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Influence of enriched spent mushroom substrate on microbial population, nutrient availability and yield of radish (*Raphanus sativus* L.)

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Abstract
A field experiment was conducted to ameliorate the quality of spent mushroom substrate by enriching it with biofertilizers like *Azotobacter*, PSB and KMB and its beneficial effect on soil health and yield of radish crop. Influence of enriched spent mushroom substrate on soil was estimated in terms of microbial activities and nutrient availability of soil to plant. The treatment T_4 - SMS + Consortium of AZT + PSB + KMB was significantly superior over other treatments in terms of microbial population, nutrient availability of soil and yield of radish followed by treatment T_5 – FYM + Consortium of AZT + PSB + KMB. The minimum observations were recorded in treatment T_8 - Absolute control. The increased microbial activities positively showed increase in nutrient availability of soil to plant and yield attributes in radish crop.

Keywords: Spent mushroom substrate, biofertilizers, enrichment, microbial population, radish

Introduction
Radish (*Raphanus sativus* L.) belongs to genus *Raphanu*s, family Brassicaceae originated from the Central and Western China and India (Thamburaj and Singh 2005) [19]. Radish is grown for its young tender fusiform root (Brickell, 1992) [5]. For the production of good quality radish, optimum nutrition through organic, inorganic and bio-fertilizers are essential for sustainable production. Organic agriculture practices rely upon recycling of crop residues, animal manure, farm organic residues and wastes etc. (Choudhary *et al.*, 2002) [6].
The substrate released after mushroom crop harvest, better known as “SMS” is also the subject of great importance (Tewari, 2007) [18]. Spent mushroom substrate possesses the quality of good organic manure for raising healthy crops of cereals, fruits, vegetables and ornamental plants, in addition to its ability of reclaiming the contaminated soil (Ahlawat and Sagar, 2007) [1]. Therefore the quality of spent mushroom substrate can be improved by enriching it with biofertilizers. In order to produce high quality compost, biofertilizers promotes growth by increasing the availability of primary nutrients to the host plant. Also they improve soil structure improving soil fertility. (Sudjana *et al.*, 2017) [16]. Enriched SMS is capable of improving the physical, biological and chemical properties of soil when it is added to the soil. SMS can improve the structure of soils, soil aeration, reduces surface crusting and compaction, promote drainage these improvements promote faster crop growth establishment and increased rooting. Also, it increases the population of beneficial microorganisms in soil which are necessary for plant growth and good yield. It also minimizes the use of chemical fertilizers (Gumus and Seker, 2017) [9]. Accordingly, the experiment on influence of enriched spent mushroom substrate (SMS) was carried out during *rabi* 2019 with the objectives as to enrich spent mushroom substrate with biofertilizers (*Azotobacter*, PSB and KMB) and to evaluate the effect of enriched spent mushroom substrate on growth and yield of radish crop.

Material and Methods
Experimental details
A field experiment was conducted to study the influence of enriched spent mushroom substrate on growth and yield of radish (*Raphanus sativus* L.) during *Rabi* 2019 at the Plant Pathology Research Farm, College of Agriculture, Pune as detailed below.

1. Replications : Three (3)
2. Treatments : Eight (8)
3. Design : Randomised Block Design
4. Spacing : 30 cm X 15 cm
5. Variety : variety from local market
6. SMS application rate : 20 T/ ha
7. FYM application rate : 20 T/ha

Treatment details

T_1: SMS + *Azotobacter* (AZT)
T_2: SMS + Phosphate Solubilizing Bacteria (PSB)
T_3: SMS + Potash Mobilizing Bacteria (KMB)
T_4: SMS + Consortium of AZT + PSB + KMB
T_5: FYM + Consortium of AZT + PSB + KMB
T_6: SMS (20 t/ha)
T_7: FYM (20 t/ha)
T_8: Absolute control

Enrichment of SMS and FYM

SMS and FYM were enriched prior to the application of individual treatments with biofertilizers *viz, Azotobacter*, PSB and KMB. The enrichment of SMS and FYM was done as per the treatments. *Azotobacter,* PSB and KMB were enriched @10 kg/ha basis. After enrichment, the SMS and FYM were kept for 4 weeks for the proper growth of microorganisms and for improving nutrient status of compost. (Shinde *et al.*, 1985) [13] and (Borah Nilay *et al.*, 2014) [4].

Microbial population in soil

Initial microbial count for total *Azotobacter*, PSB and KMB was estimated from soil before addition of enriched spent mushroom substrate to it and also after addition of enriched spent mushroom substrate to the soil, i.e. at the time of harvest irrespective of each treatment.

For this, serial dilution plate count technique was followed (Skinner *et al.*, 1952) [14]. The total number of *Azotobacter*, PSB and KMB were calculated by using following formula.

$$\text{No. of Azotobacter/PSB/KMB per g soil} = \frac{\text{Average plate count x dilution factor}}{\text{Oven dry weight of 1g of soil}}$$

Initial microbial count of total bacteria, fungi and actinomycetes was estimated from soil before addition of enriched spent mushroom substrate to it and also after addition of enriched spent mushroom substrate to the soil i.e. at the time of harvest irrespective of each treatment.

$$\frac{\text{No. of bacteria/fungi/}}{\text{actinomycetes per g soil}} = \frac{\text{Average plate count x dilution factor}}{\text{Oven dry weight of 1g of soil}}$$

Nutrient status of soil

Available nutrient status of soil before incorporation of enriched spent mushroom substrate and after harvest of radish crop was calculated by following standard methods *viz.*, alkaline KMNO4 method by Subbiah and Asija (1956) [15] for available N (kg ha^{-1}), Olsen's method by Olsen *et al.* (1954) [12] for available P (kg ha^{-1}) and ammonium acetate extractable method by Knudsen *et al.* (1982) [11] for available K (kg ha^{-1})

Result and Discussion

The microbial population of *Azotobacter*, PSB and KSB from soil before incorporation of SMS and after harvesting of radish crop was estimated. The initial microbial count of *Azotobacter*, PSB and KMB from soil before incorporation of enriched spent mushroom substrate in soil was 29.33 x 10^6, 22.67 x 10^6 and 19.67 x 10^6 respectively.

A) Influence of enriched spent mushroom substrate on microbial count of *Azotobacter*, PSB and KMB in soil after harvest of radish

***Azotobacter* population**

The result specified in Table 1, Fig.1 showed that among the different treatments, treatment T_4 i.e. SMS + Consortium of AZT + PSB + KMB recorded significantly highest *Azotobacter* population (67.00 x 10^6 per g soil)) over rest of the treatments followed by treatment T_5 i.e. FYM + Consortium of AZT + PSB + KMB (61.11 x 10^6 per g soil)). The lowest *Azotobacter* population (29.67 x 10^6 per g soil)) was recorded in treatment T_8 i.e. Absolute control.

PSB population

Among the different treatments (Table 1, Fig.1), treatment T_4 i.e. SMS + Consortium of AZT + PSB + KMB recorded significantly highest PSB population (48.89 x 10^6 per g soil)) over rest of the treatments followed by treatment T_5 i.e. FYM + Consortium of AZT + PSB + KMB (43.11 x 10^6 per g soil)). The lowest PSB population (23.00 x 10^6 per g soil)) was recorded in treatment T_8 i.e. Absolute control

KMB population

The results (Table 1, Fig.1) showed that among different treatments, treatment T_4 i.e. SMS + Consortium of AZT + PSB + KMB recorded significantly highest KMB population (44.11 x 10^6 per g soil)) over rest of the treatments followed by treatment T_5 i.e. FYM + Consortium of AZT + PSB + KMB (39.55 x 10^6 per g soil)). The lowest KMB population (20.00 x 10^6 per g soil)) was recorded in treatment T_8 i.e. Absolute control.

The results are comparable with Mallesha (2008) who reported that N_2 fixing microorganism population was significantly more in rhizosphere soil amended with mushroom spent substrate compared to rhizospheric soil amended with substrates such as coffee pulp, areca husk, paddy straw and coir pith. The results are also close accordance with Kedar *et al.*, (2019) [10] who also reported that application of enriched spent mushroom substrate significantly increased the population of *Azotobacter* and PSB in soil after harvest of cabbage crop.

Table 1: Influence of enriched spent mushroom substrate on microbial population of *Azotobacter*, PSB and KMB in soil after harvesting of radish

Tr. No	Treatment details	*Azotobacter* (*cfu* 10^6)	PSB (*cfu* 10^6)	KMB (*cfu* 10^6)
T_1	SMS + *Azotobacter* (AZT)	54.44	33.00	27.00
T_2	SMS+ Phosphate Solubilizing Bacteria (PSB)	46.44	37.78	29.89
T_3	SMS+ Potash Mobilizing Bacteria (KMB)	39.56	29.67	34.44
T_4	SMS+ Consortium of AZT+ PSB+ KMB	67.00	48.89	44.11
T_5	FYM+ Consortium of AZT+ PSB+ KMB	61.11	43.11	39.55
T_6	SMS (20 t/ha)	36.00	32.56	25.56
T_7	FYM (20 t/ha)	34.56	30.00	24.33

T_8	Absolute control	29.67	23.00	20.00
S.Em (±)		1.78	1.60	1.24
CD at 5%		5.45	4.90	3.81

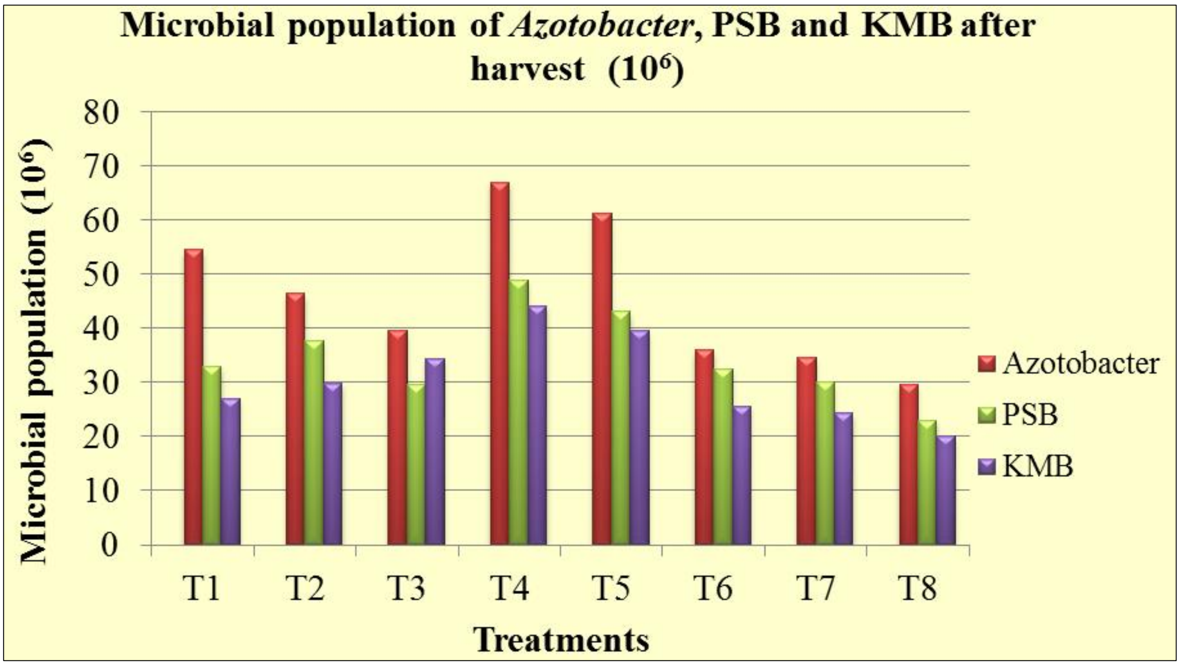

Fig 1: Influence of enriched spent mushroom substrate on microbial population of *Azotobacter*, PSB and KMB in soil after harvest of radish

B) Influence of enriched spent mushroom substrate on microbial population in soil after harvest of radish.

The initial microbial population of bacteria, fungi and actonomycetes from soil before incorporation of enriched spent mushroom substrate in soil was 19.67 x 10^6, 8.00 x 10^6 and 5.33 x 10^3 respectively.

Bacterial population

The results specified in Table 2, Fig.2 showed that among the different treatments, treatment T_4 i.e. SMS + Consortium of AZT + PSB + KMB recorded significantly highest population of bacteria (52.44 x 10^6 per g soil)) over rest of the treatments followed by treatment T_5 i.e. FYM + Consortium of AZT + PSB + KMB (47.22 x 10^6 per g soil)). The lowest population of bacteria (20.11 x 10^6 per g soil)) was recorded in treatment T_8 i.e. Absolute control

Fungi population

Among the different treatments, treatment T_4 i.e. SMS + Consortium of AZT + PSB + KMB recorded significantly highest population of fungi (27.89 x 10^6 per g soil)) over rest of the treatments followed by treatment T_5 i.e. FYM + Consortium of AZT + PSB + KMB (23.56 x 10^6 per g soil)). The lowest population of fungi (8.33 x 10^6 per g soil)) was recorded in treatment T_8 i.e. Absolute control (Table 2, Fig.2).

Actinomycetes population

The result (Table 2, Fig.2) showed that among the different treatments, treatment, T_4 i.e. SMS + Consortium of AZT + PSB + KMB was found to be the most effective as it recorded significantly highest population of actinomycetes (20.78 x 10^3 per g soil)) over rest of the treatments followed by treatment T_5 i.e. FYM + Consortium of AZT + PSB + KMB (17.78 x 10^3 per g soil)). The lowest population of actinomycetes (5.44 x 10^3 per g soil)) was recorded in treatment T_8 i.e. Absolute control.

The results are comparable with Borah *et al.* (2014) [4] who stated that microbial population significantly increased in the compost by about 35 to 133% during the 30 days incubation period with different consortia. Taha *et al.* (2016) [17] accomplished that, using compost tea combined with nitrogen fertilizers significantly increased the population of bacteria, aerobic N_2 fixing bacteria and fungi in sandy soil as well as promoting growth of radish plant.

Table 2: Influence of enriched spent mushroom substrate on microbial population of bacteria, fungi and actinomycetes in soil after harvest of radish

Tr. No	Treatment	Bacteria (*cfu* 10^6)	Fungi (*cfu* 10^6)	Actinomycetes (*cfu* 10^3)
T_1	Treatment details	40.78	19.11	14.67
T_2	SMS + *Azotobacter* (AZT)	37.00	15.22	11.22
T_3	SMS+ Phosphate Solubilizing Bacteria (PSB)	36.11	12.56	9.22
T_4	SMS+ Potash Mobilizing Bacteria (KMB)	52.44	27.89	20.78
T_5	SMS+ Consortium of AZT+ PSB+ KMB	47.22	23.56	17.78
T_6	FYM+ Consortium of AZT+ PSB+ KMB	32.33	12.89	8.22
T_7	SMS (20 t/ha)	30.33	11.89	7.66
T_8	FYM (20 t/ha)	20.11	8.33	5.44
S.Em (±)		1.61	1.05	0.93
CD at 5%		4.98	3.22	2.85

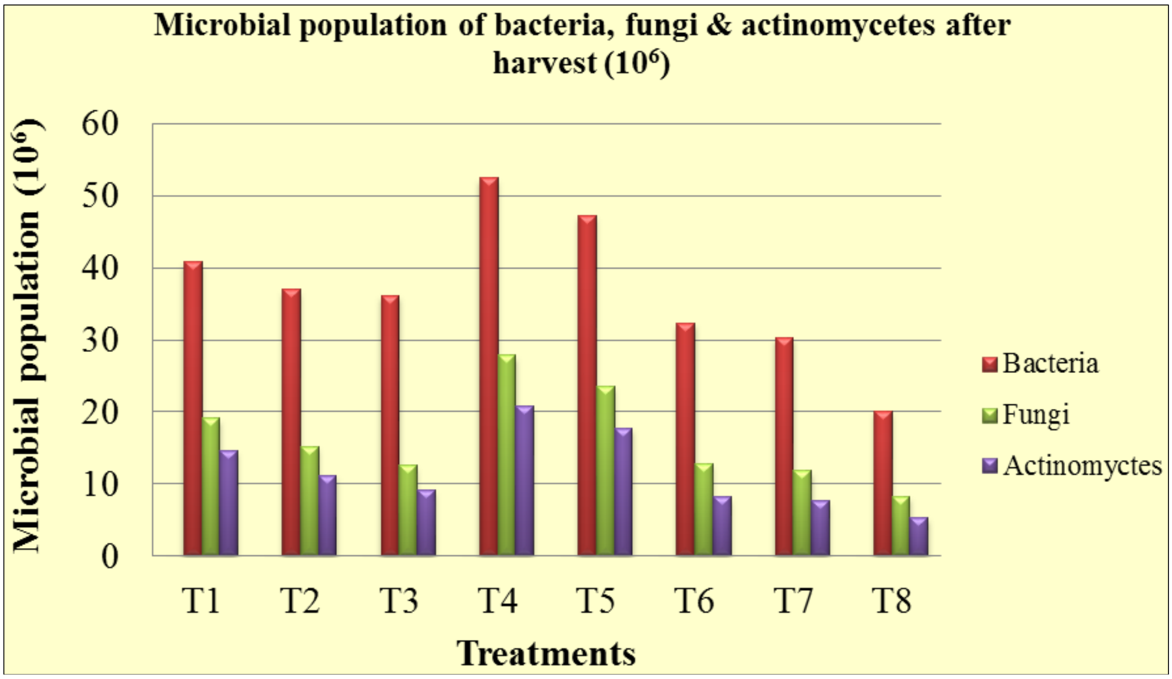

Fig 2: Influence of enriched spent mushroom substrate on microbial population of bacteria, fungi and actinomycetes in soil after harvest of radish

C) Influence of enriched spent mushroom substrate on nutrient status of soil after harvest of radish.

Available nutrient status of soil was calculated before incorporation of enriched spent mushroom substrate and after harvest of radish crop. The results are presented in Table 3. The initial soil available N, P and K (kg/ha) before incorporation of enriched SMS was 139.98 kg/ha, 9.95 kg/ha and 118.67 kg/ha respectively.

Available nitrogen in soil (kg/ha)

The result specified in Table 3, Fig.3 showed that among the different treatments, treatment T_4 i.e. SMS + Consortium of AZT + PSB + KMB recorded significantly highest available nitrogen (210.73 kg/ha) in soil over rest of the treatments followed by treatment T_5 i.e. FYM + Consortium of AZT + PSB + KMB (193.83 kg/ha). The lowest available nitrogen (140.41 kg/ha) in soil was recorded in treatment T_8 i.e. Absolute control

Available phosphorus in soil (kg/ha)

The results (Table 3, Fig.3) also showed that among the different treatments, treatment T_4 i.e. SMS + Consortium of AZT + PSB + KMB was found to be the most effective as it recorded significantly highest available phosphorus (16.95 kg/ha) in soil over rest of the treatments, however it was statistically at par with treatment T_5 i.e. FYM + Consortium of AZT + PSB + KMB (16.25 kg/ha). The lowest available phosphorus (10.25 kg/ha) in soil was recorded in treatment T_8 i.e. Absolute control.

Available potassium in soil (kg/ha)

Among the different treatments, the treatment T_4 i.e. SMS + Consortium of AZT + PSB + KMB recorded significantly highest available potassium (195.83 kg/ha) in soil over rest of the treatments, however it was statistically at par with treatment T_5 i.e. FYM + Consortium of AZT + PSB + KMB (180.75 kg/ha). The lowest available potassium (120.36 kg/ha) in soil was recorded in treatment T_8 i.e. Absolute control (Table 3, Fig.3).

The results are comparable with Ashrafi *et al.*, (2015) [3] who reported that the N, P and K (kg/ha) uptake was increased due to the influences of different treatments of SMC. Gumus and Seker (2017) [9] found that the use of SMC contributed to enhancing the level of organic carbon and nitrogen in the soil. The results are close accordance with Kedar *et al.*, (2019) [10] who also reported that application of enriched spent mushroom substrate significantly increased the available nitrogen, phosphorus and potassium in soil after harvest of cabbage crop.

Table 3: Influence of enriched spent mushroom substrate on soil available NPK (kg/ha) after harvest of radish

Tr. No	Treatment details	Available N kg/ha	Available P kg/ha	Available K kg/ha
T_1	SMS + *Azotobacter* (AZT)	181.45	12.44	158.84
T_2	SMS+ Phosphate Solubilizing Bacteria (PSB)	167.08	15.52	150.56
T_3	SMS+ Potash Mobilizing Bacteria (KMB)	128.82	12.55	177.63
T_4	SMS+ Consortium of AZT+ PSB+ KMB	210.7	16.95	195.83
T_5	FYM+ Consortium of AZT+ PSB+ KMB	193.82	16.25	180.75
T_6	SMS (20 t/ha)	169.64	12.30	150.87
T_7	FYM (20 t/ha)	159.08	11.47	149.67
T_8	Absolute control	140.31	10.25	120.36
S.Em (±)		3.12	1.07	1.82
CD at 5%		9.45	3.24	5.58

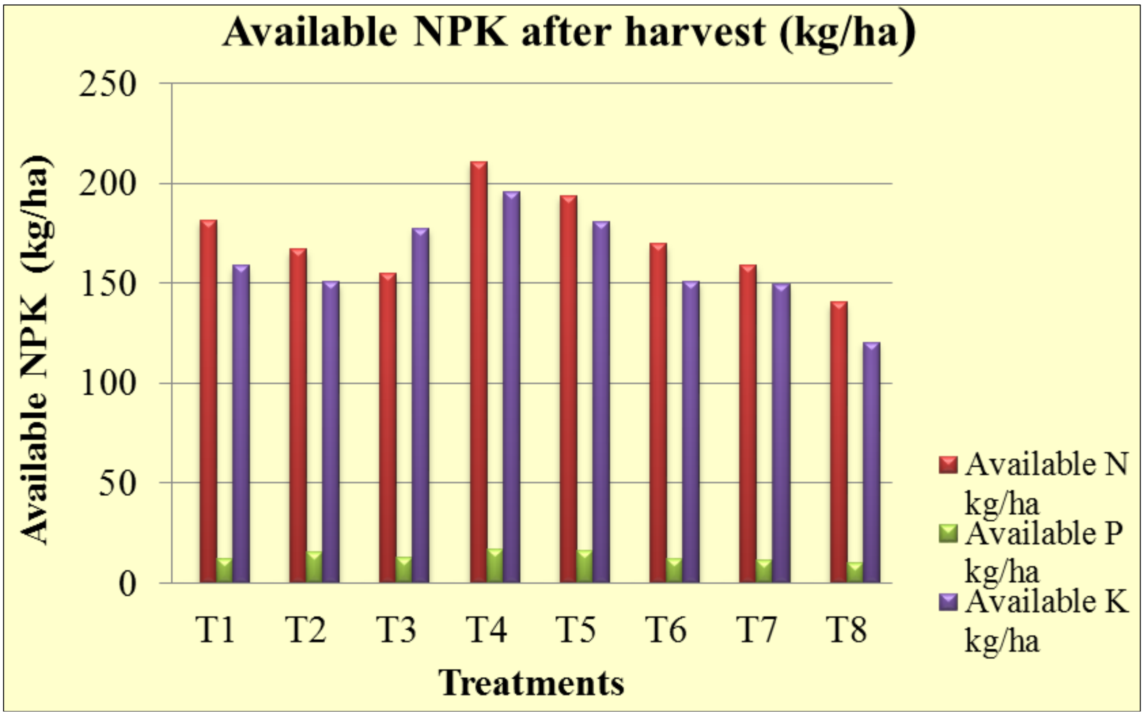

Fig 3: Influence of enriched spent mushroom substrate on soil available NPK kg/ha after harvest of radish

D) Influence of enriched spent mushroom substrate on root yield (kg/plot) and yield (t/ha)

The root yield per plot and per hector was noted immediately after harvest of radish crop. The results are presented in the Table 4, Fig.4.

Root Yield (kg/plot)

The data presented in Table 4, Fig.4 showed that among the different treatments, the treatment T_4 i.e. SMS + Consortium of AZT + PSB + KMB was found to be the most effective as it recorded significantly highest root yield (10.52 kg/plot) over rest of the treatments followed by treatment T_5 i.e. FYM + Consortium of AZT + PSB + KMB (9.39 kg/plot). The lowest root yield (4.82 kg/plot) was recorded in treatment T_8 i.e. Absolute control.

Similar trend of results was also reported by Taha *et al.*, (2018) who stated that PGPR-bacteria + SMC tea and KH present within the soil can reduce the requirement of nitrogen fertilizer applications and lead to highest yield of tomato. Yildirim *et al.* (2009) [20] also reported that the use of the inoculants (*Azotobacter* + Pseudomonas) on compost, used as radish growing medium provided high-yield crops and highest plant weight compared to that of without enrichment or singly enrichment. Gautum Singh (2018) [8] envisaged that (T_3) 60 per cent RDF + *Azotobacter* + VAM was found significantly superior to improve the growth, yield and quality of radish root.

Root Yield (t/ha)

The data (Table 4, Fig.4) showed that among all the different treatment, treatments T_4 i.e. SMS + Consortium of AZT + PSB + KMB recorded significantly highest root yield (32.48 t/ha) over rest of the treatments followed by treatment T_5 i.e. FYM + Consortium of AZT + PSB + KMB (28.98 t/ha). The lowest root yield (14.88 t/ha) was recorded in treatment T_8 i.e. Absolute control.

Similar trend of results was also reported by Seran *et al.*, (2017) [21] who reported that higher marketable radish yield was obtained with application of compost 20 t/ha + half dose of NPK fertilizers. Ashgar *et al.*, (2006) [2] also reported that yield increased by integrated fertilizer usages in radish cultivation by using compost as a combination with chemical fertilizer.

Table 4: Influence of enriched spent mushroom substrate on root yield (kg/plot) and root yield (t/ha) in radish

Tr. No	Treatment details	Root yield (Kg/plot)	Root yield (t/ha)
T_1	SMS + *Azotobacter* (AZT)	8.31	25.66
T_2	SMS+ Phosphate Solubilizing Bacteria (PSB)	6.15	18.99
T_3	SMS+ Potash Mobilizing Bacteria (KMB)	7.23	22.31
T_4	SMS+ Consortium of AZT+ PSB+ KMB	10.52	32.48
T_5	FYM+ Consortium of AZT+ PSB+ KMB	9.39	28.98
T_6	SMS (20 t/ha)	6.00	18.44
T_7	FYM (20 t/ha)	5.89	18.19
T_8	Absolute control	4.82	14.88
S.Em (±)		0.29	0.90
CD at 5%		0.88	2.76

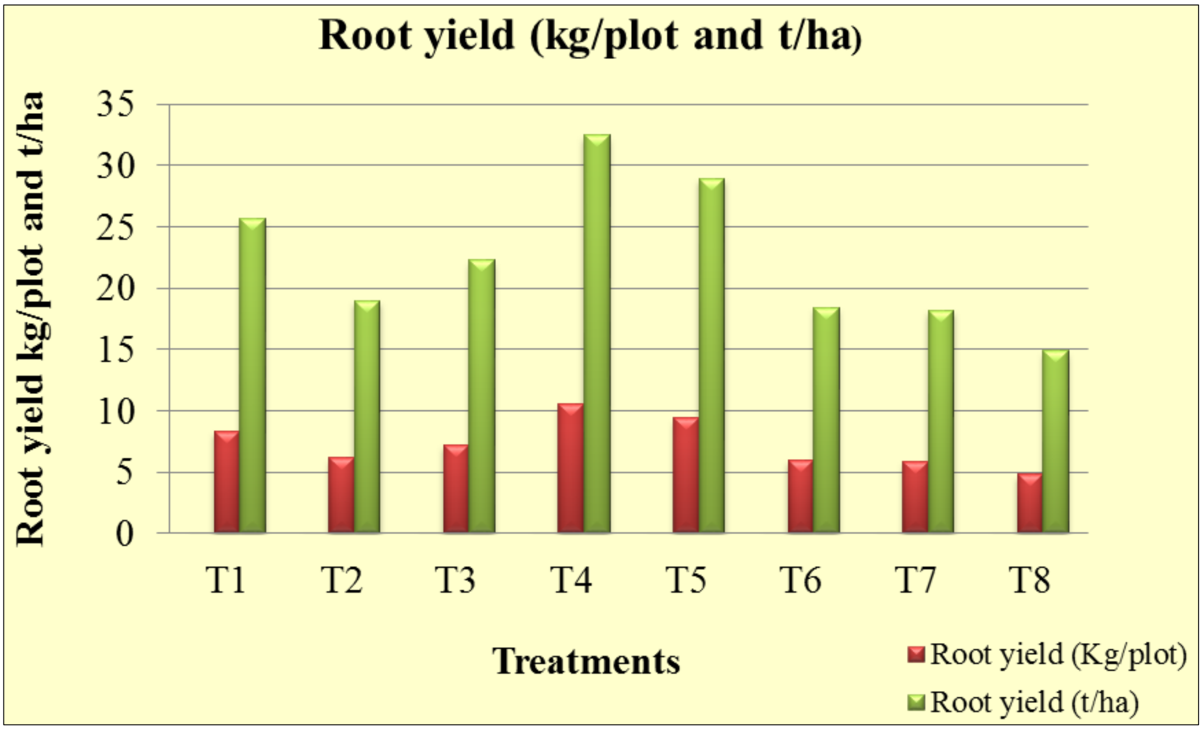

Fig 4: Influence of enriched spent mushroom substrate on root yield (kg/plot) and root yield (t/ha) of radish

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