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Impact of Spent Mushroom Substrate on *Glomus mosseae* Establishment in Wheat (*Triticum aestivum*) and Pearl Millet (*Pennisetum glaucum*)

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The application of spent mushroom substrate (SMS) in soil increases yields and improves quality of agriculture produce. *Glomus mosseae* is a predominant species of arbascular mycorrhizae (AM) fungus in soils and it help the plant in many ways. The substrate from the production process of cultivated mushrooms is a material with a high lignocellulosic content and rich in organic matter, which, when incorporated into the soil, changes its chemical attributes. Thus, this substrate can be used in the preparation of organic compounds, the manufacture of biofertilizers and chemical soil conditioner in semi-arid regions. Thus, the research tried to evaluate the presence of the substrates at different concentrations in the growth, development and establishment of *G. mosseae* fungi at 45 and 60 days after sowing to help the productivity of wheat and pearl millet for three consecutive years from 2018-19 to 2020-21under screenhouse conditions.

One year old button mushroom SMS was mixed in sterile sandy loam soil at 10, 20, 30% (w/w basis) and pure culture of *G. mossea* was applied at 450-500 sporocarp/kg of soil and then filled with earthen pots of 30 cm diameter. Twenty seeds of wheat cv. WH 1105 were sown in each pot during the third week of November every year and maintained. Similarly, twenty seeds of pearl millet cv. HHB 67 (I) was sown in each pot in first week of July every year and maintained. The plants raised in soil without SMS but inoculated with *G. mosseae* served as control. The treatments were replicated ten times and the experiments were laid out as per RCBD design. The observations on mycorrhizal colonization (*%)* and sporocarps numbers per 100g soil were taken at 45 and 60 days after sowing (DAS) in wheat and pearl millet.

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In wheat cv. WH 1105, the root colonization (%) and sporocarp numbers/100 g soil of *G. mosseae* were higher when SMS at 30% was applied in soil and lowest in control. These increased further in all treatments at 60 DAS as compared to 45 DAS stage during three years of experimentation. The root colonization at 60 DAS was significantly high at 24.9, 34.8 and 27.9 % when SMS applied in soil at 30% and it was lowest at 20.2, 30.1, 23.1% in control during 2018-19, 2019-20 and 2020-21, respectively. The sporocarp numbers at 60 DAS were also found to be high at 255, 195 and 325 sporocarps/100 g soil when 30% of SMS was applied in soil and lowest at 210, 172, 265 sporocarps/100 g soil in control during 2018-19, 2019-20 and 2020-21, respectively.
In pearl millet hybrid HHB-67 (Improved), the root colonization and sporocarp numbers/100 g soil of *G. mosseae* were higher when SMS at 20% was applied in soil and lowest in control. These increased further in all treatments at 60 DAS as compared to 45 DAS stage during three years. The root colonization at 60 DAS was significantly higher in 34.0, 35.3 and 34.7% when SMS was applied at 20% and it was lowest at 34.3, 33.2, 31.1% in control during 2018-19, 2019-20 and 2020-21, respectively. The sporocarp numbers at 60 DAS were also found to be high at 229, 250 and 174 /100 g soil when SMS at 20% was applied and it was lowest at 219, 205, 150 sporocarps/100 g soil in control during 2018-19, 2019-20 and 2020-21, respectively.

Keywords: Glomus mosseae; wheat; pearl millet; sporocarp.

1. INTRODUCTION

The worldwide agricultural food production is to be doubled up to 2050 to feed the global population and simultaneously efforts are also required to reduce dependency on chemical fertilizers, pesticides to save the environment. Therefore, there is a need of exploring eco-friendly and cost-effective techniques to increase quality production of agriculture product. The spent mushroom substrate (SMS) is the mushroom waste that is left after mushroom harvesting. Its application in soil has been found to be highly beneficial in producing quality vegetables, horticultural and field crops if applied after proper weathering. As mushroom production is growing day by day and producing a high amount of SMS and therefore, its proper use in agriculture needs attention of researchers. There is an annual production of 13 lakh MT of spent mushroom substrate only in India. It is an alternate source of less available farm yard manure. It contains nitrogen at 1.51%, phosphorus at 3.77%, potash at 0.61%, hydraulic conductivity at 6.22m/h, water holding at 95.03% capacity and pH at 7.28-7.75 [1]. Since it is an organic waste, therefore, its incorporation in soil after proper weathering improve soil carbon, soil texture, soil structure, essential nutrients required for plant growth, reduced plant pathogens and ultimately yield and quality of the produce [2,3,4, 5,6,7,8].

Many of the workers have studied the microflora present on SMS which help in modifying the plant rhizosphere environment [8,7,9,10,4,11].

Glomus mosseae an arbuscular mycorrhizae (AM) fungus belongs to phylum *Glomeromycota* and is an obligate symbiotic fungus in the roots of most land plants. The effectiveness of *G. mosseae* infection and sporulation on different hosts can be measured by its spore numbers and the root infection increased rapidly up to 10 weeks after sowing. The infectivity of *G. mosseae* increased with increasing percentage of root length and observed its highest spores in barley plant rhizosphere, followed by chickpea and beans. The lowest spore numbers were found in corn and okra plants rhizosphere. They concluded that spore population and root colonization of *G. mosseae* depended upon the crop type and its crop duration [12]. The presence of AM fungi in soil has been found to be substantially contributing the plants in the production of plant growth hormones, improved nutrients, protection from soil pathogens, uptake of heavy metals, tolerance to salinity, heat, drought, extreme temperatures etc. [13,14]. The results of AM fungi are not generally evident under naturally infested fields because of their inadequate population in the soil [15]. Since, it is an obligate endo-parasite and multiplies only in roots of host plants. However, its infectivity, multiplication in roots and establishment in soil is found to be affected by many factors like cropping system, fertilization, organic amendments, crop diversity, soil characteristics, soil microflora, agricultural management, etc. [16,17,18,19,20,21,22,23].

The SMS is found to be effective in reducing organic and inorganic contaminants in polluted soils. The incorporation of SMS of *Pleurotus*

pulmonarius and *G. mosseae* in crude oil polluted soil significantly increased plant height, number of leaves and leaf area of *Amaranthus hybridus* and reduced petroleum hydrocarbons as well as crude oil in polluted soils [24]. The rapid industrialization has increased environmental contamination with pesticides, industrial dyes, petroleum hydrocarbons, pharmaceutical waste, heavy metals etc. but in recent years, the microbial based remediation employing mushrooms, its derivatives and SMS have been reviewed as a low cost, eco-friendly and highly efficient method. It relies on production of enzymes involved in degradation of organic chemical contaminants and bioactive sites on mushrooms in adsorption of various inorganic metal contaminants [25].

There are few studies on the effect of soil application of SMS on AM fungi. *Glomus mosseae*, SMS and poultry manure had interactive affect on drought tolerance and leaf curl resistance of okra (*Abelmoschus esculentus*) genotypes. The drought tolerance and leaf curl resistance were significantly higher in plants treated with *G. mosseae*, SMS and poultry manure than other treatments including the control [26]. Similarly, application of SMS with *G. mosseae* and *G. fasciculatum* enhanced plant growth of sorghum as well as there was also increased root colonization by both AM fungi and increase of spores in the substrates [27]. Therefore, the present study was conducted to see the effect of soil application of one year old button mushroom SMS at different concentrations on the capability of *G. mosseae* in root colonization and production of sporocarps in wheat and pearl millet at 45 and 60 days after sowing.

2. MATERIALS AND METHODS

2.1 Area and Duration of Study

The study was carried out during 2018-19 to 2020-21 in the Department of Plant Pathology, CCS Haryana Agricultural University, Hisar (20^0 10' N lat.,75^0 46' E long., alt. 215 m msl), situated in the semi-arid region of N-W India. The climate of Hisar (Haryana) is semi-arid with hot and dry desiccating winds accompanied by frequent dust storms with high velocity in summer months, severe cold during in winter months and humid warm during the monsoon rainy season. The mean monthly maximum temperatures sometimes exceeds 48^0 C on hot summer days. The relative humidity varies from 5 to 100% and temperature below freezing point accompanied by frost in winter is usually experienced in this region.

2.2 Collection of Study Materials and Multiplication of *G. mosseae*

The experiment to study the effect of soil application of different concentrations of SMS on *G. mosseae* establishment in wheat and pearl millet was conducted under screen house conditions for three consecutive years from 2018-19 to 2020-21. The pure culture of AM fungus *G. mossea* was collected from the Tata Energy Research Institute, New Delhi and multiplied on pearl millet and wheat under screen house conditions of Department of Plant Pathology, CCS Haryana Agricultural University, Hisar.

2.3 Methodology and Treatments Detail

One year old spent mushroom substrate of button mushroom was collected from Mushroom Technology Laboratory, Department of Plant Pathology, CCS Haryana Agricultural University, Hisar and mixed in sterile sandy loam soil at 10, 20, 30% (w/w basis). Then sporocarps of *G. mossea* collected from the soil and rootlets of inoculated wheat or pearl millet plants were applied at 450-500 sporocarps/kg soil and thoroughly mixed soil was filled in earthen pots of 30 cm diameter. Twenty seeds of wheat cv. WH 1105 were sown 2-3 cm deep in soil in each pot during the third week of November every year as per treatments detail given below. Similarly, twenty seeds of pearl millet hybrid HHB-67 (Improved) were sown 2-3 cm deep in soil in each earthen pot as per treatment detail given below during the first week of July every year. The seeds sown in soil having no SMS but inoculated with *G. mosseae* alone served as control. The mycorrhizal colonization (%) in roots was determined by straining of roots at 45 and 60 DAS by using standard method given by Phillips and Hayman (1970) and sporocarp numbers in 100 g soil were determined at 45 and 60 DAS as per standard technique given by Gerdemann and Nicolson (1963).

The detail of treatments:

T_1 = Soil with 10% SMS and *G. mosseae*
T_2 = Soil with 20% SMS and *G. mosseae*
T_3 = Soil with 30% SMS and *G. mosseae*
T_4 = Soil with 40% SMS and *G. mosseae*
T_5 = Control (No SMS in soil but inoculated with *G. mosseae* alone)

2.4 Experimental Design and Treatments

These experiments were carried out with randomized block design (RCBD) and each treatment was replicated ten times.

2.5 Observations

Mycorrhizal colonization (%) at 45 and 60 DAS in wheat and pearl millet.

Sporocarp numbers/100 g soil at 45 and 60 DAS in wheat and pearl millet.

3. RESULTS

3.1 Effect of Spent Mushroom Substrate on Establishment of *Glomus mosseae* in Wheat cv. WH 1105

The data presented in Table 1 revealed *G. mosseae* mycorrhizal colonization(%), sporocarp numbers/100g soil in wheat at 45 and 60 DAS.

3.1.1 Mycorrhizal colonization (%) at 45 DAS in wheat

The root colonization (%) was found to be increased with high concentration of SMS in soil at 45 DAS. It was found to be significantly as high as 22.9, 31.6 and 24.5% when SMS at 30 % was applied in soil and it was as low as 20.1, 23.7, 20.0% in the control (soil without SMS) during 2018-19, 2019-20 and 2020-21, respectively. It was statistically at par when SMS at 40% was applied in soil. The mean of three years data revealed that mycorrizal colonization was at 26.7% when SMS at 30% was incorporated in soil followed by 26.0% when SMS at 40% was applied in soil. It was as low as 21.3% in control (Table 1, Fig. 1).

3.1.2 Mycorrhizal colonization (%) at 60 DAS in wheat

The mycorrhizal colonization in wheat at 60 DAS was significantly high at 24.9, 34.8 and 27.9% when SMS was applied in soil at 30% and it was lowest at 20.2, 30.1, 23.1% in control during 2018-19, 2019-20 and 2020-21, respectively. It was statistically at par when SMS was applied at 40%. The mean of three years data revealed that mycorrizal colonization was as high as 29.2% when SMS was incorporated in soil at 30%, followed by 28.5% when SMS was applied at 20 %, whereas, it was as low as 24.5% in control. It was observed that mycorrhizal colonization was higher at 60 DAS as compared to their respective treatment at 45 DAS in wheat (Table 1, Fig. 1).

3.1.3 Sporocarp numbers/100 g soil at 45 DAS in wheat

The sporocarp numbers were also found to be highest at 30% concentration of SMS in soil at 45 DAS. It was found to be significantly as high as 199, 155 and 221 when SMS at 30% was applied in soil and as low as 165, 125, 182 in control during 2018-19, 2019-20 and 2020-21, respectively. The mean of three years data revealed that sporocarp numbers were highest at 191.7/100 g soil when SMS at 30% was incorporated in soil followed by 183/100g soil when SMS was used at 20% in soil. It was as low as 157.3 sporocarps/100g soil in control (Table 1, Fig. 1).

3.1.4 Sporocarp numbers/100 g soil at 60 DAS in wheat

The sporocarp numbers were also found to be further increased at 30% of SMS in soil at 60 DAS. It was found to be significantly as high as 255, 195and 325 sporocarps/100 g soil when SMS at 30% was applied in soil and as low as 210, 172, 265 sporocarps/100 g soil in control during 2018-19, 2019-20 and 2020-21, respectively. The mean of three years data revealed that sporocarp numbers were highest at 258.3/100 g soil when SMS at 30% was incorporated in soil followed by 246.3 sporocarps/100g soil when SMS at 20% was applied in soil. It was as low as 215.7 sporocarps/100g soil in control. It was observed that sporocarp numbers in soil were higher at 60 DAS as compared to their respective treatment at 45 DAS in wheat (Table 1, Fig. 1).

3.2 Effect of Spent Mushroom Substrate on *Glomus mosseae* in Pearl Millet Hybrid HHB-67 (Improved)

The data presented in Table 2 revealed the *G. mosseae* mycorrhizal colonization (%), sporocarp numbers per 100g soil in pearl millet at 45 and 60 DAS.

Table 1. Effect of spent mushroom substrate on *Glomus mosseae* establishment in wheat cv. WH 1105

Treatments	*Mycorrhizal colonization (%)								*Sporocarp numbers/100 g soil							
	45 Days After Sowing				60 Days After Sowing				45 Days After Sowing				60 Days After Sowing			
	2018-19	2019-20	2020-21	Mean	2018-19	2019-20	2020-21	Mean	2018-19	2019-20	2020-21	Mean	2018-19	2019-20	2020-21	Mean
SMS at 10% + *G. mosseae*	20.1 (26.2)	27.2 (35.0)	22.1 (22.1)	23.1	22.3 (28.2)	32.5 (38.7)	24.6 (29.7)	26.5	180	145	200	175.0	231	200	290	240.3
SMS at 20% + *G. mosseae*	21.2 (27.4)	30.1 (37.1)	23.7 (23.7)	25.0	24.1 (29.4)	34.0 (39.7)	27.5 (31.6)	28.5	191	148	210	183.0	249	185	305	246.3
SMS at 30% + *G. mosseae*	22.9 (28.6)	31.6 (38.1)	24.5 (24.5)	26.7	24.9 (29.6)	34.8 (40.2)	27.9 (31.9)	29.2	199	155	221	191.7	255	195	325	258.3
SMS at 40% + *G. mosseae*	22.1 (28.0)	31.6 (38.1)	24.2 (24.4)	26.0	24.1 (29.7)	33.7 (39.5)	27.0 (31.3)	28.3	158	160	190	169.3	228	200	310	246.0
Control (*G. mosseae* alone)	20.1 (26.6)	23.7 (32.5)	20.0 (20.0)	21.3	20.2 (27.0)	30.1 (37.1)	23.1 (28.7)	24.5	165	125	182	157.3	210	172	265	215.7
C.D. at 5%	(0.72)	(0.72)	(1.06)	-	(0.73)	0.81	(0.57)	-	16.2	NS	12.1	-	12.6	NS	14.1	-

**Average of 10 replications;*
Figures in parenthesis are angular transformed values

Table 2. Effect of spent mushroom substrate on *Glomus mosseae* establishment in pearl millet hybrid HHB-67 (Improved)

Treatments	*Mycorrhizal colonization (%)								*Sporocarp numbers/100 g soil							
	45 Days After Sowing				60 Days After Sowing				45 Days After Sowing				60 Days After Sowing			
	2018-19	2019-20	2020-21	Mean	2018-19	2019-20	2020-21	Mean	2018-19	2019-20	2020-21	Mean	2018-19	2019-20	2020-21	Mean
SMS at 10% + *G. mosseae*	27.5 (31.6)	29.6 (36.7)	29.0 (32.4)	28.7	32.3 (34.8)	34.9 (40.3)	32.6 (34.8)	33.3	120	160	149	143.0	225	236	185	215.3
SMS at 20% + *G. mosseae*	28.2 (32.0)	32.1 (38.4)	29.5 (32.9)	29.9	34.0 (35.7)	35.3 (40.6)	34.7 (36.1)	34.7	141	185	155	160.3	229	250	174	217.7
SMS at 30% + *G. mosseae*	28.9 (32.5)	32.8 (38.9)	30.7 (33.6)	30.8	34.2 (35.8)	35.9 (41.0)	34.0 (35.7)	34.7	129	180	150	153.0	218	252	178	216.0
SMS at 40% + *G. mosseae*	28.3 (32.1)	32.0 (38.4)	30.5 (33.5)	30.3	34.8 (36.2)	35.2 (40.5)	34.5 (36.0)	34.8	148	162	135	148.3	240	244	164	216.0
Control (*G. mosseae* alone)	28.0 (32.1)	28.1 (35.7)	25.1 (30.1)	27.1	34.3 (36.2)	33.2 (39.2)	31.1 (33.8)	32.9	140	140	128	136.0	219	205	150	191.3
C.D. at 5%	(1.25)	(0.64)	(0.55)	-	(1.28)	(0.82)	(0.41)	-	11.03	NS	16.74	-	13.57	NS	15.38	-

**Average of 10 replications;*
Figures in parenthesis are angular transformed values

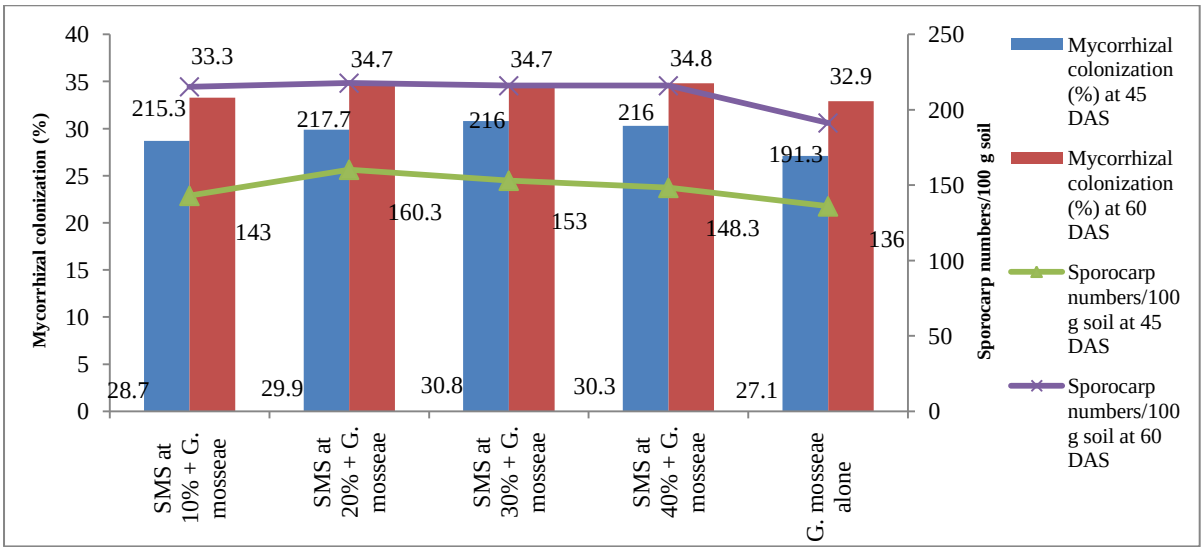

Fig. 1. Effect of spent mushroom substrate on *Glomus mosseae* establishment in wheat cv. WH 1105

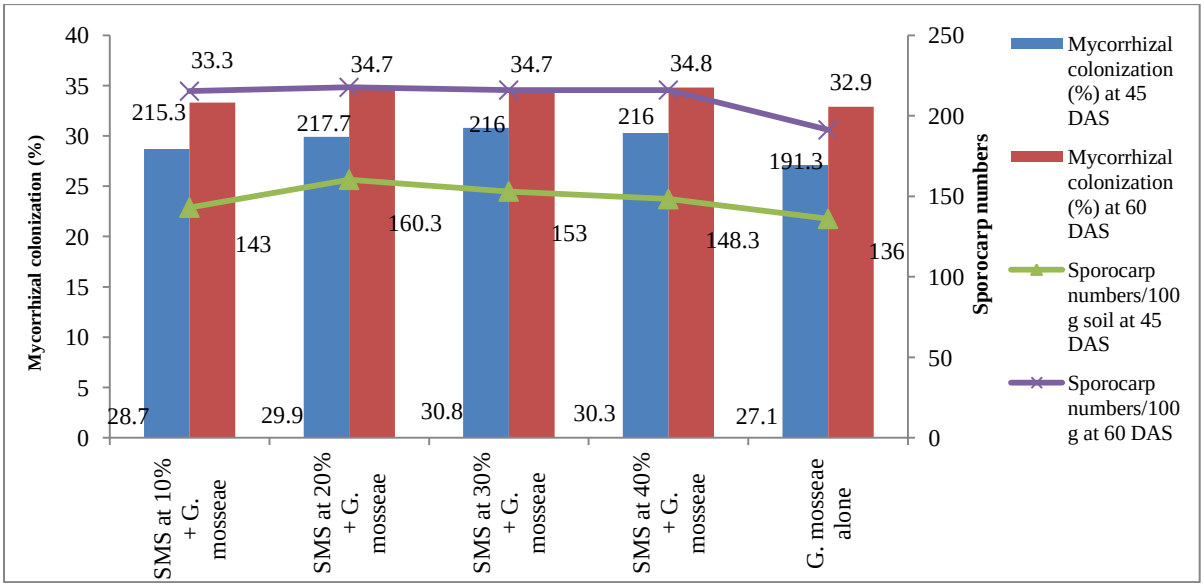

Fig. 2. Effect of spent mushroom substrate on *Glomus mosseae* establishment in pearl millet hybrid HHB-67 (Improved)

3.2.1 Mycorrhizal colonization (%) at 45 DAS in pearl millet

The root colonization was found to be increased with high concentration of SMS in soil at 45 DAS. It was found to be significantly as high as 28.9, 32.8 and 30.7% when SMS at 30% was applied in soil and as low as 28.0, 28.1, 25.1% in control during 2018-19, 2019-20 and 2020-21, respectively. The mean of three years data revealed that mycorrizal colonization was at 30.8 % when SMS at 30% was incorporated in soil followed by 30.3% when SMS at 40% was applied in soil. It was as low as 27.1% in control (Table 2, Fig. 2).

3.2.2 Mycorrhizal colonization (%) at 60 DAS in pearl millet

The mycorrhizal colonization in pearl millet at 60 DAS was significantly as high as 34.0, 35.3 and 34.7% when SMS was applied in soil at 20% and as low as 34.3, 33.2, 31.1% in control 2018-19, 2019-20 and 2020-21, respectively. The mean of three years data revealed that mycorrizal colonization was as high as 34.7, 34.7 and

34.8% when SMS was incorporated in soil at 20, 30 and 40%, respectively. It was as low as 32.9 % in control. It was observed that mycorrhizal colonization was high at 60 DAS as compared to their respective treatment at 45 DAS in pearl millet (Table 2, Fig. 2).

3.2.3 Sporocarp numbers/100 g soil at 45 DAS in pearl millet

The sporocarp numbers were also found to be increased upto 20% concentrations of SMS in soil at 45 DAS. It was found to be significantly as high as 141, 185 and 155 sporocarps/100 g soil when SMS was incorporated in soil at 20% and as low as 140, 140, 128 sporocarps/100 g soil in control during 2018-19, 2019-20 and 2020-21, respectively. The mean of three years data revealed that sporocarp numbers were at highest at 160.3/100 g soil when 20% SMS was incorporated in soil followed by 153.0 sporocarps/100 g soil when SMS at 30% was applied in soil. It was as low as 136.0 sporocarps/100g soil in control (Table 2, Fig. 2).

3.2.4 Sporocarp numbers/100 g soil at 60 DAS in pearl millet

The sporocarp numbers were also found to be further increased upto 20% concentrations of SMS in soil at 60 DAS. It was found to be significantly as high as 229, 250 and 174 sporocarps/100 g soil when 20% SMS was incorporated in soil and as low as 219, 205, 150 sporocarps/100 g soil in control during 2018-19, 2019-20 and 2020-21, respectively. The mean of three years data revealed that sporocarp numbers were highest at 217.7/100 g soil when SMS at 20% was incorporated in soil followed by 216.0/100g soil when SMS at 30 and 40% was applied in soil. It was as low as 191.3 sporocarps/100 g soils in control It was observed that sporocarp numbers in soil were higher at 60 DAS as compared to their respective treatment at 45 DAS in pearl millet (Table 2, Fig. 2).

4. DISCUSSION

In wheat, the mycorrhizal colonization at 60 DAS was significantly high at 24.9, 34.8 and 27.9% during 2018-19, 2019-20 and 2020-21, respectively, when SMS was applied in soil at 30 % and lowest at 20.2, 30.1, 23.1% in control. The mean mycorrizal colonization was as high as 29.2% when SMS was incorporated in soil at 30 %, followed by 28.5% when SMS was applied at 20%. It was as low as 24.5% in control. Similarly, the sporocarp numbers were also found to be significantly high at 255, 195 and 325 sporocarps/100 g soil at 30% of SMS in soil and low at 210, 172, 265 sporocarps/100 g soil in control during 2018-19, 2019-20 and 2020-21, respectively at 60 DAS. The mean sporocarp numbers were higher at 258.3/100 g soil when SMS at 30% was incorporated followed by 246.3sporocarps/100g soil when SMS at 20% was applied in soil. It was as low at 215.7 sporocarps/100g soil in control. The mycorrhizal colonization and sporocarp numbers were highest in all treatments at 60 DAS as compared to 45 DAS in wheat.

In pearl millet the mycorrhizal colonization at 60 DAS was found to be higher at 34.0, 35.3 and 34.7% when SMS was applied at 20% in soil and lowest at 34.3, 33.2, 31.1% in control during 2018-19, 2019-20 and 2020-21, respectively. The mean mycorrizal colonization was as high as 34.7, 34.7 and 34.8% when SMS was incorporated in soil at 20, 30 and 40%, respectively. It was as low as 32.9% in control. The sporocarp numbers at 60 DAS were also found to be highest at 229, 250 and 174 sporocarps/100 g soil when SMS applied at 20% and as low as 219, 205, 150 sporocarps/100 g soil in control during 2018-19, 2019-20 and 2020-21, respectively. The mean sporocarp numbers were high at 217.7/100 g soil when SMS at 20% was incorporated in soil. It was as low as 191.3 sporocarps/100g soil in control. The mycorrhizal colonization and sporocarps number were highest in all treatments at 60 DAS as compared to 45 DAS in pearl millet.

There is an increased mycorrhizal colonization and sporocarp numbers of *G. mosseae* in wheat and pearl millet at 45 DAS and 60 DAS when SMS is incorporated in soil. However, it is higher in all treatments at 60 DAS than 45 DAS in both wheat and pearl millet plants. The results of the present study are in conformity with the findings that application of SMS in soil having *G. mosseae* and *G. fasciculatum* resulted in increased root colonization in sorghum and increased sporulation in both AM fungi in the substrates [25]. In the present study, there was highest mycorrizal colonization and maximum sporocarp numbers of *G. mosseae* when SMS in soil was incorporated at 30 and 20% in wheat and pearl millet, respectively. In wheat, SMS application in soil beyond 30% and in pearl millet higher than 20% adversely affected the *G. mosseae* establishment. Similarly, the effectiveness of *G. mosseae* infection and

sporulation depend upon the crop type while working on barley, chickpea, beans, okra and corn [12]. There are only few studies conducted earlier to see the effect of SMS in soil on AM fungi. Since *G. mosseae* is an obligate endo-parasite of various hosts, therefore, SMS may not have directly influenced the mycorrhizal colonization and sporocarp numbers, but it might have indirectly influenced *G. mosseae*. The SMS is organic manure rich in nutrients, good water holding, high carbon, good conductivity, pH etc. It has been found to contain nitrogen at 1.51%, phosphorus at 3.77%, potash at 0.61%, hydraulic conductivity at 6.22m/h, water holding at 95.03% capacity and pH at 7.28-7.75 [1]. There are many studies which gave information that incorporation of SMS in soil improved the physical, chemical, biological characteristics of soil and a result there is an increased growth of plant, yield and quality of the produce [2,3,4,5,6, 7,8]. There are some studies which gave an indication that infectivity and multiplication of AM fungi is affected by many factors like organic amendments, cropping system, fertilization, crop diversity, soil characteristics, soil microflora, agricultural management etc. [16,17,18,19,20, 21,22,23]. Therefore, incorporation of SMS in soil might have improved the physical, chemical and biological characteristics of soil and which might have resulted in improved plant growth parameters including root system. Due to improved root growth, there might have been an increase in root surface area and it may have resulted in increased infectivity of *G. mosseae* and hence an increased mycorrhizal colonization and higher sporocarps numbers in wheat and pearl millet plants. The root exudates excreted by plants may also influence sporocarp germination of *G. mosseae* and there is possibility of increased root exudation in a healthy plant which may influence the sporocarps germination and it might have resulted in more infection, high colonization, increased sporocarps of *G. mosseae* in wheat and pearl millet plants.

Many researchers have studied the SMS microflora of different mushrooms [8,7,9,10,4, 11]. It is found to contain many beneficial fungi, bacteria, etc. Therefore, soil incorporation of SMS might have increased beneficial rhizospheric microflora and modified the rhizosphere of wheat and pearl millet plants which might have facilitated the more germination, high infectivity, higher colonization of roots and increased sporulation of *G. mosseae* directly or indirectly.

There is variability in data during conduct of experiments in different years. It may be due to the weather data differences pertaining to experiment year.

5. CONCLUSION

In wheat cv. WH 1105, soil application of SMS at 30% and *G. mosseae* at 450-500 sporocarps/kg soil increased highest mycorrhizal colonization at 29.2% and maximum sporocarp numbers at 258.3/100 g soil as compared to lowest mycorrhizal colonization at 21.3% and minimum sporocarp numbers at 215.7 / 100 g soil in control at 60 DAS stage of crop. Similiarly, in pearl millet cv. HHB 67 (I) soil application of SMS at 20% and *G. mosseae* at 450-500 sporocarps/kg soil increased highest mycorrhizal colonization at 34.7% and maximum sporocarp numbers at 217.7/100 g soil as compared to lowest mycorrhizal colonization at 32.9% and minimum sporocarp numbers at 191.3/100 g soil in control at 60 DAS stage of the crop. Therefore, it is recommended that one year old button mushroom SMS at 30% in sandy loam soil in wheat cv. WH 1105 helped in higher establishment of *G. mosseae* at 60 DAS stage, whereas, in pearl millet cv. HHB 67 (I), an application of 20% SMS in soil favored higher establishment of *G. mosseae* at 60 DAS stage.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Kumbhar AS, Gade RM, Shitole AV, Bandgar MS. Nutritional value of spent mushroom substrate of *Agaricus bisporus*. Journal of Mycopathological Research. 2014;52(1):65-68.

2. Cabrera VE, Stavast LJ, Baker TT, Wood MK, Cram DS, Flynn RP, Ulery AL. Soil and runoff response to dairy manure application on New Mexico rangeland. Agriculture, Ecosystems and Environment. 2009;131:255-262.
3. Jonathan SG, Lawal MM, Oyetunji OJ. Effect of spent mushroom compost of *Pleurotus pulmonarius* on growth performance of four Nigerian vegetables. Mycobiology. 2011;39(3):164-9.
4. Adedeji KO, Modupe AO. *In vitro* evaluation of spent mushroom compost on growth of *Fusarium oxysporium* f. sp *lycopersici*. Advances in Plants and Agriculture Research. 2016;4(4):332-339.
5. Kang DS, Min KJ, Kwak AM, Lee SY, Kang HW. Defense response and suppression of Phytophthora blight disease of pepper by water extract from spent mushroom substrate of *Lentinula edodes*. The Plant Pathology Journal. 2017;33(3):264.
6. Shitole AV, Gade RM, Bandgar MS, Archana Z. Utilization of spent mushroom substrate as carrier for biocontrol agent and biofertilizer. The Bioscan. 2014;9(1): 271-275.
7. Moraes TSJ, Costa LMAS, Souza TP, Collela CF, Dias ES. Fungal and bacterial population from spent mushroom substrate used to cultivate tomato plants. Ciencia e Agrotecnologia. 2020;44:e010120.
8. Frąc M, Pertile G, Panek J, Gryta A, Oszust K, Lipiec J, Usowicz B. Mycobiome composition and diversity under the long-term application of spent mushroom substrate and chicken manure. Agronomy. 2021;11:410.
9. Safianowicz K, Tina LB, Michael AK. Bacterial population dynamics in recycled mushroom compost leachate. Applied Microbiology and Biotechnology. 2018; 102:5335–5342.
10. Seephueak P, Preecha C, Seephueak W. Isolation and screening of cellulolytic fungi from spent mushroom substrates. International Journal of Agricultural Technology. 2017;13(5):729-739.
11. Ahlawat OP, Sagar MP. Management of spent mushroom substrate. Technical Bulletin published by National Research Centre for Mushroom (Indian Council of Agricultural Research), Chambaghat, Solan (H.P.). 2007;48.
12. A1-Raddad AM. Mass production of *Glomus mosseae* spores. Mycorrhiza. 1995;5:229-231.
13. Brahmaprakash GP, Sahu PK. Biofertilizers for sustainability. Journal of the Indian Institute of Science. 2012; 92(1):37-62.
14. Begum N, Qin C, Ahanger MA, Raza S, Khan MI, Ashraf M, Ahmed N, Zhang L. Role of arbuscular mycorrhizal fungi in plant growth regulation: Implications in abiotic stress tolerance. Frontiers in Plant Science. 2019;10:1068.
15. Powell CL, Daniel J. Growth of white clover in undisturbed soils after inoculation with efficient mycorrhizal fungi. New Zealand Journal of Aricultural Research. 1978;21: 675-681.
16. Verzeaux J, Hirel B, Dubois F, Lea PJ, Tetu T. Agricultural practices to improve nitrogen use efficiency through the use of arbuscular mycorrhizae: Basic and agronomic aspects. Plant Science. 2017; 264:48-56.
17. Ryan MH, Graham JH. Little evidence that farmers should consider abundance or diversity of arbuscular mycorrhizal fungi when managing crops. New Phytologist. 2018;220(4):1092-1107.
18. Monica IFD, Godeas AM, Scervino JM. *In vivo* modulation of arbuscular mycorrhizal symbiosis and soil quality by fungal P solubilizers. Microbial Ecology. 2020; 79(1):21-29.
19. Ma Y, Zhang H, Wang D, Guo X, Yang T, Xiang X, Walder F, Chu H. Differential responses of arbuscular mycorrhizal fungal communities to long-term fertilization in the wheat rhizosphere and root endosphere. Applied and Environmental Microbiology. 2021;87(17): e0034921.
DOI: 10.1128/AEM.00349-21.
20. Alaux PL, Mison C, Senes-Guerrero C, Moreau V, Manssens G, Foucart G, Cranenbrouck S, Declerck S. Diversity and species composition of arbuscular mycorrhizal fungi across maize fields in the southern part of Belgium. Mycorrhiza. 2021;31(2):265-272.
21. Guzman A, Montes M, Hutchins L, DeLaCerda G, Yang P, Kakouridis A, Dahlquist-Willard RM, Firestone MK, Bowles T, Kremen C. Crop diversity enriches arbuscular mycorrhizal fungal communities in an intensive agricultural landscape. New Phytologist. 2021;231(1): 447-459.
22. Floch JB, Hamel C, Laterriere M, Tidemann B, St-Arnaud M, Hijri M. Long-

term persistence of arbuscular mycorrhizal fungi in the rhizosphere and bulk soils of non-host *Brassica napus* and their networks of co-occurring microbes. Frontiers in Plant Science. 2022;13: 828145.
DOI: 10.3389/fpls.2022.828145.

23. Thanni B, Merckx R, De Bauw P, Boeraeve M, Peeters G, Hauser S, Honnay O. Spatial variability and environmental drivers of cassava-arbuscular mycorrhiza fungi (AMF) associations across southern Nigeria. Mycorrhiza. 2022;32(1):1-13.
24. Salami AO, Elum EA, Salako YA. Bioremediation of a crude oil polluted soil with the spent mushroom compost of *Pleurotus pulmonarius* and *Glomus mosseae* using *Amaranthus hybridus* as a Test Plant. International Journal of Biological Sciences and Technology. 2017; 9(5):34-47.
25. Sahithya K, Mouli T, Biswas A. Remediation potential of mushrooms and their spent substrate against environmental contaminants: An overview. Biocatalysis and Agricultural Biotechnology. 42(2022): 102323.
26. Jonathan SG, Olawuyi OJ, Babalola BJ. Effect of arbuscular mycorrhizae fungus, spent mushroom compost and poultry manure on drought and leaf curl resistance of okra (*Abelmoschus esculentus*). Nigerian Journal of Mycology. 2014;6: 37-47.
27. Aishwarya MH, Mallesha BC. Oyster mushrooms spent substrate in arbuscular mycorrhizal inoculum production. Mysore Journal of Agricultural Sciences. 2019; 53(4):49-53.

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