal contact and exchange of nutrients resulting in better plant growth. A similar kind of observation has been made by Abbott and Robson, (1982). Inoculation of mycorrhizal fungi increased the N, P, and K contents of the plants which improved plant growth. Improved phosphorus nutrition has been found to decrease the membrane permeability which reduces the root exudation (Graham et al., 1981). Mycorrhizal plants have been found to have higher shoot and root dry weights and phosphate content in pigeonpea by Munjunath and Bagyaraj (1984) and Ramraj and Shanmugam (1990). Out of the six AM fungi investigated *G. mosseae* promoted better plant growth and nutrient contents of the plants than others. *G. mosseae* inoculated plants also showed the highest percentage of intra (80.4) and extramatrical (68.4) mycelial, arbuscules (55.4) and spore production (925) compared to others. A similar situation has been come across by Abbott and Robson (1985). These mycorrhizal mycelia coupled with increased nutrient uptake results in the better performance of the mycorrhizal plants. It has been established by Rhodes and Gerdemann (1975) that the mycorrhizal plants can exploit several times the volume of soil available to a non- mycorrhizal plant, and achieve more active translocation of minerals along the extramatrical hyphae compared to the non-mycorrhizal ones. Effectiveness of a fungus has been correlated with its ability to produce more external hyphae by Scheltema et a1. (1985) as the digestion of the arbuscules could not provide the plant with more than 0.065% of thephosphorus that enter the mycorrhizae (Sanders and Tinker, 1973; Cox and Tinker, 1976). Polyphosphate granules involved in P transport within the fungal cytoplasm have been seen in vacuoles in the inter, and intracellular hyphae (Cox et al., 1975) but are no longer observed in the finest branches of arbuscules by Callow et al., (1978). These branches have been found to contain acid and alkaline phosphates (Gianinazzi et al., 1979). *Glomus mosseae* has been found in the present study to be more efficient in overall performance including N, P and K status on tomato compared to others, and it is followed by *G. constrictum*. Similarly, liamraj and Shanmugam (1990) have come across *G. etunicatum* to be more effective in increasing the shoot dry weight of cowpea. A significant response of soybean to AM fungi in phosphorus deficient soil has been reported by Raverkar and Tilak (1988) and Ross (1970). Similar results have been obtained in cassava by Sulochana et al. (1995), and in chickpea by Singh and Verma (1987) where *G. fasciculatum* and *G. etunicatum* proved to be the most effective ones in the respective crops. In the present study, it has been found that *G. mosseae* support the highest plant growth in terms of length and biomass of plants at maturity. Biomass production, mycorrhizal colonization, sporulation and nutrient contents have also been found to be significantly high in the inoculated plants with G. mosseae compared to all the other five AM fungal species. It could be, therefore, designated as the potential AMF inoculant in sandy clay loam soil for tomato var. Pusa Ruby for the successful plant growth and yield.

Conclusion

Study was conducted to screen and select potential arbuscular mycorrhizal fungi (AMF) for tomato (*Lycopersicon esculentum* Mill.) var. Pusa Ruby in sandy clay

loam soil of Aligarh. Six different AMF were evaluated for their efficacy in term of growth characteristics, nutrient status and mycorrhization. Interaction with AMF species resulted in higher plant growth parameters, root and shoot biomass and nutrient contents (N, P and K). Measurements of plants, harvested at 20, 40 and 60 days of sampling stages after inoculation showed per cent increase in external and internal colonization, percent arbuscules in roots and number of chlamydospores per1oog rhizosphere soil. Tomato responded to its best to inoculation with *Glomus mosseae*, followed by *G. constrictum*, *G. fasciculatum*, *G. aggregatum*, *Acaulospora scrobiculata* and *Gigaspora gigantea* in terms of plant fresh and dry weight, mycorrhizal colonization, sporulation and nitrogen, phosphorus and potassium content. Out of the six AM fungi screened, *G. mosseae* was found to be the most efficacious AM fungi for tomato var. Pusa Ruby which can be used as biofertilizer and potential biocontrol agent.

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Table 1. Effect of different arbuscular mycorrhizal (AM) fungi on shoot, root, and total length of tomato var. Pusa Ruby at different stages of growth

	Sampling stages (days)											
	20				40				60			
Treatments	Shoot	Root	Total	% increase	Shoot	Root	Total	% increase	Shoot	Root	Total	% increase
Control	**28**	**4.4**	**32.4**	**-**	**33.41**	**9.72**	**43.13**	**-**	**36.08**	**19.41**	**55.49**	**-**
G. mosseae	**32.4**	**5.3**	**37.7**	**16.35**	**37.42**	**15.94**	**53.36**	**23.72**	**48.07**	**25.15**	**73.58**	**32.6**
G. fasciculatum	**31.69**	**5.43**	**37.12**	**14.57**	**40.22**	**13.64**	**53.86**	**24.88**	**9.86**	**23.13**	**73.18**	**31.88**
G. aggregatum	**29.31**	**4.62**	**33.93**	**4.72**	**34.46**	**8.4**	**42.86**	**-0.63**	**39.64**	**21.27**	**61.34**	**10.54**
G. constrictum	**31.65**	**5.88**	**37.53**	**15.83**	**39.6**	**15.15**	**54.75**	**26.94**	**46.6**	**24.07**	**71.42**	**28.53**
A. scrobiculata	**28.81**	**4.42**	**33.27**	**2.69**	**33.68**	**10.01**	**43.69**	**1.3**	**37.05**	**21.26**	**58.65**	**5.69**
G. gigantea	**28.6**	**4.53**	**33.13**	**2.25**	**33.8**	**8.34**	**42.14**	**-2.3**	**36.83**	**23.09**	**60.78**	**9.53**
CD	1.4	0.58	2.72		2.96	1.1	3.73		3.76	1.28	5.82	

Table 2. Effect of different arbuscular mycorrhizal (AM) fungi on shoot, root, and total fresh weight (g/ plant) of tomato var. Pusa Ruby at different stages of growth

	Sampling stages (days)											
	20				40				60			
Treatments	Shoot	Root	Total	% increase	Shoot	Root	Total	% increase	Shoot	Root	Total	% increase
Control	**7.61**	**1.42**	**9.03**		**18.26**	**3.93**	**22.19**		**26.24**	**8.03**	**34.27**	
G. mosseae	**10.25**	**1.84**	**12.09**	**33.89**	**23.44**	**5.24**	**28.68**	**29.25**	**38.49**	**13.3**	**51.82**	**51.21**
G. fasciculatum	**9.06**	**1.8**	**10.86**	**20.27**	**21.21**	**4.34**	**25.55**	**15.14**	**33.81**	**10**	**43.81**	**27.84**
G. aggregatum	**8.07**	**1.5**	**9.57**	**5.98**	**22.47**	**4.7**	**26.57**	**19.74**	**31.23**	**8.72**	**39.95**	**16.57**
G. constrictum	**9.81**	**1.93**	**11.74**	**29.72**	**22.4**	**4.85**	**27.25**	**22.8**	**36.21**	**9.06**	**45.27**	**32.1**
A. scrobiculata	**8.07**	**1.71**	**9.78**	**8.31**	**20.82**	**3.96**	**24.78**	**11.67**	**29.43**	**10.6**	**40.05**	**16.87**
G. giganta	**7.25**	**1.61**	**8.86**	**1.88**	**17.43**	**3**	**20.43**	**-7.93**	**31.67**	**9.2**	**40.87**	**19.26**
CD	0.9	0.22	1.28		1.83	0.63	2.18		2.44	1.31	3.62	

Table 3. Effect of different arbuscular mycorrhizal (AM) fungi on shoot, root, and total dry weight (g/plant) of tomato var. Pusa Ruby at different stages of growth

	Sampling stages (days)											
	20				40				60			
Treatments	Shoot	Root	Total	% increase	Shoot	Root	Total	% increase	Shoot	Root	Total	% increase
Control	**1.23**	**0.12**	**1.35**	**-**	**3.08**	**0.32**	**3.4**	**-**	**8.6**	**1.65**	**10.25**	**-**
G. mosseae	**1.9**	**0.2**	**2.1**	**55.56**	**4.58**	**0.46**	**5.04**	**48.24**	**12.14**	**2.58**	**14.72**	**43.61**
G. fasciculatum	**1.8**	**0.15**	**1.95**	**44.44**	**4.02**	**0.42**	**4.44**	**30.59**	**10.81**	**2**	**12.81**	**24.98**
G. aggregatum	**1.3**	**0.22**	**1.52**	**12.59**	**3.67**	**0.38**	**4.05**	**19.12**	**9.83**	**1.85**	**11.68**	**13.95**
G. constrictum	**1.44**	**0.18**	**1.62**	**20.0**	**4.0**	**0.34**	**4.34**	**27.65**	**11.12**	**2.12**	**13.24**	**29.17**
A. scrobiculata	**1.42**	**0.14**	**1.56**	**15.56**	**3.44**	**0.36**	**3.80**	**11.76**	**9.09**	**1.83**	**10.92**	**6.54**
G. giganta	**1.4**	**0.11**	**1.51**	**11.85**	**3.03**	**0.30**	**3.33**	**-0.59**	**8.65**	**2.08**	**10.73**	**4.68**
CD	0.1	0.03	0.18		0.58	0.07	0.63		0.93	0.19	1.18	

Table 4. Effect of different arbuscular mycorrhizal (AM) fungi on N, P and K of tomato var. Pusa Ruby at different stages of growth

	Sampling stages (days)								
	20			40			60		
Treatments	N	P	K	N	P	K	N	P	K
Control	**1.6**	**0.276**	**1.52**	**1.9**	**0.322**	**1.95**	**1.87**	**0.294**	**1.54**
G. mosseae	**1.92**	**0.389**	**2.21**	**2.31**	**0.419**	**2.3**	**2.18**	**0.366**	**2.02**
G. fasciculatum	**1.86**	**0.344**	**2.11**	**2.29**	**0.391**	**2.15**	**2.15**	**0.289**	**2.05**
G. aggregatum	**1.8**	**0.363**	**1.63**	**2.1**	**0.356**	**1.97**	**2**	**0.322**	**1.85**
G. constrictum	**1.75**	**0.252**	**2**	**2.49**	**0.338**	**2.26**	**2.23**	**0.351**	**2.1**
A. scrobiculata	**1.64**	**0.309**	**1.68**	**1.98**	**0.352**	**1.96**	**1.88**	**0.324**	**1.58**
G. giganta	**1.67**	**0.286**	**1.55**	**2**	**0.325**	**1.95**	**1.97**	**0.303**	**1.66**
CD	0.18	0.031	0.18	0.15	0.031	0.13	0.16	0.034	0.12

Table 5. Effect of different arbuscular mycorrhizal (AM) fungi inoculation on micorrhizal infection of tomato var.. Pusa Ruby at different stages of growth

	Mycorrhyzation												No. of chlamydospores recovered from 100 g rhizosphere soil		
	After 20 days				After 40 days				After 60 days				Days of sampling		
Treatments	A	B	C	D	A	B	C	D	A	B	C	D	20	40	60
Control															
G. mosseae	**34.8**	**23.4**	**12**	**10**	**80**	**68**	**55**	**43**	**69**	**61**	**33**	**37**	**352**	**336**	**925**
G. fasciculatum	**22.9**	**13.4**	**4**	**13**	**57**	**39**	**22**	**12**	**65**	**52**	**52**	**28**	**215**	**293**	**727**
G. aggregatum	**11.2**	**9**	**4.2**	**2.8**	**24**	**14**	**10**	**9.2**	**42**	**21**	**5**	**3**	**214**	**224**	**658**
G. constrictum	**29.4**	**17.2**	**3**	**12**	**70**	**57**	**48**	**36**	**60**	**53**	**37**	**12**	**227**	**316**	**788**
A. scrobiculata	**12**	**10.6**	**3.2**	**3**	**24**	**18**	**12**	**11**	**47**	**32**	**12**	**4**	**200**	**174**	**638**
G. gigantea	**8.4**	**8.8**	**1.4**	**1.8**	**19**	**11**	**8.4**	**3.6**	**33**	**12**	**4**	**2**	**160**	**189**	**430**
CD	2	1.9	0.7	1.4	6	2	1.9	1.7	5.3	3	3	2.1	13	16	36

A=External colonization per cent; B=Internal colonization per cent; C= Percent arbuscules