

**“INFLUENCE OF ENRICHED SPENT MUSHROOM SUBSTRATE ON
GROWTH AND YIELD OF RADISH (*Raphanus sativus* L.)”**

by

Mr. Bhosale Pritam Anantrao

(Reg. No. 018/247)

A Thesis submitted to the
**MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI- 413 722, DIST- AHMEDNAGAR,
MAHARASHTRA, INDIA**

In partial fulfillment of the requirements for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

in

AGRICULTURAL MICROBIOLOGY



**DEPARTMENT OF PLANT PATHOLOGY AND
AGRICULTURAL MICROBIOLOGY**

COLLEGE OF AGRICULTURE, PUNE 05

**MAHATMA PHULE KRISHI VIDYAPEETH,
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**MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI- 413 722, DIST- AHMEDNAGAR
MAHARASHTRA STATE, INDIA**

2020

CANDIDATE'S DECLARATION

I hereby declare that this thesis or part
Thereof has not been submitted
By me or other person to any
Other University or Institute
For a Degree or
Diploma

Place : Pune

Date : / / 2020

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Dr. A. C. Jadhav

Research Guide &

Jr. Mycologist,

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College of Agriculture, Pune-05.

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CERTIFICATE

This is to certify that the thesis entitled, “**INFLUENCE OF ENRICHED SPENT MUSHROOM SUBSTRATE ON GROWTH AND YIELD OF RADISH (*Raphanus sativus* L.)** ” submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (Maharashtra) in partial fulfillment of the requirement for the award of the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **AGRICULTURAL MICROBIOLOGY**, embodies the result of a piece of bona fide research work carried out by **MR. BHOSALE PRITAM ANANTRAO** under my guidance and supervision and that no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been duly acknowledged.

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This is to certify that the thesis entitled, “**INFLUENCE OF ENRICHED SPENT MUSHROOM SUBSTRATE ON GROWTH AND YIELD OF RADISH (*Raphanus sativus* L.)**” submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (Maharashtra) in partial fulfillment of the requirement for the award of the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **AGRICULTURAL MICROBIOLOGY**, embodies the result of a piece of bonafide research work carried out by **Mr. BHOSALE PRITAM ANANTRAO** under the guidance and supervision of **Dr. A. C. JADHAV**, Jr. Mycologist, AICRP on Mushroom, College of Agriculture, Pune-05 and that no part of the thesis has been submitted for any other degree or diploma.

Place : Pune

Date : / / 2020

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Date : / / 2020

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“Gratitude is the most exquisite form of memory”

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(Pritam Anantrao Bhosale)

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CONTENTS

Chapt er No.	TITLE	PAGE NO.
	CANDIDATE'S DECLARATION	I
	CERTIFICATE OF RESEARCH GUIDE	II
	CERTIFICATE OF HEAD OF THE DEPARTMENT	III
	CERTIFICATE OF ASSOCIATE DEAN	IV
	ACKNOWLEDGEMENT	V
	CONTENTS	VII
	LIST OF TABLES	XII
	LIST OF FIGURES	XIII
	LIST OF PLATES	XIV
	LIST OF ABBREVIATIONS	XV
	ABSTRACT	XVI
1.	INTRODUCTION	1
2.	REVIEW OF LITERATURE	5
	2.1 Spent mushroom substrate	5
	2.2 Microorganisms associated with spent mushroom substrate	6
	2.3 Soil chemical properties after addition of spent mushroom substrate	8
	2.4 Influence of spent mushroom substrate on plant growth and yield	10
	2.5 Influence of biofertilizers on plant growth	13
	2.6 Enrichment of spent mushroom substrate with biofertilizers	17
3.	MATERIALS AND METHODS	20
	3.1 Material	20

	3.1.1	Seed	20
	3.1.2	Spent mushroom substrate (SMS)	20
	3.1.3	Farm Yard Manure (FYM)	20
	3.1.4	Glass wares	20
	3.1.5	Equipments	20
	3.1.6	Miscellaneous materials	20
	3.1.7	Biofertilizers	20
	3.2	Methods	21
	3.2.1	Experiment site	21
	3.2.2	Soil status of experimental field	21
	3.2.3	Climatic condition	21
	3.2.4	Rate of Farm Yard Manure	21
	3.2.5	Rate of spent mushroom substrate	21
	3.2.6	Enrichment of spent mushroom substrate and Farm yard manure	21
	3.2.7	Experimental details	22
	3.2.7.1	Treatment details	22
	3.2.7.2	Design and Layout of plot	23
	3.2.8	Cultural operation	23
	3.2.8.1	Land preparation	23
	3.2.8.2	Application of spent mushroom substrate and farm yard manure	23
	3.2.8.3	Seed and sowing	23
	3.2.8.4	Weed management	23
	3.2.8.5	Water management	24
	3.2.8.6	Crop protection	24

	3.2.8.7	Harvesting	24
	3.2.8.8	Collection of experimental data	24
	3.3	Growth parameters	24
	3.3.1	Plant height (cm)	24
	3.3.2	Number of leaves	24
	3.4	Yield parameters	24
	3.4.1	Length of root at harvest (cm)	24
	3.4.2	Diameter of root at harvest (cm)	24
	3.4.3	Total fresh weight of plant (g)	25
	3.4.4	Fresh weight of leaves (g)	25
	3.4.5	Fresh weight of root (g)	25
	3.4.6	Total dry weight of plant (g)	25
	3.4.7	Yield (kg/plot)	25
	3.4.8	Yield per hectare (t/ha)	25
	3.5	Microbial population in soil	25
	3.6	Soil Chemical Analysis	26
	3.7	Statistical analysis	27
4.	RESULTS AND DISCUSSION		
	4.1	Influence of enriched spent mushroom substrate on vegetative growth parameters of radish	28
	4.1.1	Number of leaves per plant	28
	4.1.2	Plant height per plant (cm)	29
	4.2	Influence of enriched spent mushroom substrate on yield parameters in radish	30
	4.2.1	Root length at harvest (cm)	30
	4.2.2	Root diameter at harvest (cm)	31

	4.2.3	Fresh weight of plants, fresh weight of leaves, fresh weight of roots and dry matter weight of roots (g)	31
	4.2.3.1	Fresh weight of plants (g)	31
	4.2.3.2	Fresh weight of leaves (g)	32
	4.2.3.3	Fresh weight of roots (g)	32
	4.2.3.4	Dry matter weight of roots (g)	33
	4.2.4	Root yield (kg/plot) and yield (t/ha)	34
	4.2.4.1	Root Yield (kg/plot)	34
	4.2.4.2	Root Yield (t/ha)	34
	4.3	Influence of enriched spent mushroom substrate on microbial count of <i>Azotobacter</i> , PSB & KMB in soil after harvesting of radish.	35
	4.3.1	<i>Azotobacter</i> population (10^6)	35
	4.3.2	PSB population (10^6)	35
	4.3.3	KSB population (10^6)	36
	4.4	Influence of enriched spent mushroom substrate on microbial population in soil after harvesting of radish.	37
	4.4.1	Bacterial population (10^6)	37
	4.4.2	Fungi population (10^6)	37
	4.4.3	Actinomycetes population (10^3)	38
	4.5	Initial microbial count of <i>Azotobacter</i> , PSB and KMB from soil before incorporation of enriched spent mushroom substrate in soil	38
	4.6	Initial microbial population from soil before incorporation of enriched spent mushroom substrate in soil	39
	4.7	Influence of enriched spent mushroom substrate on nutrient status of soil after harvesting of radish.	39
	4.7.1	Available nitrogen from soil after harvesting of radish crop	39

		(kg/ha)	
	4.7.2	Available phosphorus from soil after harvesting of radish crop (kg/ha)	39
	4.7.3	Available potassium from soil after harvesting of radish crop (kg/ha)	39
	4.8	Initial soil available N, P and K (kg/ha)	40
5.	SUMMERY AND CONCLUSION		46
6.	LITERATURE CITED		50
7.	APPENDIX		64
8.	VITA		66

LIST OF TABLE

Table No.	Title	Page No.
4.1	Influence of enriched spent mushroom substrate on number of leaves at 30, 45 DAS and at harvest of crop.	29
4.2	Influence of enriched spent mushroom substrate on plant height (cm) at 30, 45 DAS and at harvest of crop.	30
4.3	Influence enriched spent mushroom substrate on root length and root diameter (cm) of radish.	31
4.4	Influence of enriched spent mushroom substrate on fresh weight of whole plant, fresh weight of leaves, fresh weight of roots and dry matter weight of roots of radish (g)	33
4.5	Influence of enriched spent mushroom substrate on root yield (kg/plot) and root yield (t/ha) of radish.	35
4.6	Influence of enriched spent mushroom substrate on microbial population of <i>Azotobacter</i> , PSB and KMB in soil after harvest of radish	37
4.7	Influence of enriched spent mushroom substrate on microbial population of bacteria, fungi and actinomycetes in soil after harvest of radish	38
4.8	Influence of enriched spent mushroom substrate on soil available NPK kg/ha after harvesting of radish.	40

LIST OF FIGURES

Figure No.	Title	Between Page No.
4.1	Influence of enriched spent mushroom substrate on number of leaves at 30, 45 DAS and at harvest of crop.	29
4.2	Influence of enriched spent mushroom substrate on plant height (cm) at 30, 45 DAS and at harvest of crop.	31
4.3	Influence enriched spent mushroom substrate on root length and root diameter (cm) of radish.	31
4.4	Influence of enriched spent mushroom substrate on fresh weight of whole plant, fresh weight of leaves, fresh weight of roots and dry matter weight of roots of radish (g)	33
4.5	Influence of enriched spent mushroom substrate on root yield (kg/plot) and root yield (t/ha) of radish.	35
4.6	Influence of enriched spent mushroom substrate on microbial population of <i>Azotobacter</i> , PSB and KMB) in soil after harvest of radish	39
4.7	Influence of enriched spent mushroom substrate on microbial population of bacteria, fungi and actinomycetes in soil after harvest of radish	39
4.8	Influence of enriched spent mushroom substrate on soil available NPK kg/ha after harvesting of radish.	40

LIST OF PLATES

Plate No.	Title	Between Page No.
4.1	General view of field experimental plot	41
4.2	Influence of enriched SMS on growth parameters of radish in different treatments	42
4.3	Comparison of treatment plot between T ₄ and T ₅ along with control (T ₈)	43
4.4	Influence of enriched SMS on yield parameters of radish in different treatments	44
4.5	Comparison of radish plant between T ₄ and T ₅ along with control (T ₈)	45

LIST OF ABBREVIATION

%	:	Per cent
/	:	Per
@	:	at the rate of
⁰ C	:	Degree Celsius
BOD	:	Biological oxygen demand
C. D.	:	Critical Difference
cm	:	Centimeter (s)
e.g.	:	example gratia (for example)
<i>et al.</i>	:	et alia (and others)
etc.	:	Et cetera
FYM	:	Farm Yard Manure
Fig.	:	Figure
g	:	Gram
ha	:	Hectare
i.e.	:	id est. (that is)
kg	:	Kilogram
mg	:	Milligram
N	:	Nitrogen
No.	:	Number
P	:	Phosphorus
K	:	Potassium
pH	:	Potenz (-log H ⁺)
SMS	:	Spent mushroom substrate
S.E.	:	Standard error
spp.	:	Species

ABSTRACT

“INFLUENCE OF ENRICHED SPENT MUSHROOM SUBSTRATE ON GROWTH AND YIELD OF RADISH” (*Raphanus sativus* L.)

By

Mr. BHOSALE PRITAM ANANTRAO

A candidate for the degree

Of

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Research Guide	:	Dr. A. C. Jadhav
Discipline	:	Agricultural Microbiology

The present investigation entitled studies on “Influence of enriched spent mushroom substrate on growth and yield of radish.” was conducted at field of Plant Pathology Section, College of Agriculture, Pune in *Rabi* 2019 in Randomized Block Design with eight treatments and three replications.

Spent substrate from button mushroom production has been found to be nutritionally rich with respect to its N, P, K contents and being having high cation exchange capacity; it has the ability to replace Farm Yard Manure for the purpose of raising horticultural and cereal crops. Also, to find out substitute for FYM because of its less availability, 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 growth and yield of radish crop as well as microbial population and chemical properties of soil.

The observations were recorded on growth parameters viz., number of leaves, plant height, fresh weight of plant, fresh weight of leaves, fresh weight of root, root length at harvest, diameter of root, yield of root per plot (kg), dry weight of root. Additionally, under laboratory conditions total microbial population of bacteria, fungi, actinomycetes, *Azotobacter*, PSB and KSB from soil before sowing and after harvest of crop were recorded. The soil available N, P and K was worked out before sowing and at the harvest.

It was observed that the treatment *i.e.* T₄ - Consortium of AZT + PSB + KMB was statistically superior among all other treatments with respect to growth and yield parameters such as number of leaves, plant height, root length, root diameter at harvest, fresh weight of plant, leaves, root and dry weight of root plant, root yield per plot (kg) and root yield (t/ha).

During the experiment, the treatment T₄ (SMS + Consortium of AZT + PSB + KMB) recorded maximum values in the number of leaves (25.73), plant height (45.20 cm), root length (42.35 cm), root diameter (4.24 cm), fresh weight of whole plant (375.41 g), fresh weight of root (288.11 g), fresh weight of leaves (87.07 g), dry matter weight of plant (52.36 g) and yield of radish (32.48 t/ha) with significant increase in microbial population from soil and nutrient status of soil. The minimum values were recorded in absolute control treatment *i.e.* T₈.

The above investigation suggested that application of enriched spent mushroom substrate with biofertilizers like *Azotobacter*, PSB and KMB *i.e.* treatment T₄ (SMS + Consortium of AZT + PSB + KMB) was found more beneficial and significantly improved growth and yield of radish as well as for improving biological and nutrient status of soil.

1. INTRODUCTION

Radish (*Raphanus sativus* L.) belongs to genus *Raphanus*, family Brassicaceae originated from the Central and Western China and India (Thamburaj and Singh 2005). The radish is a diploid species and has 18 chromosomes ($2n=18$), (Dixon, 2007). Radish is grown for its young tender fusiform root (Brickell, 1992).

Radish is predominantly a cool season vegetable crop. But, Asiatic types can tolerate higher temperature than European varieties. Being a cool season crop, it is sown during winter from September to January in northern plains. In the mild climate of peninsular India, radish can be grown almost all the year round except for few months of summer. It is an annual or biennial depending upon the type for the purpose it is grown (Zohary and Hope, 2000).

The growth and yield of radish greatly depends on soil and climatic conditions. Different varieties have different soil and climatic requirements for their optimum performance. India being a vast country with varied agro-climatic region viz., temperate, subtropical, tropical and coastal tropical humid regions, it attain best flavour, texture and size at 10 to 15 °C. Soil with a pH rang of 6.0 – 7.5 are more suitable for radish farming (Randy, 2016).

Among the root vegetables, radish is the most popular and widely grown for its fresh edible roots and it is rich source of Ca, K, P and vitamin C. The edible roots can be used as raw, as salad or cooked (Antonova, 1991). Radish roots are said to be useful in urinary complaints, piles and in gastrodynia and also it is considered as an appetizer. The juice of fresh leaves is diuretic and laxative (Kirtikar and Basu, 1935). The leaves of radish are good source for extraction of protein on a commercial scale (Kumar *et al.*, 2014). In a 100 gram serving, raw radishes provide 16 calories and moderate amount of vitamin C (18% of daily value), with other essential nutrients in low content. A raw radish is 95% water, 3% carbohydrates, 1% protein and has negligible fat (Anonymous, 2014)

As a radish is an important salad vegetable, it is in demand throughout the year in big cities. The vegetables from this region are also sold in big markets like Mumbai, Pune, Nagpur and Hyderabad. One of the most important reasons for low production of the radish in farmer's field is lack of knowledge on suitable varieties (Gautam and Khatiwada, 1997).

In India radish is cultivated on area of 173.33 (000 ha) with total production of 2484.85 (000 MT) and the productivity of 14.35 t ha⁻¹ during 2015-16 as per NHB data base (Anonymous, 2016).

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).

Soil application of organic manure such as spent mushroom substrate (SMS), farm yard manure (FYM), vermicompost, neem cake and biodynamic manure has a positive effect on crop production. SMS has all characteristics to use it as the most valuable organic manure. The *Azotobacter* and PSB are the main bio-fertilizers which are biologically active products containing bacteria and they improve soil health and fertility. They can add 20-25 kg N ha⁻¹ and solubilize 30-50 kg P₂O₅ ha⁻¹. They liberate growth promoting substances and vitamins which may increase crop yield (Sharma *et al.*, 2013).

Mushrooms are the fruiting bodies of fungi belong to basidiomycetes and ascomycetes which are edible. They are considered as good vegetable, containing more of protein, most of the essential amino acids, fewer amounts of fat, significant amount of minerals and many vitamins. It has been reported that mushrooms are good for diabetic, high blood pressure, old age people (Chadha and Sharma, 1995; Bhatt *et al.*, 2006).

The global mushroom industry has expanded very rapidly in the last two decades by the addition of newer types of mushrooms for commercial cultivation. Total world production is estimated to be more than 5 million tonnes, with an increasing of 5-7% per annum (Tewari, 2003 a). So far, Button mushroom stands first in modern mushroom production. At present the total mushroom production in India is approximately 0.13 MT (Singh and Sharma, 2017). In India, Tamil Nadu shares 25% of total production in the country (Tewari, 2003b). There is continuous increase in export of mushroom from India to China during last five years. However, when compared to China, India is far lagging behind (Tewari, 2004).

Mushroom growing is an eco-friendly activity as it utilizes the wastes from agriculture, poultry, brewery *etc.* and in turn produces fruit bodies with excellent and unique nutritional and medicinal attributes. The production of spent mushroom substrate after crop harvest is a matter of concern because it creates various environmental problems including ground water contamination and nuisance if not handled properly. (Ahlawat and Sagar, 2007c).

The substrate released after mushroom crop harvest, better known as “SMS” is also the subject of great importance. The recomposed SMS has been found to be a good growing medium for majority of vegetables and the field crop. It has shown multi facet utilities in improving the yield and qualities of the crop. The other utilities of SMS, like in vermicomposting, bioremediation and as organic-mineral fertilizer are boon to the country’s farming system (Tewari, 2007).

Mushroom industry needs to dispose off more than 50 million tonnes of used mushroom compost each year called 'Spent Mushroom Substrate' (SMS) (Fox and Chorover, 1999). Compost is considered 'spent substrate' when one full crop of mushroom has been taken and further extension becomes unremunerative (Wuest and Fahy, 1991).

The SMS has been found to be a good nutrient source for agriculture mainly because of its rich nutrient status, high cation exchange capacity (CEC) and slow mineralization rate which retain its quality as an organic matter. Further, SMS contains 45% water though bulky, is light in weight. (Dann, 1996).

Spent mushroom substrate (SMS) is also a good source of carbon, nitrogen and other elements. Nitrogen content varies from 0.4-13.7% with a C: N ratio of 9 to 15:1 which enhances the growth of plants (Roy *et al.*, 2015).

Spent substrate from button mushroom has been found to be nutritionally rich with respect to its N:P:K contents and being having high cation exchange capacity, it has the ability to replace Farm Yard Manure for the purpose of raising horticultural and cereal crops (Ahlawat and Sagar, 2007b).

Spent mushroom compost when added to soil can have a number of beneficial effects. Because it contains significant amounts of essential plant nutrients, it can supply these to the crop and thus replace inorganic fertilizer (Hui *et al.*, 2007). 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, 2007a).

Biofertilizers are the substances which contain strains of beneficial microorganisms and carrier material which add, fix, conserve and mobilize crop nutrients. In other words, biofertilizer is a substance which contains living microorganisms which when applied to seed, plant surfaces, or soil colonize the rhizosphere or the interior of the plant and promotes growth by increasing the availability of primary nutrients to the host plant (Mazid and Khan, 2011a). Also they improve soil structure and improve soil fertility. It maintains the natural habitat of the soil. It increases crop yield by 20-30%, replaces chemical nitrogen and phosphorus by 25%, and stimulates plant growth (Kapoor *et al.*, 2015). It can also provide protection against drought and some soil borne diseases (Nilabja Ghosh, 2007).

Therefore the quality of spent mushroom substrate can be improved by enriching it with biofertilizers. In order to produce high quality compost, it is necessary to add bio-activator containing nitrogen and phosphorus that can be inoculants (Widawati *et al.*, 2003). *Azotobacter*

and *Pseudomonas* were able to enrich the quality of mushroom compost heap to become a new ameliorant (Sudjana *et al.*, 2017).

When *Azotobacter* is added to the compost, it increases the availability of nitrogen in compost as well reduces the time of composting. Application of inoculants *Pseudomonas* to compost in large amounts can increase the population in soil so that the competition between microorganisms in the soil does not affect the solubility of PO₄ in the soil (Ginting and Rohini, 2006).

Enriched SMS is capable of improving the physical, biological and chemical properties of soil when it is added to the soil. It also 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 (Ilknur and Cevdet, 2017).

Compost with combined inoculation of *Azotobacter* sp. and *Tricoderma harzianum* significantly affected the highest plant fresh biomass and number of nodules (Espiritu, 2011). The use of enriched compost with N fixing microbes and PO₄ solubilizing could provide a better plant performance compared with without compost or without enriched compost (Sudjana *et al.*, 2017).

Keeping this in view, the present experiment entitled “Influence of enriched spent mushroom substrate (SMS) on growth and yield of radish (*Raphanus sativus* L.) was conducted with the following objectives:

1. To enrich spent mushroom substrate with biofertilizers (*Azotobacter*, PSB and KMB).
2. To evaluate the effect of enriched spent mushroom substrate on growth and yield of radish crop.

2. REVIEW OF LITERATURE

Mushrooms are the fruiting bodies of fungi belong to basidiomycetes and ascomycetes which are edible. They are considered as good vegetable, containing more of protein, most of the essential amino acids, fewer amounts of fat, significant amount of minerals and many vitamins. It has been reported that mushrooms are good for diabetic, high blood pressure, old age people (Chadha and Sharma 1995; Bhatt *et al.*, 2006).

The substrate released after mushroom crop harvest, better known as “SMS” is also the subject of great importance. The recomposed SMS has been found to be a good growing medium for majority of vegetables and the field crop. It has shown multi facet utilities in improving the yield and qualities of the crop. The other utilities of SMS, like in vermicomposting, bioremediation and as organic-mineral fertilizer are boon to the country’s farming system (Tewari, 2007).

The spent substrate from different mushrooms varies in its physical, chemical, and biological properties and each one has its own specific utility. The spent substrate has been found to be nutritionally rich with respect to its N:P:K content, and being having high cation exchange capacity, it has the ability to replace Farm Yard Manure for the purpose of raising horticulture and cereal crops (Ahlawat and Sagar, 2007).

The relevant literature on different methods of using SMS for better crop yield has been presented in this chapter.

2.1 Spent Mushroom Substrate

Lohr *et al.* (1984) observed that the composting of SMS in semi-enclosed drums for 6 weeks enhances its bulk density from 0.256 g cm⁻³ to 0.293 g cm⁻³.

Lohr and Coffey (1987) reported that mushroom spent compost earlier considered as a waste, recently found many uses for organic farming. The mushroom spent compost after proper decomposition / suitable treatment could be used for cultivation of fruits, vegetables, flowers and foliage crops.

Devonald (1987) noted that SMC contained 1.9% N, 0.6% P and 1.0% K respectively after 8 to 16 months of decomposition and thus increasing the soil fertility.

Wuest and Fahy (1991) reported that compost is considered ‘spent’ when the full crop of mushroom has been taken and further extension of cropping becomes un-remunerative.

Dann (1996) concluded that SMS has many positive attributes and can be used further. The material has been found to be good nutrient source for agriculture because of its high nutrient status, high cation exchange capacity and slow mineralization rate.

Fox and Chorover (1999) noted that mushroom industry needs to dispose off more than 50 million tons of used mushroom compost each year called spent mushroom substrate (SMS.)

Romaine and Hokomb (2001) found that mushroom spent compost has a disease suppressive quality rendering it a unique multifunctional constituent of a potting mix.

Gupta *et al.* (2004) recorded that spent mushroom substrate (SMS) normally contains 1.9:0.4:2.4 percent, N-P-K before weathering and 1.9:0.6:1.0 percent, N-P-K after weathering for 8 to 16 months.

Ahlawat *et al.* (2005) reported that mushrooms are being grown primarily for delicacy and nutritional attributes. However, the multifold increase in production as well as productivity of mushroom in India during the last two decades has also increased the quality of SMS.

Ahlawat and Sagar (2007) reported that the spent substrate from button mushroom has been found to be nutritionally rich with respect to its N:P:K contents, and being having high cation exchange capacity, it has the ability to replace Farm Yard Manure for the purpose of raising horticultural and cereal crops.

Liang and Chiu (2007) observed that SMS not only served as the sole fertilizer to produce normal growth and grain yield of wheat but also improved the soil quality after harvest to increase the soil organic matter, maintain the soil alkalinity and increase field capacity unlike the synthetic fertilizer amendment. Simultaneously, SMS treatment enhanced drought tolerance of wheat by enabling germination at 8.5% soil moisture and completing sexual reproduction to grain production even at 6.3% soil moisture.

Mustapha and Kadiri (2010) noted that SMC is believed to be a source of humus formation and humus is known to provide plant micronutrients, improve soil aeration, soil water holding capacity and contribution to maintenance of soil structure.

Jonathan *et al.* (2012) reported that spent mushroom compost (SMC) is the leftover of wastes after different flushes of mushrooms have been harvested.

Zhang *et al.* (2012) described that SMS should be considered as an alternative for widely used but expensive and resource limited peat in greenhouse cultivation.

2.2 Microorganisms associated with SMS

Barea *et al.* (1976) showed the production of plant growth regulator by rhizosphere phosphate solubilizing bacteria. Phosphate solubilizing microorganisms are also reported to produce siderophores and auxins.

Desai (1982) reported that microflora associated with paddy straw during *Pleurotus florida* cultivation had three fold higher microbial count (1324 cfu per gram of straw) on untreated straw substrate than chemically treated paddy straw substrate which had microbial count (98 cfu per gram of straw) only.

Zheng *et al.* (1988) showed that microbial associates and their products served as a source of nitrogen, carbon, minerals and water reserve in button mushroom production. The synergistic interaction between cultivated mushroom fungi *Agaricus sp.*, *Calocybe sp.*, *Volvariella sp.* and *Pleurotus sp.* and nitrogen fixing organisms.

Pill *et al.* (1993) noted that SMC released after mushroom harvest contains all the essential nutrients which controls the pathogenic fungal biomass and rich in population of heterotrophic microbes.

Malewar and Hasnabade (1995) observed that application of SMC in combination with chemical fertilizers increased the microbial activities and in turn increased the kinetics of CO₂ evaluation.

Ntougias *et al.* (2004) carried out an investigation of bacterial diversity in SMC using DNA molecular techniques in order to reveal the origin of SMC microflora and its potential effects on soil microbial communities after incorporation into soil. The bacterial population was estimated by the plate count method to mean of 2.7×10^9 colony forming units per gram of dry weight, while the numbers of gram positive and gram negative bacteria were 1.9×10^9 and 4.9×10^8 cfu per gram of dry weight respectively as estimated by enumeration on semi selective media.

Ahlawat *et al.* (2007c) found that the microbes, especially actinomycetes (*Streptomyces sp.* and *Thermomonospora sp.*) present in SMS also have strong pollutants catabolising capabilities which result in decreased level of pollutants in contaminated soil after incubation with SMS.

Mallesha (2008) has reported that nitrogen fixing microorganism population was significantly more in rhizosphere soil amended with mushroom spent substrate compared to rhizosphere soil amended with substrates such as coffee pulp, areca husk, paddy straw and coir pith.

Taha *et al.* (2016) accomplished that, using of compost tea combined with nitrogen fertilizers significantly increased the population of bacteria, aerobic – N₂ – fixing bacteria and fungi in sandy soil as well as promotion growth of radish plant.

2.3 Soil chemical and physical properties after addition of SMS

Wang *et al.* (1984) reported that increased demand for organic residues and compost provides a potential outlet for SMC, thus generating more income for mushroom growers and increasing crop production and improving soil quality.

Robbins *et al.* (1986) described that the SMS, which contains simpler form of protein rich component formed by modification of agricultural materials by the fungus after few cycles of cultivation, can be used as very good soil conditioners for the cultivation of fruits, vegetables flower and foliage crops.

Kaddous and Morgans (1986) revealed that the SMS incorporation in soil leads to an increase in both pH as well as the organic carbon content.

Wisniewska and Pankiewicz (1989) found SMS treatment in soil elevated the P, K, Ca, and Mg contents in soil.

Maher (1991) reported that the P and K requirement of crops can be fully met by incorporating 5 per cent of SMC by volume, while nitrogen requirement by 25 per cent of SMC by volume.

Manyard (1993) recorded in his study with SMC @ 50 T per acre each year for three years for vegetable production reported that nitrate leaching was greater in plots with inorganic fertilizers than SMC amended soils.

Rupert (1994) observed that SMC contains calcium carbonate (CaCO_3), which provides short term buffering of the acidic waters and elevates soil pH.

Piccolo and Mbagwu (1994) found that the SMC is able to bind mineral particles together promoting a good soil structure and improving aeration and moisture retention.

Szmidt (1994) reported the use of SMC in agriculture reduces the quantity of biodegradable waste disposed in land fill site sand also transforms them into economically useful agricultural products.

Landschoot and McNitt (1994) described that the SMS not only improves soil health but also helps in the turf establishment which, however, depends on the rate of SMS application in soil.

Rhodas and Olsen (1995) recommended that optimum SMC was 44.8 ton/ha for many crops and they postulated the increased yield due to the nitrogen availability which was resulted with SMC treatments.

Levanon and Denai (1995) reported that SMC adds organic matter to the soil which increases soil water and nutrient holding capacity improves soil structure.

Wuest *et al.* (1995) stated that when fresh SMC was applied to the corn field at a thickness of 10 cm, soil cation exchange capacity, Mg, K, Ca and P levels were improved, whereas solute loss with runoff and leaching to depth was negligible.

Bellaki and Badanur (1997) found that available N, P, K and micronutrient increased significantly with organic sources (FYM and SMC) of nutrients either alone or in combination with fertilizers over a fertilizer alone.

Stewart *et al.* (1998) noted that SMS treatment positively affected the crop yield and plant nutrition uptake due to reducing the volume, weight, soil clod, slide layer formation and increasing infiltration rate, water holding capacity of soil.

Sangwan *et al.* (2002) stated that highest uptake of nutrients N, P and K in treatment receiving SMC + 100 per cent recommended dose of fertilizer where in the absence of inorganic fertilizers, organic amendments increased nutrient uptake over control.

Ahlawat *et al.* (2004) observed that the button mushroom spent substrate shows higher activity of lignin peroxidase only.

Peter *et al.* (2007) found that the SMC has high organic matter content; it can have important benefits in improving the physical structure of the soil. Soils in continuous tillage systems can have reduced organic matter content with a consequent poor structure that makes the soil difficult to work and impedes drainage. This is probably most likely in intensive horticultural or tillage systems where, in the past, farmyard manure was traditionally used. Use of SMC will increase the activity of soil micro-organisms and earth worms, help develop a good crumb structure, improve soil porosity and make it easier to work.

Dar *et al.* (2009) described that physiological efficiency was increased due to luxury uptake of nitrogen with use of SMC and N fertilizer @ 120 kg / ha. Agronomic efficiency was also improved due to the addition of N in the rice crop by incorporating SMC and N fertilizer @ 90 kg / ha.

Sagar *et al.* (2009) revealed that the SMC, in general, has been widely used as “manure” in India with great success.

Medina *et al.* (2009) found that addition of SMC to the growing media increased pH values, salt content and macro and micro nutrient concentrations.

Ahlawat *et al.* (2010) observed that apart from using SMS as feeding material for vermicomposting, plant disease management, preparation of organic-mineral fertilizer and bioremediation of contaminated soils.

Mustapha and Kadiri (2010) reported that SMC is believed to be a source of humus formation and humus is known to provide plant micronutrients, improve soil aeration, soil water holding capacity and contributes to the maintenance of soil structure.

Gounani *et al.* (2011) found that the use of SMC as an additive to growing media not only would be economically advantageous but also, field inventories of the waste by product and minimize the contamination of ground-water.

Phan and Sabaratan (2012) stated that among many different characteristics and possible applications, SMS was also shown to be a source of enzymes, enabling its use in animal nutrition, energy production, or even bioremediation.

Roy *et al.* (2015) revealed that using the SMC as organic manure is one of the solutions to utilize the spent compost in a better way. The rich organic matter, moderate nutrient load, near neutral pH and presence of beneficial microbial population make SMC as a suitable organic waste for its conversion into quality manure for crops.

Tuhy *et al.* (2015) noted that SMS improved soil structure, quality and its absorption capacity. It also characterized by preferred ratios of micronutrients that are essential to plants in cultivation. SMS enriched with micronutrients in bio sorption process can be treated as an alternative to traditional micronutrient fertilization with direct use of an inorganic salt.

Gumus and Seker (2017) found that the physical and chemical properties of the soil, such as aggregate stability, soil modulus of rupture, organic carbon, and total nitrogen, were improved by SMC amendment. The addition of SMC increased soil EC. Soil aggregate stability and the modulus of rupture were the most significantly affected parameters by SMC application. Moreover, the use of SMC contributed to enhancing the level of organic carbon and nitrogen in the soil.

2.4 Influence of SMS on plant growth and yield

Chong *et al.* (1987) showed the effect of SMS on several crops and shown that the dry matter content of plants increases with incorporation of increasing amount of weathered or unweathered SMS in soil.

Ranganathan and Selvaseelan (1997) noted that the application of mushroom spent rice straw compost enhanced grain yield of rice and tuber yield of potato in field. Further, there was higher uptake of Ca, Mg and Fe by rice and potato tuber.

Ranganathan and Augustine (1997) observed that application of FYM and SMC to potato appreciably enhanced the N, Fe, and Zn uptake. MSC application significantly enhanced the uptake of K, Ca and Mg by potato shoot and Mn uptake by both shoot and tubers.

Li *et al.* (1998) seen that crop yield dramatically increased in SMC and vermiculite ratio of 2:1 in tomato (72 q/ha) and cucumber (67q/ha) in a comparison to the control.

Dange *et al.* (2001) stated that application of 50% RDF + 50% SMC produced significantly maximum number of fruits and length over control in chilli crop.

Yadav *et al.* (2001) compared 5 levels of two-year-old well decomposed SMC viz. 100, 125, 150, 175, and 200 q/ha were compared with no SMC application i.e. control. The higher grain yield and vigorous plant growth were obtained from all treatments as compared to control. The highest grain yield of 66.14 and 84.35 q/ha were obtained with 150 and 152 q/ha SMC application in maize hybrids *Kanchan*.

Sangwan *et al.* (2002) found that the yield (grain and straw) of wheat crop were highest in the treatment receiving SMC + 100% RDF.

Polat *et al.* (2004) stated statistically significant result in terms of total marketable yield due to the application of 2 to 4 t/ha SMC in lettuce.

Geetha *et al.* (2005) Coir pith composted with *Pleurotus sojar-caju* and applied along with 25 per cent recommended nitrogen improved the yield of banana.

Ahlawat *et al.* (2006) revealed that mixing of 12 months old aerobically recomposed SMC @ 25 t/ha along with chemical fertilizers enhances the vegetative growth and total yield of cauliflower in comparison to yield obtained from FYM manure field. It also leads to superior stalk length, curd length and curd diameter.

Ahlawat and Sagar (2007) observed that amendment of arable land with 25 t/ha of 6 to 18 months old naturally weathered SMC enhances plant growth, fruit yield and fruit quality in comparison to farm yard manure (52.5) and recommended dose of fertilizers in chilli.

Song and Sui-Wai (2007) reported that SMS not only served as the sole fertilizer to produce normal growth and grain yield of wheat but also improved the soil quality after harvest to increase the soil organic matter, maintain the soil alkalinity and increase field capacity unlike the synthetic fertilizer amendment. Simultaneously, SMS treatment enhanced drought tolerance of wheat by enabling germination at 8.5% soil moisture and completing sexual reproduction to grain production even at 6.3% soil moisture.

Mallesha (2008) reported that mushroom spent substrate incorporation into soil improve tomato plant growth.

Polat *et al.* (2009) recorded the effects of SMS on several yield related characteristics such as total yield, fruit width, fruit length; total soluble solids, fruit quality and nutrition content of the cucumber fruit were statistically significant.

Sagar *et al.* (2009) found that the 6-18 months old naturally weathered SMS and 12 months old aerobically recomposed SMS enhanced the yield of capsicum along with better quality of fruits and restricted incidence of fruit rot disease (*Phytophthora sp.*) the chemical fertilizers supplemented anaerobically recomposed SMS gave superior yield in cauliflower, brinjal and wheat, while better fruit quality and lower incidence of diseases was recorded in plain anaerobically recomposed SMS treatment (without chemical fertilizers).

Yildirim *et al.* (2009) reported that the use of the same inoculants (*Azotobacter* + *Pseudomonas*) on compost used as cauliflower growing medium provided high-yield crop and highest plant weight compared to that without enrichment or singly enrichment.

Sidhant and Singh (2009) reported that SMS obtained after the cultivation of *Pleurotus* was applied to *Spinacea oleracea* plants at different proportions (1, 3 and 5%). Application of SMS showed quick seed emergence and higher yield than pure soil.

Jonathan *et al.* (2012) showed that the different concentration of SMC of *Pleurotus ostreatus* in the soil has a direct effect on the yield and nutrient compositions of *Agaricus hybridus*. All the vegetables cultivated on soil treated with SMC showed yield different from those of the control, this establishes the fact that SMC has effects on the growth of the vegetable. This study revealed that 20% and or 30% of SMC in soil best supported *Agaricus hybridus* growth. It was also observed that application of SMC at these rates raises the nutrient content of the plant used.

Jadhav *et al.* (2014) conducted an experiment on radish which revealed that the yield obtained with treatment T4 (1.2 kg vermicompost + RDF + FYM) was significantly higher than all other treatments in addition to other growth parameters like highest leaf length (37.59cm), leaf weight (13.20gm), total no of leaves per plant (10.60), root length (23.11 cm), single root weight (89.03 gm), yield / plot (17.81 kg), yield / ha (59.35 t/ha) and marketable yield (44.51 t/ha) while B:C ratio (2.99:1) was maximum in T1.

Ashrafi *et al.* (2015) concluded that combined application of SMS compost at the rate of 2.5 t ha⁻¹ and recommended inorganic fertilizer could give higher yield of tomato along with high quality.

Unal (2015) stated that the addition of SMC into the growth media had a positive impact on the quality properties of tomato seedlings. The values of hypocotyls length, seedling length, seedling root length, shoot fresh weight and root fresh weight gave the best results in the seedlings grown in 100% SMC (H7).

Zeljko *et al* (2015) reported that the SMC can be used in the production of *Pelargonium peltatum* L. and *Petunia hybrida* Jus. seedlings as a supplement to commercial compost in the amount of 70%. Efficient use of SMC is reflected in an increase in the average measured value of morphological indicators of growth and development (plant height, leaf number, number of flowers and number of flowering branches) and the increase in fresh dry mass of above ground parts or root relative to the average value of control plants seedlings.

Wiafe-Kwagyan (2014) showed that tomato and pepper seedlings raised on different concentrations of SMC (5, 10, 15, 20, 25 and 30 %) amended with sandy loam soil supported vegetative growth (plant height, number of leaves, leaf area, chlorophyll content) and fruit yield. SMC10: sandy loam soil medium (0.6 kg SMC: 5.85 kg sandy loam soil combination) was the best suitable medium to support optimum vegetative growth of both test plants. These nutrients acted in concert to promote growth of the two plants in the greenhouse at least to a certain level of concentration of soil with SMC.

Mardiyani *et al.* (2019) observed that the application of SMC with diverse materials of initial compost starter showed a significant interaction in the width of the leaf at 10 days after sowing (DAP), the height of the plant at 30 DAP, dry weight, and leaf area ratio at 20 +DAP. The result of the research proved that the spent mushroom using effective microorganism and fertilizers as compost starter have a good quality and suitable to support the vegetative growth of kangkong.

2.5 Influence of biofertilizers on plant growth

Panwar *et al.* (2001) reported in radish (*Raphanus sativus* L.) that maximum growth occurred with the application of nitrogen dose 120 kg/ha in plants inoculated with *Azotobacter* + *Azospirillum*.

Kamalakannan and Manivannan (2002) recorded maximum yield with 100% NPK + FYM @ 10t/ha in carrot, they further reported maximum root length, width and length with 100% NPK + *Azospirillum* in radish and carrot.

Sharma *et al.* (2003) obtained that maximum root yield (32.26 t/ha) of carrot was for plants treated with ½ RDF + ½ FYM + rhizosphere bacteria followed by RDF (29.53 t/ha), while minimum root yield (20.01 t/ha) was for controls. Higher value of vitamin A (997.52 IU) was observed in plants treated with ½ RDF + ½ FYM + rhizospheric bacteria.

Choudhary *et al.* (2004) advocated that the highest plant growth parameter of cauliflower was recorded with *Azotobacter*, PSB and FYM along with inorganic fertilizers.

Suja *et al.* (2005) conducted an experiment to evaluate the effectiveness of bio-fertilizers (*Azospirillum* and *Phosphobacterium*) conjointly with chemical fertilizers and organic manures on biomass production and yield of cassava. They reported that integrated use of bio-fertilizers (*Azospirillum* + *Phosphobacterium*) with the recommended dose of FYM and K and 50% of N and P produced tuber yield (26.87 t/ha). The above treatment favored crop growth by enhancing tuber and whole plant biomass.

Rai (2006) reported that the use of multiple inoculations can aim to stimulate N₂ fixation, P-uptake and mineral nutrition in general, but they can also help in controlling plant pathogens. Such application would be welcomed as they allow reduction in chemical fertilizers and pesticides that are expensive and environmentally unsound. An interesting issue, in addition to the infection potential, is the persistence of the biofertilizers after inoculation. If an inoculation can be built into agricultural soils, the interval between biofertilizer application could be increased and costs lowered.

Kore *et al.* (2006) reported that plant height and number of leaves per plant in garlic were found maximum in the plants receiving combined nutrients dose @ 10 t FYM + 3 kg *Azotobacter* + 3 kg PSB + 75 per cent RDF ha⁻¹.

Singh *et al.* (2007) studied the effect of integrated nutrient management on the growth and root yield of carrot. They found that treatment consisted of half strength recommended NPK + 2.5 t green leaf manure + 5.0 kg *Azotobacter* + 5.0 kg PSB ha⁻¹ gave maximum plant height (61.39 cm), leaf length (45.00 cm), number of leaves per plant (12.08), fresh weight of leaves per plant (25.92 g), root length (16.37 cm), root diameter (2.85 cm) and yield (212.85 q/ha).

Upadhyay *et al.* (2007) evaluated effect of bio-fertilizers in combination of organic amendments on growth, yield and quality attributes of cabbage and reported that the use of bio-fertilizers in combination with organic amendments significantly influenced the ascorbic acid, total carotenoids, total carbohydrates and crude fibre content.

Padamwar and Dakore (2010) studied the effect of vermicompost, farmyard manure (FYM) and bio-fertilizers on the nutritional quality of cole crops and found that there was significant increase in percentage dry matter, protein, carbohydrate, vitamin C and calcium contents of curd of all the cole crops due to application of vermicompost fertilizers.

Sentiyangla *et al.* (2010) reported significant increase in plant height and number of leaves in radish with application of chemical fertilizers, organic manures and bio-fertilizers (50 per cent NPK + 50 per cent FYM + bio-fertilizers).

Subramani *et al.* (2010) conducted an experiment to study the effect of organic nutrients and biostimulants on growth parameters in radish cv. *Pusa Chetki*. The results of the experiment

revealed that the growth parameters viz., root length, number of leaves, leaf area and root weight were recorded the highest with the application of FYM @ 25 t ha⁻¹ plus consortium of bio-fertilizers @ 2 kg ha⁻¹.

Subramani *et al.* (2011) concluded that the growth parameters viz., shoot length, number of leaves, leaf area and shoot weight were the highest with application of FYM @ 25 t ha⁻¹ plus consortium of bio-fertilizers @ 2 kg ha⁻¹ combined with EM @ 1:1000 dilution ha⁻¹ and MMT @ 3 per cent for both seasons in radish cv. Pusa Chetki.

Khan *et al.* (2011a) found that the biofertilizers are the preparations containing cells of microorganisms which may be N fixers, P solubilizers, S oxidizers or organic matter decomposers. In short, they are called as bio inoculants which on supply to plants improve their growth and yield.

Eid and El-sayed (2012) conducted an experiment to study the effect of using 100 per cent compost (15 t/ha) and 50 per cent compost + nitrogen fixing bacteria (*Azotobacter* and *Pseudomonas* alone or together) on potato growth and yield as compared to the conventional mineral fertilization (120-75-150 kg/ha NPK + 5t compost/ha). T1 (Mineral NPK (476.2- 309.5 - 464.3 kg) + compost 11.9 t/ha) significantly produced high yield per hectare than using 50 per cent compost + any bio-fertilizer treatment.

Jawadagi *et al.* (2012) reported that organic sources of nutrients significantly increased plant height (29.05, 39.52, 48.06 and 50.83 cm) and leaf length (24.03, 28.06, 34.75 and 36.38 cm respectively at 30, 60, 90 DAT and at harvest) with 50 per cent FYM (12.5 t ha⁻¹) + 50 per cent VC (2 t ha⁻¹) + biofertilizers as compared to 50 per cent FYM (12.5 t ha⁻¹) + 50 per cent VC (2 t ha⁻¹) + bio-fertilizers in onion cv. Bellary Red.

Kanaujia *et al.* (2012) conducted an experiment on integrated nutrient management and found that 50 per cent NPK + 50 per cent FYM + bio-fertilizers recorded maximum yield of carrot. Their combination had a beneficial impact on carotene content in roots. Maximum carotene (3.41 mg 100 g⁻¹) was recorded with 50 per cent NPK + 50 per cent FYM + bio-fertilizer.

Yeptho *et al.* (2012) conducted a field experiment on quality production of *kharif* onion (*Allium cepa*) in response to bio-fertilizers inoculated organic manures and found that 20 ton/ha was a better source of manuring with regard to increasing plant height, number of leaves and other yield components followed by FYM 40 ton/ha and vermicompost 10 ton/ha.

Sharma *et al.* (2013) conducted an experiment on cabbage crop using *Azotobacter*, *Azospirillum* and VAM. The results proved that 4kg ha⁻¹ dose of each bio-fertilizer resulted the maximum plant height, number of leaves per plant, diameter of stem, length of longest leaf, broadest leaf and plant spread than other doses.

Wani *et al.* (2013) conducted an experiment on *Azotobacter chroococcum* in crop production. *Azotobacter* genus synthesizes auxins, cytokinins and GA like substances, and these growth materials are the primary substances controlling the enhanced growth.

Kumar *et al.* (2014a) reported that the plant height, number of leaves, root length and root diameter were significantly increased by application of organic manures and these were maximum under treatment T9 i.e. vermicompost + poultry manure (50 per cent each) on growth and yield of radish cv. Japanese white.

Mazid and Khan (2014) found that the bio-fertilizers offer a safe option to utilize renewable inputs to improve the fertility of land using biological wastes with those beneficial micro-organisms which impart organic nutrients to the farm produces. Biofertilizers have emerged as potential environment friendly inputs that are supplemented for proper plant growth. They hold vast potential in meeting plant nutrient requirements while minimizing the use of chemical fertilizers.

Khalid *et al.* (2015) concluded that the combination of inorganic, organic and bio-fertilizers had given good results. It attributed to the increase in the height of plant, number of leaves, length of leaves, leaves size, fresh weight of leaves, length of root, and diameter/thickness of main root, leaf: root length ratio, leaf: root weight ratio, fresh weight of root and ultimately yield in radish.

Ziaf *et al.* (2016) reported that number of leaves per plant, root fresh weight and marketable yield were significantly high owing to the combined application of PSB and RDF. Root diameter increased when RDF was used along with PSB in radish.

Kapoor *et al.* (2015) revealed that bio-fertilizers can be expected to reduce the use of chemical fertilizers and pesticides. Biofertilizers provide eco-friendly organic agro-input and are more cost-effective than chemical fertilizers.

Khalid *et al.* (2016) reported that application of NPK 80:60:60 + FYM (10 t/ha) + PSB (5 kg / ha) (T₈) significantly increased yield attributing characters of radish.

Kumar *et al.* (2016) concluded that application of 25 per cent PSB + 25 per cent *Azospirillum* + 25 per cent RDF + 25 per cent *Azotobacter* (T₁₂) increased the growth, yield and nutritional quality of radish.

Shruthi *et al.* (2016) reported that the plants provided with 25 per cent RDF + *Azotobacter* + PSB + KMB + *Pseudomonas* (T₁₀) recorded maximum plant height (30.90 cm), number of leaves (12.50), leaf length (30.47 cm), root length (27.03), root girth (14.17 cm), fresh weight of root (186.63 g) and dry weight of root (8.62 g) in radish.

Mali *et al.* (2018) reported that application of PSB 4 kg ha⁻¹ + vermicompost 5 t ha⁻¹ (T₁₂) results in maximum values of growth and yield attributes of radish crop.

Kumar *et al.* (2017) reported that biofertilizers being essential components of organic farming play a vital role in maintaining long term soil fertility and sustainability by fixing atmospheric di-nitrogen, mobilizing fixed macro and micro nutrients in the soil into forms available to plants. Currently there is a gap of ten million tons of plant nutrients between removal of crops and supply through chemical fertilizers. In context of both the cost and environmental impact of chemical fertilizers, excessive reliance on chemical fertilizers is not practicable in the long run because of the cost, both in domestic resources and foreign exchange involved in setting up of fertilizer plants and sustaining the production. In this context, biofertilizers would be the viable option for farmers to increase productivity per unit area.

Gautum *et al* (2018) envisaged that (T₃) 60 per cent RDF + *Azotobacter* + VAM was found significantly superior to improve the growth, yield and quality of radish root.

Jaishankar (2018) reported that application of vermicompost 12.5 tonnes ha⁻¹ + *Azospirillum* @ 5 kg ha⁻¹ + Humic acid @ 0.2 per cent ha⁻¹ (T₈) to enhance growth and yield in addition to improve soil fertility in radish cultivation.

Naik and Sreedhar (2018) reported that , plant height (28.55cm), leaf count (19.02) and leaf area (106.74 cm²) was maximum when the radish plant were treated with *Azospirillum* 5 kg ha⁻¹ + PSB 7.50 kg ha⁻¹ + VAM 12.50 kg ha⁻¹ + 50 per cent NPK (T₄).

Shanu *et al* (2019) reported that treatment T₉ - 25 per cent RDF + 50 per cent FYM @ 6 t ha⁻¹ +50 per cent vermicompost @ 3 t ha⁻¹ + 50 per cent Rhizospheric bacteria registered significantly higher plant height (53.50cm), more number of leaves per plant (16.40), maximum leaf length (38.20 cm) and fresh weight of leaves (62.40 gm) at harvest stage of carrot.

2.6 Enrichment of SMS with biofertilizers:

Moorthy and Rao (1997) reported that to enhance the quality of spent substrate it can be enriched with cultures of beneficial microorganisms such as *Trichoderma*, *Azotobacter* and PSB so that compost could serve both biofertilizer and bio pesticide.

Kostov and Lynch (1998) found that microbial inoculation in compost tends to further improve its productivity.

Widawati (2003) explained that in order to produce high quality compost, it is necessary to add bio-activator containing nitrogen and phosphorus that can be inoculants.

Ginting and Rohini (2006) stated that application of inoculant *Pseudomonas* on compost in large amounts can increase the population in soil so that the competition between microorganisms in soil does not affect the solubility of P in the soil.

Espiritu, *et al.* (2011) investigated that compost prepared from coconut coir dust chicken manure was inoculated with nitrogen fixing bacteria (*Azotobacter sp.*) and or cellulolytic fungi (*Trichoderma harzianum*), incubated for seven days and applied to in potted mungbean plants at 5 g per plot and grown for 30 days. Mungbean (*Vigna radiata* L. Wilczek) supplied with uninoculated compost had the lowest fresh biomass and the lowest number of nodules. Compost with combined inoculation of *Azotobacter sp.* and *Trichoderma. harzianum* (each added into compost 0.5% w/w) significantly affected the highest plant fresh biomass and number of nodules.

Hamastauti *et al.* (2012) described that the organism can be used to enrich the quality of nutrients that are best applied as biological fertilizers in soil or attached to compost which then used in cultivation process.

Almaghrabi *et al.* (2013) revealed that the genera of plant growth promoting rhizobacteria (PGPR) which are habitant of in the rhizosphere of plants i.e. *Pseudomonas*, *Azospirillum*, *Azotobacter*, *Enterobacter*, *Bacillus*, *Rhizobium*, *etc* which could be proved their beneficial effects on tomato crop productivity in sustainable agriculture as biofertilizers.

Chatterjee and Bandyopadhyay (2014) stated that inoculation with *Azotobacter* and PSB biofertilizers increased the macro and micro nutrient content of plants as well as soil in case of combination with vermicompost.

Borah *et al.* (2014) reported that enrichment of vermicompost and FYM with consortium of biofertilizer i.e. *Azotobacter*, *Azospirillum* and PSB improved the quality of compost in terms of total nutrient content and microbial population count.

Subardja *et al.* (2016) noted that the use of compost enriched as seedling media providing improved quality of cauliflower plants because apart from adequate nutrients it can also stimulate root growth better because compost has the ability to improve the physical, chemical and biological properties that are unable to do by inorganic fertilizers.

Sudjana *et al.* (2017) described that the use of enriched mushroom compost with N fixing microbe and P solubilizing could provide a better plant performance with without enriched mushroom compost in cauliflower.

Kedar *et al.* (2019) reported that application of button mushroom spent compost enriched with *Azotobacter*, PSB and decomposing culture exhibiting better influence on growth and yield parameter in cabbage.

After going through the review of literature, it is clear that the use of SMS and bio-fertilizers particularly FYM, vermicompost, neem cake along with *Azotobacter*, PSB and KMB improve the growth, yield and quality of various vegetable crops as reported by several research workers in the different parts of the country and abroad. However, the beneficial effect of SMS and biofertilizers on growth, yield and quality of radish has not yet been fully exploited on the commercial scale.

3. MATERIALS AND METHODS

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 and the laboratory studies were conducted at PG laboratory, Department of Plant Pathology and Agricultural Microbiology, College of Agriculture, Pune. Detail information on different materials used and experimental techniques adopted for the study are presented in this chapter.

3.1 Material

3.1.1 Seed

Seeds of radish cultivar were collected from local market of Pune and used for sowing.

3.1.2 Spent Mushroom Substrate (SMS)

SMS was collected from All India Coordinated Research Project on Mushroom, College of Agriculture, Pune (MS).

3.1.3 Farm Yard Manure (FYM)

FYM was collected from Department of Animal Husbandry and Dairy Science, College of Agriculture, Pune.

3.1.4 Glass Wares

The glass wares used in the experimental studies viz. test tubes, conical flask, spirit lamp, petriplates, measuring cylinder and beakers *etc.* were available at Plant Pathology laboratory, College of Agriculture, Pune.

3.1.5 Equipments

Common laboratory equipments used for laboratory studies were autoclave, Biological Oxygen Demand (BOD) incubator, hot air oven, laminar air flow cabinet, weighing balance, refrigerator, Spectrophotometer, N analyser, *etc.*

3.1.6 Miscellaneous Materials

Miscellaneous materials included marker, thread, knapsack sprayer, *khurpi*, measuring tape, vernier calliper, bamboo sticks, labels, bucket, scale *etc.* were used during present studies.

3.1.7 Biofertilizers

Biofertilizers like *Azotobacter*, Phosphate Solubilizing Bacteria (PSB) and Potash Mobilizing Bacteria (KMB) were collected from BNF Scheme, College of Agriculture, Pune.

3.2 Methods

3.2.1 Experiment site

The present field experiment was carried out at Plant Pathology Research Farm, College of Agriculture Pune.

3.2.2 Soil status of experimental field

The soil in the plot was black in colour, well drained with good structure. The soil sampling was done on the experimental plot before application of treatments into the plot. The representative composite samples were taken from randomly selected spots before sowing with the help of screw auger. The samples were mixed together, labelled accordingly and air-dried under shade. A representative soil sample was prepared for determining chemical properties of the experimental soil.

3.2.3 Climatic conditions

Pune is situated on elevation of 557.7 meters above mean sea level on 18° 22' North latitude and 73° 51' East longitudes. Agro climatically, Pune comes under the plain zones. The average annual rainfall of Pune is 675 mm. Out of the total annual precipitation, 75 per cent received from June to September from South West monsoon while the remaining is received mostly in the month of October and November from North – East monsoon. The annual average maximum and minimum temperature range between 34 to 40 °C and 6 to 10 °C, respectively.

3.2.4 Rate of Farm Yard Manure

The recommended rate of application of FYM @ 20t /ha was applied treatment wise.

3.2.5 Rate of Spent Mushroom Substrate

The spent mushroom substrate was applied @ 20t /ha per plot.

3.2.6 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) and (Borah *et al.*, 2014)

3.2.7 Experimental details

The field experiment trial was conducted at Plant Pathology Research Farm, College of Agriculture, Pune (MS) during *Rabi*, 2019.

The present experiment was conducted as per the details mentioned below to evaluate the influence of enriched spent mushroom substrate on radish crop.

3.2.7.1 Treatments details

T₁ - SMS + *Azotobacter* (AZT)

T₂ - SMS + Phosphate Solubilizing Bacteria (PSB)

T₃ - SMS + Potash Mobilizing Bacteria (KMB)

T₄ - SMS + Consortium of AZT + PSB + KMB

T₅ - FYM + Consortium of AZT + PSB + KMB

T₆ - SMS (20 t/ha)

T₇ - FYM (20 t/ha)

T₈ - Absolute control

3.2.7.2 Design and layout

- 1) Replications : Three (3)
- 2) Treatments : Eight (8)
- 3) Total number of plots : 24
- 4) Design : Randomised Block Design
- 5) Spacing : 30 X 15 cm
- 6) Irrigation channel : 1.0 m
- 5) Gross plot size : $2.4 \times 2.1 \text{ m}^2 = 5.04 \text{ m}^2$
- 6) Net plot size : $1.8 \times 1.8 \text{ m}^2 = 3.24 \text{ m}^2$

3.2.7.2 Layout of plot

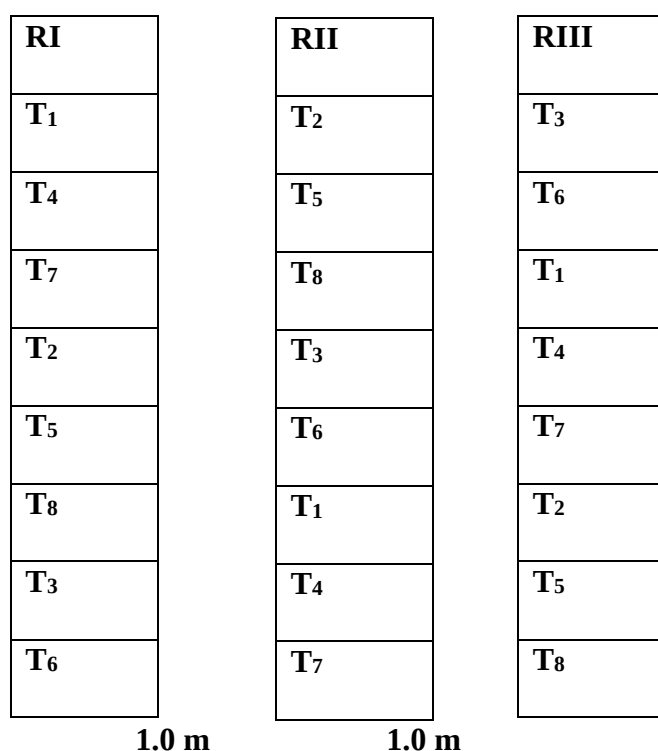


Fig.1. layout plan

3.2.8 Cultural operations

3.2.8.1 Land preparation

The land was ploughed once and harrowed twice with tractor drawn disc, dry weeds and stubbles were removed. The ridges and furrows were made 30 cm apart in each plot and irrigation channels were provided with proper irrigation. The plot borders, plot bunds were made manually as per the layout plan.

3.2.8.2 Application of SMS and FYM

Application of enriched SMS and FYM (20 t/ha) was taken up 15 days before sowing of crop as per the treatment.

3.2.8.3 Seed and sowing

Radish is usually grown on ridges to facilitate good root proliferation. The plant row or ridges of 22 cm high were kept about 30 cm apart, whereas the plants within the row were kept 15 cm apart. Generally the seed sowing was done 2 cm deep.

3.2.8.4 Weed Management

Regular weeding was done to check the growth of weeds.

3.2.8.5 Water Management

It was necessary that enough soil moisture should be available to help uniform seed germination and growth of the plant. The first irrigation was given immediately after sowing. Depending upon soil moisture availability, the crop was irrigated once or twice a week.

3.2.8.6 Crop protection

For controlling pests and diseases, spraying of Neem ark 4% and Chlorpyrifos 50% were done when the pest attack was seen.

3.2.8.7 Harvesting

Harvesting was done manually. A light irrigation was given before harvesting to facilitate lifting of roots.

3.2.8.8 Collection of experimental data

Observations were recorded of five randomly selected and labelled plants from each treatment and each replication for growth and yield parameters at intervals of 30, 45 days and at harvest.

3.3 Growth parameters

3.3.1 Plant height (cm)

The plant height of radish plants was recorded at an interval of 30 and 45 days and at harvest. The average values were calculated and interpreted the results.

3.3.2 Number of leaves

Number of leaves of radish plant was recorded at an interval of 30 and 45 days and at harvest. The average values were calculated and presented in the results.

3.4 Yield parameter

3.4.1 Length of root (cm)

Root length of radish was recorded at the time of harvest by using measuring scale and average values were calculated and presented in the results.

3.4.2 Diameter of root at harvest (cm)

The diameter of roots of radish was recorded with the help of Vernier Calliper in centimetres. The average values were calculated and interpreted in the results.

3.4.3 Fresh weight of plant (g)

The treatment wise fresh weight of five randomly selected radish plants with leaves and root was taken immediately after harvesting. The average values were calculated and presented in the results.

3.4.4 Fresh weight of leaves (g)

The treatment wise fresh weight of leaves of five randomly selected radish plants was taken immediately after harvesting. The average values were calculated and presented in the results.

3.4.5 Fresh weight of root (g)

The treatment wise fresh weight of roots of five randomly selected radish plants was taken immediately after harvesting. The average values were calculated and presented in the results.

3.4.6 Dry weight of plant (g)

The five labelled plants were collected and kept in hot air oven at 60⁰ C till constant weight was obtained and their dry weight was recorded.

3.4.7 Yield (kg/plot)

The weight of roots was recorded treatment-wise from each net plot from each replication. The average values were calculated and presented in the result.

3.4.8 Yield per hectare (tonnes)

The weight of roots was recorded treatment-wise from each net plot and from each replication. Total yield per hectare in tonnes was calculated using the formula:

$$\text{Yield per hectare (t)} = \frac{\text{Yield per net plot (kg)} \times 10,000 \text{ m}^2}{\text{Net area of the plot (m}^2\text{)} \times 1000}$$

3.5 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, standard plate count technique was used (Skinner *et al.*, 1952). The total number of *Azotobacter*, PSB and KMB were calculated by using following formula.

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

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

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.

Nutrient media used for different microorganisms

Organisms	Medium
<i>Azotobacter</i>	Jenson's medium
PSB	Pikovaskaya's medium
KMB	Aleksandrovsk medium
Bacteria	Nutrient agar medium
Fungi	Potato dextrose agar medium (PDA)
Actinomycetes	Ken Knight medium

3.6 Soil Chemical analysis

In order to determine the chemical properties and fertility status of experimental soil, the soil samples were collected from different spots in the field with the help of screw auger, up to the depth of 45 cm before the commencement of experiment. The collected soil samples were mixed thoroughly on a clean piece of cloth and the bulk reduced by quartering so that about 500 g of composite sample was obtained. Collected samples were brought to the laboratory and spread on a thick brown paper. Stones, pieces of roots, leaves and other decomposed organic residues were removed. Large lumps of moist soil were broken by hand. It was air dried at 20-25° C and 20 to 60 per cent relative humidity (Jackson, 1973). After air drying, soil samples were crushed gently by pastel and mortar and sieved through 92 mm sieve. Grounded samples were stored in glass containers. The grounded samples were mixed well before a sample was weighed for analysis. A representative sample was prepared and subjected to chemical analysis.

Following methods were used for analysis of soil sample

Parameter	Method employed
Available N (kg ha^{-1})	Alkaline KMNO_4 method. Subbiah and Asija (1956)
Available P (kg ha^{-1})	Olsen's method. Olsen <i>et al.</i> (1954)
Available K (kg ha^{-1})	Ammonium acetate extractable method. Knudsen <i>et al</i> (1982).

3.7 Statistical analysis

The data collected for various observations was analyzed using Randomized Block Design with 8 treatments and 3 replications. The standard statistical methods as provided by Panse and Sukhmate were (1985) followed for statistical significance. The data is mentioned in tabular form and illustrated by graphs and figures as and when necessary.

4. RESULTS AND DISCUSSION

The results of the field experiment entitled “Influence of enriched spent mushroom substrate on growth and yield of radish (*Raphanus sativus* L.)” conducted during Rabi 2019 at an experiment field of Plant Pathology Section, College of Agriculture, Pune are discussed here. The data pertaining to the influence of different treatments on growth and yield of radish and soil nutrient status and microbial population in soil was statistically analyzed for test of significance of the result.

4.1 Influence of enriched spent mushroom substrate on vegetative growth parameters of radish

The observations for number of leaves per plant and plant height were recorded and presented in table 4.1 and 4.2 and fig-4.1 and fig-4.2

4.1.1 Number of leaves per plant

Number of leaves per plant was recorded at 30, 45 DAS and at harvest and presented in Table-4.1 and Fig-4.1

The data presented in Table 4.1 showed that among the different treatments, treatment T₄ i.e. SMS + Consortium of AZT + PSB + KMB was found to be the most effective as it recorded significantly highest number of leaves per plant (10.5, 17.73 and 25.73) at 30, 45 days of sowing and at time of harvesting respectively over rest of the treatment, followed by the treatment T₅ i.e. FYM + Consortium of AZT + PSB + KMB (9.53, 15.20 and 21.23) at 30, 45 days of sowing and at time of harvesting respectively. The lowest number of leaves (6.20, 9.23 and 11.03) at 30, 45 days of sowing and at time of harvesting respectively were recorded in treatment T₈ i.e. absolute control.

The results are in agreement with Espiritu (2011) who recorded that compost when inoculated with desired beneficial microorganisms could lead to the growth promotion like number of leaves, plant height etc. Khalid *et al.* (2015) and Shruthi *et al.* (2016) concluded that the combination of inorganic, organic and biofertilizers had given good results which attributed to maximum increase in the height of plant and number of leaves in radish crop. The obtained results were in accordance with Roshni *et al.*, (2019) concluded that application of biofertilizers PSB + KSB + *Azospirillum* + *Azotobacter* + VAM recorded the highest number of leaves (18.60).

Table 4.1: Influence of enriched spent mushroom substrate on number of leaves at 30, 45 DAS and at harvest of crop.

Number of laves				
Tr. No.	Treatment details	30 DAS	45 DAS	At Harvest
T ₁	SMS + <i>Azotobacter</i> (AZT)	8.70	14.97	20.10
T ₂	SMS+ Phosphate Solubilizing Bacteria (PSB)	7.90	12.70	16.57
T ₃	SMS+ Potash Mobilizing Bacteria (KMB)	8.13	13.53	18.53
T ₄	SMS+ Consortium of AZT+ PSB+ KMB	10.50	17.73	25.73
T ₅	FYM+ Consortium of AZT+ PSB+ KMB	9.53	15.20	21.23
T ₆	SMS (20 t/ha)	7.67	11.83	15.03
T ₇	FYM (20 t/ha)	7.17	11.37	14.20
T ₈	Absolute control	6.20	9.23	11.03
SEm (±)		0.30	0.55	0.77
CD at 5%		0.90	1.67	2.33

4.1.2 Plant height (cm)

Plant height per plant recorded at 30, 45 DAS and at harvest is presented in Table 4.2

The data presented in Table 4.2 showed that among the different treatments, treatment T₄ *i.e.* SMS + Consortium of AZT + PSB + KMB was found to be the most effective as it recorded significantly highest plant height (26.09, 35.53 and 45.20 cm) respectively at 30, 45 days of sowing and at time of harvesting over rest of the treatment, followed by treatment T₅ *i.e.* FYM + Consortium of AZT + PSB + KMB (24.15, 31.80 and 41.33 cm) respectively at 30, 45 days of sowing and at time of harvesting. The lowest plant height (14.06, 18.03 and 23.02 cm) was recorded in treatment T₈ *i.e.* Absolute control at 30, 45 days of sowing and at time of harvesting.

The results are in agreement with Espiritu (2011) who reported increase in plant height due to application of compost with *Azotobacter*.

Khalid *et al.* (2015) and Shruthi *et al.* (2016) concluded that the combination of inorganic, organic and biofertilizers had given good results which attributed to maximum increase in the height of plant and length of leaves in radish crop. The obtained results are in accordance with Roshni *et al.*, (2019) and Naik and Sreedhar (2018) who concluded that application of biofertilizers PSB + KSB + *Azospirillum* + *Azotobacter* + VAM combination with RDF recorded the highest plant height.

Table 4.2: Influence of enriched spent mushroom substrate on plant height at 30, 45 DAS and at harvest of crop.

Plant height (cm)				
Tr. No	Treatment details	30 DAS	45 DAS	At Harvest
T ₁	SMS + <i>Azotobacter</i> (AZT)	22.28	29.35	37.59
T ₂	SMS+ Phosphate Solubilizing Bacteria (PSB)	19.82	24.93	31.84
T ₃	SMS+ Potash Mobilizing Bacteria (KMB)	20.55	26.50	33.36
T ₄	SMS+ Consortium of AZT+ PSB+ KMB	26.09	35.53	45.20
T ₅	FYM+ Consortium of AZT+ PSB+ KMB	24.15	31.80	41.33
T ₆	SMS (20 t/ha)	18.55	24.23	30.50
T ₇	FYM (20 t/ha)	17.71	22.72	29.27
T ₈	Absolute control	14.06	18.03	23.02
SEm (±)		0.57	0.78	1.01
CD at 5%		1.73	2.37	3.05

4.2 Influence of enriched spent mushroom substrate on yield parameters in radish

4.2.1 Root length at harvest (cm)

The data presented in Table 4.3 showed that among the different treatments, treatment T₄ i.e. SMS + Consortium of AZT + PSB + KMB was found to be the most effective as it recorded significantly highest root length (42.35 cm) at time of harvest over rest of the treatments followed by treatment T₅ i.e. FYM + Consortium of AZT + PSB + KMB (38.93 cm). The lowest root length (21.73cm) was recorded in treatment T₈ i.e. Absolute control at the time of harvest.

These results are comparable with the reports of Vithwel Kanaujia (2013); Khalid *et al.*, (2015) and Gautum Singh (2018) who also reported increase in root length in carrot and radish crops respectively. Shruthi *et al.* (2016) reported that the plants provided with 25 per cent RDF + *Azotobacter* + PSB + KMB + *Pseudomonas* (T₁₀) recorded maximum root length (27.03) and root girth (14.17 cm) radish. Also, similar trend of results were obtained by Sudjana *et al.*, (2017) who reported that the use of enriched compost with N fixing microbe and P solubilizing could provide plant performance a better compared with without compost or without enriched compost. The results obtained are in agreement with Jaishankar (2018) who reported that the maximum root length (15.63 cm) was recorded in with organic manure 12.5 t/ha + *Azospirillum* @ 5 kg/ha + Humic acid @ 0.2 % ha⁻¹ (T₈) in radish crop.

4.2.2 Root diameter at harvest (cm)

The data presented in Table 4.3 showed that among the different treatments, treatment T₄ *i.e.* SMS + Consortium of AZT + PSB + KMB was found to be the most effective as it recorded significantly highest root diameter (4.24 cm) at time of harvest over rest of the treatments followed by treatment T₅ *i.e.* FYM + Consortium of AZT + PSB + KMB (3.83 cm). The lowest root diameter (2.02 cm) was recorded in treatment T₈ *i.e.* Absolute control at the time of harvest.

The results obtained are in agreement with Khalid *et al.* (2015), Shruthi *et al.* (2016) and Jaishankar (2018) who concluded that the combination of inorganic, organic and biofertilizers attributed to the increase in the diameter/thickness/root girth of main root in radish.

Table 4.3: Influence of enriched spent mushroom substrate on root length and root diameter of radish (cm).

Tr. No	Treatment details	Root length (cm)	Root diameter (cm)
T ₁	SMS + <i>Azotobacter</i> (AZT)	34.57	3.58
T ₂	SMS+ Phosphate Solubilizing Bacteria (PSB)	31.20	3.10
T ₃	SMS+ Potash Mobilizing Bacteria (KMB)	33.13	3.40
T ₄	SMS+ Consortium of AZT+ PSB+ KMB	42.35	4.24
T ₅	FYM+ Consortium of AZT+ PSB+ KMB	38.93	3.83
T ₆	SMS (20 t/ha)	28.23	2.87
T ₇	FYM (20 t/ha)	27.23	2.72
T ₈	Absolute control	21.73	2.02
SEm (±)		1.04	0.13
CD at 5%		3.16	0.38

4.2.3 Fresh weight of plants, fresh weight of leaves, fresh weight of roots and dry matter weight of roots

The fresh weight of plant, leaves and roots was recorded immediately after harvest of plant. Dry matter weight of root was also recorded. The results obtained are presented in Table 4.4.

4.2.3.1 Fresh weight of plant (g)

The data described in Table 4.4 showed that among the different treatments, treatment T₄ *i.e.* SMS + Consortium of AZT + PSB + KMB was found to be the most effective as it recorded significantly highest fresh weight of plant (375.41 g) at time of harvest over rest of the

treatments followed by treatment T₅ *i.e.* FYM + Consortium of AZT + PSB + KMB (327.80 g). The lowest fresh weight of plant (123.90 g) was recorded in treatment T₈ *i.e.* Absolute control at the time of harvest.

Similar trend of results was also reported by Espiritu (2011) who stated that fresh and dry weight of pechay was significantly increased by combined inoculation of *Azotobacter* sp. and *Trichoderma harzianum*. The obtained results are in accordance with Roshni *et al.*, (2019) who concluded that application of biofertilizers PSB + KSB + *Azospirillum* + *Azotobacter* + VAM combination with 100% RDF recorded the highest fresh weight of plant (107.57 g) in carrot.

These findings are in line with reports of Singh *et al.*, (2017), Kirad *et al.*, (2010), Vithwel Kanaujia (2013) in carrot and Khalid *et al.*, (2015) and Singh *et al.* (2018) in radish crop.

4.2.3.2 Fresh weight of leaves (g)

The data presented in Table 4.4 showed that among the different treatments, treatment T₄ *i.e.* SMS + Consortium of AZT + PSB + KMB was found to be the most effective as it recorded significantly the highest fresh weight of leaves (87.07 g) at time of harvest over rest of the treatments followed by treatment T₅ *i.e.* FYM + Consortium of AZT + PSB + KMB (76.03 g). The lowest fresh weight of leaves (23.43 g) was recorded in treatment T₈ *i.e.* Absolute control at the time of harvest.

Similar trend of results was also reported by Espiritu (2011) who stated that fresh and dry weight of pechay was significantly increased by combined inoculation of *Azotobacter* sp. and *Trichoderma harzianum*. The results are comparable with those of Singh *et al.*, (2017) in carrot; Khalid *et al.*, (2015) and Singh *et al.* (2018) in radish crop.

4.2.3.3 Fresh weight of root (g)

The data shown in Table 4.4 showed that among the different treatments, treatment T₄ *i.e.* SMS + Consortium of AZT + PSB + KMB was found to be the most effective as it recorded significantly highest fresh weight of root (288.11 g) at time of harvest over rest of the treatments followed by treatment T₅ *i.e.* FYM + Consortium of AZT + PSB + KMB (251.77 g). The lowest fresh weight of root (100.47 g) was recorded in treatment T₈ *i.e.* Absolute control at the time of harvest.

Similar trend of results was also reported by Espiritu (2011) who stated that fresh and dry weight of pechay was significantly increased by combined inoculation of *Azotobacter* sp. and *Trichoderma harzianum*. The results are comparable with Khalid *et al.* (2015) and Shruthi *et al.* (2016) who also concluded that the combination of inorganic, organic and bio fertilizers had attributed to the increase in the leaf: root weight ratio, fresh weight of root and ultimately yield in radish.

The obtained results are in accordance with Roshni *et al.*, (2019) who concluded that application of biofertilizers PSB + KSB + *Azospirillum* + *Azotobacter* + VAM combination with 100% RDF recorded the highest fresh weight of root (121.99 g) in carrot crop.

4.2.3.4 Dry matter weight of root (g)

The data shown in Table 4.4 showed that among the different treatments, treatment T₄ *i.e.* SMS + Consortium of AZT + PSB + KMB was found to be the most effective as it recorded significantly highest dry weight of plant (52.36 gm) over rest of the treatments followed by treatment T₅ *i.e.* FYM + Consortium of AZT + PSB + KMB (45.50 g). The lowest dry weight of plant (18.41 g) was recorded in treatment T₈ *i.e.* Absolute control.

The obtained results are in accordance with Roshni *et al.*, (2019) who concluded that application of biofertilizers PSB + KSB + *Azospirillum* + *Azotobacter* + VAM combination with 100% RDF recorded the highest dry matter weight of root (34.25 g) in carrot.

The results are similar with Sudjana *et al.*, (2017) who concluded that plant dry weight of cauliflower was recorded highest in treatment of mushroom compost enriched with *Azotobacter* 10% + *Pseudomonas* 10%.

Table 4.4: Influence of enriched spent mushroom substrate on fresh weight of whole plant, fresh weight of leaves, fresh weight of roots and dry matter weight of roots of radish (g)

Tr. No.	Treatment details	Fresh weight of plant (g)	Fresh weight of leaves (g)	Fresh weight of root (g)	Dry weight of plant (g)
T ₁	SMS + <i>Azotobacter</i> (AZT)	229.93	52.90	176.10	39.15
T ₂	SMS+ Phosphate Solubilizing Bacteria(PSB)	208.97	39.20	168.90	27.01
T ₃	SMS+ Potash Mobilizing Bacteria (KMB)	217.70	44.30	172.67	32.93
T ₄	SMS+ Consortium of AZT+ PSB+ KMB	375.41	87.07	288.11	52.36
T ₅	FYM+ Consortium of AZT+ PSB+ KMB	327.80	76.03	251.77	45.50
T ₆	SMS (20 t/ha)	189.13	34.29	154.84	25.91
T ₇	FYM (20 t/ha)	183.20	31.83	151.37	23.35
T ₈	Absolute control	123.90	23.43	100.47	18.41
SEm (±)		1.69	1.43	1.97	1.15
CD at 5%		5.12	4.34	5.98	3.50

4.2.4 Root yield (kg/plot) and yield (t/ha)

The root yield per plot and per hectare was noted immediately after harvest of radish crop. The results are presented in the Table 4.5.

4.2.4.1 Root Yield (kg/plot)

The data presented in Table 4.5 showed that among the different treatments, treatment T₄ 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 T₅ i.e. FYM + Consortium of AZT + PSB + KMB (9.39 kg/plot). The lowest root yield (4.82 kg/plot) was recorded in treatment T₈ i.e. Absolute control.

Similar trend of results was also reported by Taha *et al.*, (2016) 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) also reported that the use of the inoculant (*Azotobacter* + *Pseudomonas*) on compost, used as radish growing medium provided high-yield crops and the highest plant weight compared to that of without enrichment or singly enrichment. Singh *et al.* (2018) envisaged that (T₃) 60 per cent RDF + *Azotobacter* + VAM was found significantly superior to improve the growth, yield and quality of radish root.

4.2.4.2 Root Yield (t/ha)

The data presented in Table 4.5 showed that among all the different treatment, treatments T₄ i.e. SMS + Consortium of AZT + PSB + KMB was found to be the most effective as it recorded significantly highest root yield (32.48 t/ha) over rest of the treatments followed by treatment T₅ i.e. FYM + Consortium of AZT + PSB + KMB (28.98 t/ha). The lowest root yield (14.88 t/ha) was recorded in treatment T₈ i.e. Absolute control.

Similar trend of results was also reported by Seran and Imthiyaz (2017) 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) also reported that yield increased by integrated fertilizer usages in radish cultivation by using compost as a combination with chemical fertilizer.

Table 4.5: 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 + <i>Azotobacter</i> (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
SEm (±)		0.29	0.90
CD at 5%		0.88	2.76

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

The microbial population of *Azotobacter*, PSB and KSB from soil before incorporation of SMS and after harvesting of radish crop was estimated and the results are presented in Table 4.6.

4.3.1 *Azotobacter* population

The result specified in Table 4.6 showed that among the different treatments, treatment T₄ i.e. SMS + Consortium of AZT + PSB + KMB was found to be the most effective as it recorded significantly highest *Azotobacter* population (67.00×10^6 per g soil)) over rest of the treatments followed by treatment T₅ i.e. FYM + Consortium of AZT + PSB + KMB (61.11×10^6 per g soil)). The lowest *Azotobacter* population (29.67×10^6 per g soil)) was recorded in treatment T₈ i.e. Absolute control.

4.3.2 PSB population

The result specified in Table 4.6 showed that among the different treatments, treatment T₄ i.e. SMS + Consortium of AZT + PSB + KMB was found to be the most effective as it recorded significantly the highest PSB population (48.89×10^6 per g soil)) over rest of the treatments followed by treatment T₅ i.e. FYM + Consortium of AZT + PSB + KMB (43.11×10^6

per g soil)). The lowest PSB population (23.00×10^6 per g soil)) was recorded in treatment T₈ *i.e.* Absolute control

4.3.3 KMB population

The result specified in Table 4.6 showed that among different treatments, treatment T₄ *i.e.* SMS + Consortium of AZT + PSB + KMB was found to be the most effective as it recorded significantly highest KMB population (44.11×10^6 per g soil)) over rest of the treatments followed by treatment T₅ *i.e.* FYM + Consortium of AZT + PSB + KMB (39.55×10^6 per g soil)). The lowest KMB population (20.00×10^6 per g soil)) was recorded in treatment T₈ *i.e.* Absolute control.

The results are comparable with Mallesha (2008) who reported that N₂ 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. Taha *et al.* (2016) accomplished that use of compost tea combined with nitrogen fertilizers significantly increased the population of bacteria, aerobic N₂ fixing bacteria and fungi in sandy soil as well as promoting growth of radish plant.

The results obtained are in agreement with Sudjan *et al.* (2017) who concluded that the use of dose inoculation 10% *Azotobacter* + 10% *Pseudomonas* on composting media of mushroom compost heap provided the highest total population of population of *Azotobacter* at 7, 14, 21 and 28 days after inoculation and significantly different in the treatment of 5% *Azotobacter* + 10 % *Pseudomonas* without enrichment.

The results are close accordance with Kedar *et al.* (2019) who reported that application of enriched spent mushroom substrate significantly increased the population of *Azotobacter* and PSB in soil after harvest of cabbage crop.

Table 4.6. Influence of enriched spent mushroom substrate on microbial population of *Azotobacter*, PSB and KMB in soil after harvesting of radish.

Tr. No	Treatment details	<i>Azotobacter</i> (cfu 10 ⁶)	PSB (cfu 10 ⁶)	KMB (cfu 10 ⁶)
T ₁	SMS + <i>Azotobacter</i> (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
SEm (±)		1.78	1.60	1.24
CD at 5%		5.45	4.90	3.81

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

4.4.1 Bacterial population

The results presented in Table 4.7 showed that among the different treatments, treatment T₄ *i.e.* SMS + Consortium of AZT + PSB + KMB was found to be the most effective as it recorded significantly the highest population of bacteria (52.44 x 10⁶ per g soil)) over rest of the treatments followed by treatment T₅ *i.e.* FYM + Consortium of AZT + PSB + KMB (47.22 x 10⁶ per g soil)). The lowest population of bacteria (20.11 x 10⁶ per g soil)) was recorded in treatment T₈ *i.e.* Absolute control

4.4.2 Fungi population

The result presented in Table 4.7 showed that among the different treatments, treatment T₄ *i.e.* SMS + Consortium of AZT + PSB + KMB was found to be the most effective as it recorded significantly the highest population of fungi (27.89 x 10⁶ per g soil)) over rest of the treatments followed by treatment T₅ *i.e.* FYM + Consortium of AZT + PSB + KMB (23.56 x 10⁶ per g soil)). The lowest population of fungi (8.33 x 10⁶ per g soil)) was recorded in treatment T₈ *i.e.* Absolute control

4.4.3 Actinomycetes population

The result presented in Table 4.7 showed that among the different treatments, treatment, T₄ *i.e.* SMS + Consortium of AZT + PSB + KMB was found to be the most effective as it recorded significantly the highest population of actinomycetes (20.78×10^3 per g soil)) over rest of the treatments followed by treatment T₅ *i.e.* FYM + Consortium of AZT + PSB + KMB (17.78×10^3 per g soil)). The lowest population of actinomycetes (5.44×10^3 per g soil)) was recorded in treatment T₈ *i.e.* Absolute control.

Borah *et al.* (2014) 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) accomplished that, using compost tea combined with nitrogen fertilizers significantly increased the population of bacteria, aerobic N₂ fixing bacteria and fungi in sandy soil as well as promoting growth of radish plant.

Table 4.7 Influence of enriched spent mushroom substrate on microbial population of bacteria, fungi and actinomycetes in soil after harvest of radish.

Tr. No	Treatment	Bacteria (<i>cfu</i> 10 ⁶)	Fungi (<i>cfu</i> 10 ⁶)	Actinomycetes (<i>cfu</i> 10 ³)
T ₁	Treatment details	40.78	19.11	14.67
T ₂	SMS + <i>Azotobacter</i> (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
SEm (±)		1.61	1.05	0.93
CD at 5%		4.98	3.22	2.85

4.5 Initial microbial count of *Azotobacter*, PSB and KMB from soil before incorporation of enriched spent mushroom substrate in soil

1. *Azotobacter* - 29.33×10^6
2. PSB - 22.67×10^6

3. KMB - 19.67×10^6

4.6 Initial microbial population from soil before incorporation of enriched spent mushroom substrate in soil.

1. Bacteria - 19.67×10^6
2. Fungi - 8.00×10^6
3. Actinomycetes - 5.33×10^3

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

Available nutrient status of soil was calculated after harvest of radish crop. It consists of available nitrogen (kg/ha), available phosphorus (kg/ha) and available potassium (kg/ha) of soil. The results are presented in Table 4.8.

4.7.1 Available nitrogen in soil (kg/ha)

The result presented in Table 4.8 showed that among the different treatments, treatment T₄ *i.e.* SMS + Consortium of AZT + PSB + KMB was found to be the most effective as it recorded significantly highest available nitrogen (210.73 kg/ha) in soil over rest of the treatments followed by treatment T₅ *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 T₈ *i.e.* Absolute control

4.7.2 Available phosphorus in soil (kg/ha)

The result presented in Table 4.8 showed that among the different treatments, treatment T₄ *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 on par with treatment T₅ *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 T₈ *i.e.* Absolute control.

4.7.3 Available potassium in soil (kg/ha)

The result specified in Table 4.8 showed that among the different treatments, treatment T₄ *i.e.* SMS + Consortium of AZT + PSB + KMB was found to be the most effective as it recorded significantly highest available potassium (195.83 kg/ha) in soil over rest of the treatments, however it was followed by treatment T₅ *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 T₈ *i.e.* Absolute control.

The result are in close agreement with the finding Jawadagi *et al*, (2012) who reported that application of organic manures and biofertilizers increased organic carbon, available N, P, K and micro nutrients thus improve soil fertility.

The results are also similar with Randhavan (2012) who stated that addition of SMC increased the nutrient uptake in radish crop.

The results are comparable with Ashrafi *et al.*, (2015) 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) 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) who also reported that application of enriched spent mushroom substrate significantly increased the available nitrogen, phosphorus and potassium (kg/ha) in soil after harvest of cabbage crop.

4.8 Initial soil available N, P and K (kg/ha) before incorporation of enriched SMS.

1. Available nitrogen - 139.98 kg/ha
2. Available phosphorus - 9.95 kg/ha
3. Available potassium - 118.67 kg/ha

Table 4.8 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 + <i>Azotobacter</i> (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
SEm (±)		3.12	1.07	1.82
CD at 5%		9.45	3.24	5.58

5. SUMMARY AND CONCLUSION

Mushroom industries generate a virtually inexhaustible supply of a co-product called spent mushroom substrate (SMS). As the mushroom industry is steadily growing, the volume of SMS generated annually is increasing. In recent years, the mushroom industry has faced challenges in storing and disposing the SMS. SMS available in huge amounts underlined by the fact that 1 kg of fresh mushrooms results in 5 kg of spent mushroom substrate (SMS). This enormous amount of SMS considered a waste stream. The obvious solution is to use that SMS as organic manure in agriculture sector.

Spent mushroom substrate from button mushroom has been found to be nutritionally rich with respect to its N, P, K contents and being having high cation exchange capacity, low bulk density, increases water holding capacity and improves soil structure by increasing organic matter. Spent mushroom substrate has ability to replace Farm Yard Manure for purpose of raising horticultural and cereal crops. The present experiment shows that spent mushroom substrate can be used as substitute for Farm Yard Manure or organic manure.

The experiment was conducted to study the influence of enriched spent mushroom substrate on growth and yield of radish. The experiment showed that SMS could be converted into enriched compost as a value added product rich in plant nutrient by enriching with biofertilizers like *Azotobacter*, PSB and KSB. Microbial consortium enhances the process of composting and enriches nutrient content to the soil. Biofertilizers combined with organic manures influences the plant growth by enhancing root biomass, total root surface facilities higher absorption of nutrient and increase in yield by reducing consumption of natural source of energy. The effect of enriched spent mushroom substrate on growth and yield parameters was assessed using radish as the test plant in field trial.

Enriched SMS with biofertilizers is capable of improving the physical, biological and chemical properties of soil when it was 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. Accordingly, the present experiment was carried out in an experimental field of Plant Pathology Section, College of Agriculture, Pune in *rabi* 2019

The observations for growth parameters like number of leaves and plant height was recorded. Similarly yield parameters like fresh weight of plant, leaves and root, root length and diameter of root harvest, yield kg/ha, yield q/ha and dry matter weight of root of radish were recorded. Also, the microbial count of bacteria, fungi, actinomycetes and *Azotobacter*, PSB and

KMB of soil before addition of enriched SMS and after harvest of radish crop were recorded. The available N, P, and K of soil after harvesting of crop also determined.

The statistically significant results were obtained by application of enriched spent mushroom substrate on growth parameters, yield and on N, P, and K content and microbial population of soil. The treatment with T₄ - SMS + Consortium of AZT + PSB + KMB recorded higher number of leaves at 30, 45 DAS and at harvest was 10.50, 17.73 and 25.73 respectively. The minimum number of leaves at 30, 45 DAS and at harvest was 6.20, 9.23 and 11.03 respectively, recorded in T₈ – Absolute control.

The plant height was also significantly influenced at 30, 45 and at harvest in the treatment of T₄ - SMS + Consortium of AZT + PSB + KMB. It had highest plant height 26.09 cm, 35.53 cm and 45.20 cm respectively, while minimum plant height was recorded in control T₈ – Absolute control where in it was 14.06 cm, 18.03 cm and 23.02 cm at 30, 45 and at harvest, respectively.

The observations for fresh weight of plant, fresh weight of leaves, fresh weight of root and dry weight of root of radish indicated that the treatment with T₄ - SMS + Consortium of AZT + PSB + KMB recorded the highest fresh weight of plant (375.41g), fresh weight of leaves (87.07 g), fresh weight of root (288.11 g) and dry weight of plant (52.36 g) while treatment control T₈ – Absolute control had lowest fresh weight of plant (123.90 g), fresh weight of leaves (23.43 g), fresh weight of root (100.47 g) and dry weight of root (18.41 g).

The root length was significantly influenced by application of T₄ - SMS + Consortium of AZT + PSB + KMB. It had highest root length of 42.35 cm at the time of harvest while minimum root length was recorded in control T₈ – Absolute control was 21.73 cm.

The root diameter was significantly influenced by the application of T₄ - SMS + Consortium of AZT + PSB + KMB. It had highest root diameter of 4.24 cm at the time of harvest while minimum root diameter was recorded in control T₈ – Absolute control was 2.02 cm at harvest.

The treatment T₄ - SMS + Consortium of AZT + PSB + KMB recorded the highest root yield (10.52 kg/plot) and root yield (32.48 t/ha) than other treatment and lowest root yield (4.82 kg/plot) and root yield (14.88 t/ha) was obtained in treatment control i.e. T₈ – Absolute control. The treatment T₄ was significantly superior over other treatments in terms of growth and yield followed by treatment T₅ – FYM + Consortium of AZT + PSB + KMB.

Among all the treatments, the highest microbial population i.e. *Azotobacter* population was (67.00 x10⁶ g⁻¹ of soil) recorded in treatment of T₄ - SMS + Consortium of AZT + PSB +

KMB, PSB population (48.89×10^6 g⁻¹ of soil) and KMB population (44.11×10^6 g⁻¹ of soil). The lowest *Azotobacter* population (29.67×10^6), PSB population (23.00×10^6) and KMB population (20.00×10^6) was recorded in treatment T₈ – Absolute control.

Among all the treatments, the highest microbial population i.e. Bacteria population was (52.44×10^6 g⁻¹ of soil) recorded in treatment of T₄ - SMS + Consortium of AZT + PSB + KMB, Fungi population (27.89×10^6 g⁻¹ of soil) and Actinomycetes population (20.78×10^6 g⁻¹ of soil). The lowest Bacteria population (20.11×10^6), Fungi population (8.33×10^6) and Actinomycetes population (5.44×10^6) was recorded in treatment T₈ – Absolute control.

The effect of treatments on chemical properties was estimated in terms of nutrient availability of soil to plants i.e. N, P and K in kg/ha at harvest soil was collected and analysis was done for N, P and K. The significantly highest nutrient availability of soil (210.73: 16.95: 195.83 kg/ha N: P: K.) to plants was observed in the treatment of T₄ - SMS + Consortium of AZT + PSB + KMB over control i.e. treatment T₈ – Absolute control (140.31: 10.25: 120.36 kg/ha N: P: K).

The treatment T₄ - SMS + Consortium of AZT + PSB + KMB was significantly superior over other treatments in terms of growth and yield of radish as well as microbial population and nutrient availability in soil followed by treatment T₅ – FYM + Consortium of AZT + PSB + KMB.

From the present findings it could be concluded that,

1. The application of SMS enriched with *Azotobacter*, PSB and KMB i.e. (treatment T₄) exhibited better influence on growth and yield parameters of radish crop.
2. It influenced the maximum no. of leaves (25.73), plant height (45.2 cm), root length (42.35 cm), root diameter (4.24 cm), fresh wt. of plant (375.41 g), leaves (87.07 g), and root (288.11 g) and dry wt. of plant (52.36 g).
3. The treatment T₄ was found to be statistically superior over all the treatments and recorded the maximum root yield (32.48 t/ha) of radish crop.
4. It could be concluded that harvesting of radish should be started in between 45-50 days of sowing to get marketable acceptance and fetching good price to radish crop.
5. The treatment T₄ also have better influence on nutrient availability of N (210.7 kg/ha), P (16.95 kg/ha) and K (195.83 kg/ha) to radish crop and it enhanced the soil fertility.
6. The treatment T₄ also enhanced microbial activities with maximum microbial population of *Azotobacter* (67.00×10^6), PSB (48.89×10^6), KMB (44.11×10^6), bacteria (52.44×10^6), fungi (27.89×10^6) and actinomycetes (20.78×10^3) in soil.
7. The increased microbial activities positively showed increase in growth and yield attributes in radish crop.

8. Thus, from present investigation, it could be concluded that application of SMS enriched with *Azotobacter*, PSB and KMB i.e. treatment T₄ was found to be the most beneficial for getting higher root yield in radish crop.

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7. APPENDIX

A) Jensens medium (1 L)	
Sucrose	20.0 g
Dipotassium phosphate	1.0 g
MgSO ₄ ·7H ₂ O	0.5 g
NaCl	0.5g
Ferrous sulphate	0.1 g
Sodium molybdate	0.005 g
Calcium carbonate	2.0g
Agar agar	15.0 g
Distilled water	1000 ml
pH	7.0
B) Pikovskaya's agar medium (1 L)	
Glucose	10.0 g
Tricalcium phosphate	5.0 g
Ammonium sulphate	0.5 g
Yeast extract	0.5 g
Magnesium sulphate	0.1 g
Potassium chloride	0.2 g
Manganese sulphate	Trace
Iron sulphate	Trace
Agar agar	20.0 g
Distilled water	1000 ml
pH	7.5
C) Alexandrov agar medium (1 L)	
Glucose	5.0 g
Calcium carbonate	0.1 g
Potassium alumina-silicate minerals	2.0 g
Calcium phosphate	2.0 g
Magnesium sulphate	0.5 g
Ferric chloride	0.005 g
Agar agar	20.0 g
Distilled water	1000 ml
pH	7.5

D) Nutrient agar medium (1 L)	
Peptone	5.0 g
Yeast Extract	2.0 g
NaCl	0.5 g
Agar agar	15.0 g
Distilled water	1000 ml
pH	7.0
E) Potato dextrose agar (PDA) medium (1 L)	
Potato	250.0 g
Dextrose	20.0 g
Agar agar	20.0 g
Distilled water	1000 ml
pH	5.6
F) Ken Knight's medium (1 L)	
Dextrose	1.0 g
KH ₂ PO ₄	0.1 g
Sodium nitrate	0.1 g
Potassium chloride	0.1 g
Magnesium sulphate	0.1 g
Agar agar	15.0 g
Distilled water	1000 ml
pH	7.4

8. VITAE

MR. BHOSALE PRITAM ANANTRAO

MASTER OF SCIENCE (AGRICULTURE)

IN

AGRICULTURAL MICROBIOLOGY

2020



Title of the Thesis		:	Influence of enriched spent mushroom substrate on growth and yield of radish (<i>Raphanus sativus</i> L.)
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