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Comparative efficacy of arbuscular mycorrhizal inoculum on the growth of Sorghum (*Sorghum vulgare* L.) under municipal solid waste amended soil

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Arbuscular mycorrhizal (AM) fungi are among the most common of all soil fungi and they form symbiotic associations with the roots of most vascular plants. AM fungi are of importance as they play a vital role in metal tolerance and accumulation in plants. AM inoculum collected from plant rhizosphere of municipal solid waste (MSW) amended soil showed positive growth response of sorghum with respect to root and shoot biomass production and phosphorus nutrition. The response increased with the increase in AM inoculum doses, whereas, growth response was marginal when inoculated with AM fungal strains collected from normal alluvial soil in MSW amended soil. Infection percentage data indicated that AM from alluvial soil did not work properly at any inoculum potential level. Cadmium, the heavy metal, was found to accumulate in root in higher quantity than in shoot when inoculated with AM of MSW source. Positive impact of MSW origin AM could also be confirmed by the total root dry weight and total cadmium content in root out of total plant biomass and cadmium content. This observation indicates that heavy metal tolerant AM strains are the better candidate than AM from normal alluvial soil to promote plant growth under heavy metal stress prone MSW amended soil.

Key words: AM inoculum, MSW amended soil, sorghum

INTRODUCTION

Arbuscular mycorrhiza (AM) is an integral part of most angiospermic plants providing a direct link between the soil and plants. Mycorrhizal symbiosis results in improvements of the plant's overall physiology. Arbuscular mycorrhizal fungi have also been shown to improve plant tolerance to heavy metal stress in polluted soils. However, large applications of Zn, Cu, Ni, and Cd can eliminate AM infection in contaminated soils. AM fungal infection may decrease metal accumulation in plants growing in polluted soils and thus protect the host against phytotoxic metal effects. Another important feature of this symbiosis is that AM fungi can increase plant establishment and growth despite high levels of soil heavy metals, due to better nutrition, water availability and soil aggregation properties associated with this symbiosis. AM fungi are significant in the ecological improvement of rhizosphere. It has been found that AM fungal spore numbers, species richness and diversity depend on the level of heavy metal contamination of a soil amended with sewage sludge and that host plant species exert a selective influence on AM fungal population size and diversity. It has been found that heavy metal tolerant AM fungi could protect plants against harmful effects of excessive heavy metals. The present investigation was carried out to know the differential functional response of sorghum to arbuscular mycorrhizal inoculum from MSW amended soil source and AM inoculum from non amended alluvial soil source.

MATERIALS AND METHODS

Investigations were carried out in the Laboratory for Plant and Microbial Biotechnology, Research Complex Building of BCKV at Kalyani, Nadia, West Bengal. Investigations were carried out mainly with transported Kolkata municipal solid waste (MSW) amended agricultural soil from *Dhapa* disposal site in a well-ventilated nursery house under ambient light and temperature condition. This experiment was conducted in municipal solid waste amended soils with varying AM inoculum doses. AM strain

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was collected from different plant rhizosphere of experimental MSW amended location soil. The mixed AM culture collected was multiplied in the net house in MSW amended soil with low dose of cadmium in the form of cadmium chloride solution ($10 \mu ml^{-1}$) drenching. Another AM inoculum was collected from plant rhizosphere in alluvial soil having no metal stress and multiplied in alluvial soil without metal stress.Root based inoculum of both the AM cultures were added in unsterilized MSW amended soil @ 15, 30 and 45 g kg^{-1} soil in case of MSW soil source AM and 20 and 40 g kg^{-1} in case of alluvial soil source AM.Control soil received only root based heat killed AM inoculum. After mixing the MPN values for infective propagules were 46, 88 and $131 g^{-1}$ soil for MSW inoculums and 63 and 106 g^{-1} soil for alluvial inoculums.Sorghum seeds were shown in AM inoculated soil in plastic cups containing 500 g soil. Seedlings were maintained in wire net nursery under ambient temperature, light and humidity. Seedlings were fertilized with half strength Hoagland's solution without phosphorus twice at 15 days interval. All plants while in the nursery were routinely sprayed with insecticide to keep the pest incidence in check. After germination plant roots were collected and observed for AM colonization at periodic intervals. After 50 days, the plants were harvested and growth was measured in terms of dry weight per plant. Data are presented in Tables 1, 2, 3 and 4.

RESULTS AND DISCUSSION

Inoculation of both the AM inoculums i.e. inoculum from MSW amended soils and inoculums from alluvial soils improved sorghum root and shoot dry matter production (Table 1 and 2). However, the magnitude of increase in dry matter production with the increase in inoculum dose was much higher in case of MSW inoculum than alluvial inoculum, with marginally lower root-shoot ratio in MSW inoculum source than alluvial inoculum source at all concentration.

Shoot and root dry matter production was improved more than 90% to that of non-inoculated seedling at 50 days of growth with MSW AM inoculum but values remained very low with alluvial inoculum. Sorghum root infection percentage improved with increase in concentrations considerably in MSW AM inoculum applications and reached to more than 75% at 131 g^{-1} inoculum concentrations.

At higher dose of MSW inoculum onset of root infection was recorded at 5 days of seed germination with higher number of infection points per cm of root observed. Whereas, in case of alluvial inoculum strain and at basal level of inoculum concentration onset of infection was observed 16 days after seed germination with few number of infection points per cm root length observed (Table 2).

Root and shoot phosphorus concentrations and total shoot phosphorus contents were significantly improved with increasing concentrations of MSW AM inoculation. However, a marginal decrease in both root and shoot phosphorus concentration was recorded at highest inoculum dose ($131 g^{-1}$ soil). There was no significant change in tissue phosphorus concentration with increase in alluvial AM inoculum concentration. However, root phosphorus content improved with increased concentration of alluvial AM inoculum as compared to uninoculated plants.

Cadmium, the target heavy metal of the present study was measured in both roots and shoots with both the types of AM inoculum application. It revealed from the Table 3 and 4 that with the increase in MSW AM inoculum there were significant increases in Cd root concentrations and contents.

But, in case of alluvial AM strain such increase in Cd concentration in root was not recorded. Cadmium might have been bound in greater quantity to the fungal bodies present in the root and restricted to move to the shoot. Positive impact of MSW origin AM could also be confirmed by the total root dry weight and total Cd content in root out of total plant biomass and Cd content. Total root dry matter percentage remaining almost equal in plants inoculated with either of the AM inoculum source but major portion of total plant Cd retained in the roots (> 50%) of plants infected with AM from MSW source whereas, the alluvial AM inoculated plant roots contained only about 20% of total plant Cd contents. Similar phenomenon was observed by earlier workers while studying on heavy metals and AM fungal interactions (Mandal and Saha, 2014).

The observation of differential functional response of AM inoculum from MSW and sewage amended soil source and AM inoculum from non amended alluvial source to promote plant growth in heavy

Table 1: Growth of sorghum in MSW amended soil with AM inoculation (AM inoculum of MSW soil origin)

Treatment (AM infective propagule g^{-1} soil)	Plant height (cm)	Root dry weight (g)	Shoot dry weight (g)	Total Biomass dry weight (g)	Root : Shoot	Infection %	Onset of root infection	No. of infection points per cm root at initiation
8.2	74.20 ± 1.29	1.14 ± 0.08	1.63 ± 0.14	2.77 ± 0.19	0.70	42.7 ± 3.95	16DAS	0.8
46	79.00 ± 1.92	1.76 ± 0.03	2.59 ± 0.11	4.35 ± 0.10	0.68	60.5 ± 6.20	5DAS	2.1
88	86.32 ± 1.41	1.84 ± 0.07	2.84 ± 0.18	4.68 ± 0.24	0.65	67.9 ± 4.10	5DAS	2.8
131	91.50 ± 1.42	2.18 ± 0.13	3.15 ± 0.13	5.33 ± 0.11	0.69	75.6 ± 5.23	5DAS	4.6
SEm(±)	0.765	0.040	0.071	0.086	-	-	-	--
LSD $_{0.05}$	2.295	0.127	0.212	0.257	-	-	-	-

Values are averages of 3 replications ± SD

Table 2: Growth of sorghum in MSW amended soil with AM inoculation (AM inoculum of alluvial soil origin)

Treatment (AM infective propagule g^{-1} soil)	Plant height (cm)	Root dry weight (g)	Shoot dry weight (g)	Total biomass dry weight (g)	Root : Shoot	Infection %	Onset of root infection	No. of infection point per cm root at initiation
8.2	74.2 ± 0.44	1.14 ± 0.08	1.63 ± 0.12	2.77 ± 0.08	0.70	42.71 ± 1.32	16DAS	0.8
63	75.8 ± 0.84	1.28 ± 0.04	1.78 ± 0.05	3.06 ± 0.03	0.72	44.85 ± 3.69	15DAS	1.1
106	78.6 ± 0.76	1.38 ± 0.02	1.86 ± 0.04	3.24 ± 0.04	0.74	46.26 ± 3.18	15DAS	1.0
SEm(±)	0.351	0.026	0.039	0.028	-	-	-	0.0528
$CD_{0.05}$	1.08	0.080	0.120	0.086	-	-	-	0.163

Values are averages of 3 replications ± SD

Table 3: Phosphorus (P) and cadmium uptake by sorghum in MSW amended soil (AM inoculums of MSW soil origin)

Treatment AM infective propagule g^{-1} soil)	Root P concentration (mg kg^{-1})	Root P content (mg $plant^{-1}$)	Shoot P concentration (mg kg^{-1})	Shoot P content (mg $plant^{-1}$)	Root Cd concentration (mg kg^{-1})	Shoot Cd concentration (mg kg^{-1})	Total plant Cd content (mg $plant^{-1}$)
8.2	1377 ±148.4	1.57 ± 0.10	1861 ± 137.0	3.03 ± 0.07	1.80 ± 0.03	7.08 ± 0.17	0.014 ± 0.002
46	1884 ± 64.4	3.32 ± 0.13	2341 ± 278.2	6.06 ± 0.76	5.32 ± 0.18	3.12 ± 0.08	0.017 ± 0.001
88	2010 ± 160.1	3.70 ± 0.18	3112 ± 172.7	8.84 ± 0.05	7.96 ± 0.10	3.27 ± 0.13	0.024 ± 0.002
131	1802 ± 88.1	3.93 ± 0.10	2895 ± 114.4	9.12 ± 0.13	11.92 ± 0.26	4.44 ± 0.07	0.039 ± 0.001
SEm(±)	61.02	0.065	93.22	0.194	0.083	0.058	0.0008
LSD $_{0.05}$	182.93	0.196	279.50	0.582	0.249	0.173	0.0035

Values are averages of 3 replications ± SD

Table 4: Phosphorus (P) and cadmium uptake by sorghum in MSW amended soil (AM inoculums of alluvial soil origin)

Treatment (AM infective propagule g^{-1} soil)	Root P concentration (mg kg^{-1})	Root P content (mg $plant^{-1}$)	Shoot P concentration (mg kg^{-1})	Shoot P content (mg $plant^{-1}$)	Root Cd concentration (mg kg^{-1})	Shoot Cd concentration (mg kg^{-1})	Total plant Cd content (mg)
8.2	1377 ± 148.4	1.57 ± 0.19	1861 ± 137.0	3.03 ± 0.15	1.80 ± 0.03	7.08 ± 0.17	0.0136 ±0.0001
63	1424 ± 13.2	1.82 ± 0.05	1801 ± 17.8	3.21 ± 0.09	2.01 ± 0.06	6.67 ± 0.13	0.0146 ±0.0001
106	1366 ± 8.2	1.88 ± 0.03	1916 ± 10.1	3.56 ± 0.09	2.21 ± 0.04	6.82 ± 0.19	0.0160 ±0.0001
SEm(±)	43.07	0.057	39.99	0.058	0.024	0.081	0.00007
$CD_{0.05}$	NS	0.176	NS	0.178	0.073	0.251	0.00022

Values are averages of 3 replications ± SD

metal polluted soil indicated the tolerance of AM strains to heavy metals due to prolong application of metal contaminated wastes and adapted to such environment. Such differential tolerance and adaptation of AM fungi to heavy metals has been reported earlier (Mandal *et al*, 2007).

On the other hand, there are reports on arbuscular mycorrhiza from metal contaminated soils which suggest that selection of metal-tolerant strains has occurred. There is also mounting evidence that AM infection may decrease metal accumulation in plants growing in polluted soils and thus protect the host against phytotoxic metal effects. Therefore, the importance of metal tolerant AM fungi for soil reclamation and protection of food chain is currently under discussion.

Sorghum growth was promoted due to mycorrhization by AM inoculum of MSW amended soil origin with increased biomass production and P nutrition but inoculation by AM fungi of alluvial soil origin could not perform well in such heavy metal polluted MSW amended soil. There was a inoculum dose dependent positive response in sorghum growth with increased root infection intensity in case of AM of MSW source clearly indicate that tolerance and adaptation of AM in that particular environment than AM of alluvial soil origin.

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