Studies on Different Aspects of Casing Material for Improvement in Yield of Button Mushroom (*Agaricus bisporus* L.)

Sumila Gul
(MSA/2018/1233)

Division of Plant Pathology

Faculty of Agriculture

Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir

2021

Studies on Different Aspects of Casing Material for Improvement in Yield of Button Mushroom (*Agaricus bisporus* L.)

Sumila Gul
(MSA/2018/1233)

Thesis

Submitted to
Faculty of Agriculture

Sher-e-Kashmir
University of Agricultural Sciences &Technology of Kashmir
in partial fulfilment of requirements for the award of the degree of

Master of Science in Agriculture
(Plant Pathology)

2021

O our lord! Do not make us responsible if we forget or make mistake

O our lord! Do not lay on us burden such as you laid on those before us

O our lord! Do not impose upon us that which we have not the strength

Pardon us
Forgive us
And have mercy upon us

You are our lord – master

So help us against unbelieving people

(Al –Baqarah: 286)

DEDICATED TO

To the most beautiful creature of Allah I have ever seen, strong and gentle soul who taught me to trust Allah, believe in hard work and that so much could be done with little

"MY BELOVED MOTHER"

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Faculty of Agriculture, Division of Plant Pathology,
Wadura, Sopore-193201

Certificate – I

This is to certify that the thesis entitled **"Studies on Different Aspects of Casing Material for Improvement in Yield of Button Mushroom (*Agaricus bisporus* L.)"** submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science in Agriculture (Plant Pathology),** to the **Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir** is a record of bonafide research work carried out by **Ms. Sumila Gul (Regd. No. MSA-2018-1233)** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that any help or information received during the course of investigation has duly been acknowledged.

(Dr. Mohammad Najeeb Mughal)
Chairman
Advisory Committee

Endorsed

Head,
Division of Plant Pathology

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Faculty of Agriculture, Division of Plant Pathology,
Wadura, Sopore-193201

Certificate – II

We, the members of the Advisory Committee of **Ms. Sumila Gul (Regd. No. MSA-2018-1233)** a candidate for the degree of **Master of Science in Agriculture (Plant Pathology)** have gone through the manuscript of the thesis entitled, **"Studies on Different Aspects of Casing Material for Improvement in Yield of Button Mushroom (*Agaricus bisporus* L.)"** and recommend that it may be submitted by the student in partial fulfilment of the requirements for the award of the degree.

Advisory Committee

Chairman
Dr. Mohammad Najeeb Mughal
Assistant Professor, Division of Plant Pathology,
SKUAST-Kashmir, Shalimar

Members
Dr. Farooq Ahmad Bhat
Assistant Professor, Division of Plant Pathology,
SKUAST-Kashmir, Wadura

Dr. Abdul Rouf Wani
Former Professor and Head,
Division of Entomology,
SKUAST-Kashmir, Wadura

Dr. Mushtaq Ahmad Bhat
Assistant Professor, Division of Agri. Economics
and Statistics, SKUAST-Kashmir, Wadura

Dean's Nominee
Dr. A.H. Hakeem
Dean,
FoA, SKUAST-Kashmir, Wadura

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Faculty of Agriculture, Division of Plant Pathology,
Wadura, Sopore-193201

Certificate – III

This is to certify that the thesis entitled, **"Studies on Different Aspects of Casing Material for Improvement in Yield of Button Mushroom (*Agaricus bisporus* L.)"** submitted by **Ms. Sumila Gul (Regd. No. MSA-2018-1233)** to the **Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir** in partial fulfilment of the requirements for the award of the degree of **Master of Science in Agriculture (Plant Pathology)** was examined and approved by the Advisory Committee and External Examiner on …….

Chairman
Advisory Committee

External Examiner

Head,
Division of Plant Pathology

Dean,
Faculty of Agriculture

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Faculty of Agriculture, Division of Plant Pathology,
Wadura, Sopore-193201

Name of the student	:	**Sumila Gul**
Registration No.	:	**MSA/2018/1233**
Major Subject	:	Plant Pathology
Minor Subject	:	Entomology/Soil Science and Soil Chemistry
Major Advisor	:	**Dr. Mohammad Najeeb Mughal,** Assistant Professor, Division of Plant Pathology, SKUAST-K, Shalimar
Title of the Thesis	:	**"Studies on Different Aspects of Casing Material for Improvement in Yield of Button Mushroom (*Agaricus bisporus* L.)"**

ABSTRACT

The studies to evaluate the effect of different casing materials, methods for sterilization of casing material and casing depths on growth and yield of button mushroom (*Agaricus bisporus* L.) were carried out at Mushroom Technology cum Training Centre, Division of Plant Pathology, FoA, Wadura during the year 2020. Among the five locally available casing materials evaluated *viz.*, vermi compost, soil + cow dung (2:1), soil + sand (2:1), soil + local peat (Demb) (2:1) and spent mushroom compost (SMC), casing material soil + local peat (Demb) took minimum number of days for case run (15.00 days) and pinhead initiation (20.50) and produced highest number of total fruiting bodies (105.00 per tray) and resulted in highest button mushroom yield (1500.00 g per tray). Spent mushroom compost was least efficient casing material which took maximum number of days for case run (19.25 days) and pinhead initiation (27.25 days) and recorded the lowest total number of fruit bodies (57.00 per tray) and lowest yield (604.25 g per tray). Among the different sterilization methods *viz.*, autoclaving, formalin (2%) treatment, heat treatment (local method) and solarization evaluated for sterilization of casing material (soil + sand), sterilization by autoclaving was most effective and resulted in quick case run (16.00 days) and pinhead initiation (22.00

days) and highest total number of fruit bodies (100.00 per tray) and highest yield (1284.00 g per tray) whereas sterilization by solarization was least effective and resulted in slowest case run (21.00 days) and pinhead initiation (27.25 days) and lowest total number of fruit bodies (42 per tray) and yield (430.00 g per tray). Among different casing depths evaluated *viz.*, 1.5 cm, 3 cm, 4 cm, 5 cm and 6 cm, casing depth of 1.5 cm resulted in minimum number of days for case run (12.00 days) while maximum days for case run were recorded with 6 cm casing depth (22.00 days). However, pinhead initiation was fastest in 5 cm casing depth (22.00 days) which was however statistically at par with 4 cm depth (22.00 days) whereas 6 cm casing depth took maximum number of days for pinhead initiation (30.25). Casing depth of 5 cm resulted in highest total number of fruit bodies (91.00 per tray) and maximum yield (1010.25 g per tray). It was, however, statistically at par with 4 cm casing depth where number of fruit bodies and yield were 90.00 per tray and 999.75 g per tray, respectively. The casing depth of 1.5 cm was least favourable and resulted in lowest total number of fruit bodies (46.00 per tray) and lowest button mushroom yield of 441.25 g per tray.

Keywords: *Agaricus bisporus*, Casing depths, Casing materials, Sterilization methods, Yield.

Signature of Student
Dated: _____

Signature of Major Advisor
Dated: _____

ACKNOWLEDGEMENT

*Praise be to **Almighty Allah (SAW)** the merciful for His uncountable blessings, and peace be upon His messenger **Muhammad (SAW)**, his descendants, his family and his noble companions.*

*I take this opportunity to express my sincere and profound gratitude to my major Advisor **Dr. Mohammad Najeeb Mughal**, Assistant Professor, SKUAST-K, Shalimar throughout the different phases of the present studies. I was privileged to be directed, guided and inspired by the indispensable inputs from my esteemed guide. Thank you for your time, your generosity, and patience.*

*I extend my sincere thanks to my co-advisor **Dr. Farooq Ahmad Bhat**, Assistant Professor, SKUAST-K, Wadura for his valuable guidance and suggestions during the course of study besides helping in meticulously finalization of the manuscript.*

*It is a great opportunity to express my sincere thanks to **Dr. Shaheen Kausar**, Professor and Head Division of Plant Pathology, whose unceasing, whole hearted support and time to time valuable suggestions enabled me to take this research to its logical end.*

*With highest degree of veneration, I express my profound gratitude to **Dr. A. H. Hakeem**, Dean, FoA Wadura (Dean P. G's Nominee), **Dr. Abdul Rouf Wani**, Former Professor & Head, Division of Entomology and **Dr. Mushtaq Ahmad Bhat**, Assistant Professor, Division of Agri-Economics and Statistics, SKUAST-Kashmir, Wadura, the worthy members of my Advisory Committee, for their cooperation, guidance, whole hearted support, timely help and useful suggestions.*

I am highly grateful to all members of teaching/research staff of Division of Plant Pathology particularly, Dr. T. A. Wani, Dr. T. R. Rather, Dr. K. A. Bhat, Dr. B. Summouna and Dr. Asha Nabi for their unflinching support, during the course of this study.

I also avail this opportunity to pay my heartfelt thanks to non-teaching staff of Division of Plant Pathology for their unparalleled help and cooperation during this research work.

Sincere thanks are due to my seniors of Division of Plant Pathology especially Rouf Ahmad Rather, Avinash Pila, Shugufta Parveen, Shifa

Showket, Raheeba-tun-Nisa, Irfan Khan and Fazil Fayaz for their timely help and constant encouragement.

I owe my thanks to my friends and colleagues especially Humira Gulzar, Nazmina, Sabiya, Saika, Razia, Humaira Rasool, Gousia, Tabasum, Insha Mehreena, Rukaya, Zohra, Zarka, Mariya, Asima, Seema, Rifat, Anisa, Seerat, Zakir, Tabish, Shafat and Mashouq for their kindness, generosity, moral support and inspirational encouragement throughout, which brought a ray of humanity to my mental life during the course of study.

I unfeignedly owe my parents a tremendous filial respect and gratitude for their unending love and affection. The moral support and confidence-build up provided by my mother, ***Ms Kulsuma Jan*** *in my meek times has been pivotal during my studies. Whenever anything fascinated my eyes I never received a "No" from her. She always wanted me to excel in my academic and research endeavours and never let me fall victim to the misgivings and premonitions. She is the orchestrator of the chapters of the book of my life. I can hardly imagine a moment of my life when her love did not play along. The paradise of my dreams is assuredly beneath her feet.*

My heartfelt thanks to my brother ***Muzamil Ahmad Bhat****, my uncle, my grandparents and my cousins. Thank you for your love, blessings and sacrifices and for encouraging me to achieve my goal. Thank you for your patience and help. You were the motivating force behind me at all junctures. May Almighty Allah bestow and bless you with his blessings.*

At last I express my gratitude to all those who care for me, are in my heart and mind and may not have got a mention, but none shall ever be forgotten.

Sumila Gul

Place: Wadura, Sopore
Dated:

CONTENTS

Chapter	Particulars	Page No.
1.	INTRODUCTION	1-3
2.	REVIEW OF LITERATURE	4-14
	2.1 Casing material	4
	2.2 Casing sterilization	11
	2.3 Casing depth	13
3.	MATERIALS AND METHODS	15-20
	3.1 Evaluation of different casing materials	15
	3.2 Evaluation of sterilization methods	17
	3.3 Evaluation of casing depths	18
	3.4 Cropping room environment	19
	3.5 Harvesting	19
	3.6 Monitoring	19
	3.7 Observations recorded	19
	3.8 Statistical Analysis	20
4.	EXPERIMENTAL FINDINGS	21-29
	4.1 Effect of different casing materials on yield	21
	4.2 Effect of different sterilization methods of casing material on yield of button mushroom	24
	4.3 Effect of different depths of casing material on yield of button mushroom	27
5.	DISCUSSION	30-34
6.	SUMMARY AND CONCLUSION	35-37
	LITERATURE CITED	i-xiii

LIST OF TABLES

Table No.	Particulars	Page No.
1.	Effect of casing material type on growth and yield of button mushroom	23
2.	Effect of different sterilization methods of casing material on growth and yield of button mushroom	26
3	Effect of casing material depths on growth and yield of button mushroom	29

LIST OF PLATES

Plate No.	Particulars	After page No.
1.	Sporocarps of *Agaricus bisporus* on different casing materials	23
2	Sporocarps of *Agaricus bisporus* on casing mixture (soil +sand) sterilized by different methods	26
3	Sporocarps of *Agaricus bisporus* at different casing depths	29

Chapter–1

INTRODUCTION

Mushroom is a macro fungus with a distinct fruiting body which can be either epigeous or hypogeous and large enough to be seen with a naked eye and to be picked by hand (Chang and Miles, 1989). Mushrooms comprise of a large heterogenous group with different shapes, sizes, colour and edibility. There are about 2000 edible species of mushroom, out of which 300 species belonging to 70 genera are reported from India. Out of prime edible mushrooms, about 80 have been grown experimentally, 20 cultivated commercially and 4 to 5 species produced on industrial scale throughout the world (Chang and Miles, 1991).

Button mushroom (*Agaricus bisporus* L.) is the most well known edible mushroom and has high commercial value (Jiskani *et al.,* 1999). It has been placed in the Division Basidiomycota, class Agaricomycetes and family Agaricaceae. The genus '*Agaricus*' signifies gilled mushroom, has got good satisfying taste and fragrance and species '*bisporus*' refers to two basidiospores on every basidia. Button mushroom, when mature is known as Portobello mushroom and when immature and white, as regular mushroom, table mushroom or button mushroom or white button mushroom but when immature and brown, it is known as Swiss brown mushroom, Roman brown mushroom or chestnut mushroom (Anonymous, 2013).

Button mushroom contains moisture 90 to 93 per cent, crude protein 28.0 to 42.5 per cent, carbohydrates 59.4 per cent, fat 3.1 per cent, crude fiber 8.3 to 16.2 per cent and ash 9.4 to 14.5 per cent (Mehta *et al.,* 2011). Among the minerals, it contains calcium (71 mg), phosphorous (912 mg), sodium (106 mg), iron (8.8 mg) and potassium (2850 mg) per 100 gram dry weight. Among the vitamins, 8.9 mg thiamine (B_1), 3.7 mg riboflavin (B_2), 26.5 mg ascorbic acid (C) and 42.5 mg niacin (B_3) per 100 gram dry weight basis. Among the different amino acids, it contains leucine (7.5%), isoleucine (4.5%), valine (2.5%),

tryptophan (2.0%), lysine (9.1%), threonine (5.5%), phenyl alanine (4%), methionine (0.9%) and histidine (2.7%) (Bano and Rajarathnam,1982).

Button mushroom is the most widely cultivated and consumed mushroom throughout the world and contributes about 40 per cent of total world mushroom production (Kaur *et al.*, 2017). It is the most widely cultivated mushroom in USA, Europe and Australia. World's largest button mushroom growing unit is located in India (Punjab). The world button mushroom production is 4.43 billion kg (Royse *et al.*, 2017). The production of button mushroom in India is 946 thousand metric tonnes (ICAR-DMR, 2016) while its production is 565 metric tonnes in J&K (ICAR-DMR, 2016).

Because of increased population and shrinkage of arable land, diversification in agriculture has become inevitable. Mushroom farming has also emerged as a potential field of diversified approach having distinct advantages over others (Khajuria, 2005). It is labour intensive and as such ideally suited to the economy of developing countries like India where raw materials and labour is cheap and easily available. Mushroom cultivation generates sufficient employment for unemployed youth and provides support to women folk and other weaker sections of the society (Munshi *et al*., 2010). India is largely an agriculture based country with 70 per cent of its population dependent on agriculture and live in villages (Kesavan and Swaminathan, 2008). The large proportion of the population is mainly vegetarian in its food habits. Deficient intake of good quality protein is the main dietary defect in India. It is desirable that one-third of the total protein intake should be of good quality protein. FAO has highly recommended mushrooms especially button mushroom, to supplement protein nutrition of the developing countries.

The temperate climatic conditions, availability of cheap raw material and labour are favourable for mushroom cultivation almost throughout the year in Kashmir valley. Button mushroom has a requirement for 'casing layer' that has specific physical, chemical and microbiological properties which stimulate and

promote the initiation of fruiting body (Taherzadeh *et al*., 2013). Casing layer provides an environment change in which the mushroom shift from a vegetative stage to a reproductive one. The casing layer is applied 14-16 days after spawning. Casing material has significant impact on yield of button mushroom, provides support for development and growth of mushrooms (Colauto *et al*., 2011). Although different materials may function as a casing layer, peat is generally used. Because of its unique water holding capacity and structural properties, it is widely accepted as best for casing. Peat has a neutral pH and because of its organic content and granular structure, holds moisture, allows gaseous exchanges and helps microbial population to release hormone-like substances which are likely involved in stimulating the formation of fruit bodies (Eger, 1972). Spent mushroom compost as a casing soil material can also be used to reduce the cost of production and it can also reduce pollution (Pardo *et al*., 2011). Thickness of casing layer is an important factor affecting the yield of button mushroom (Vijay and Gupta, 1988). Casing thickness usually ranges from 3.8 to 5.0 cm. Any material used for casing purpose is first sterilized so that the competitors and parasitic moulds of mushroom present in the material get killed which otherwise would result in low production of mushroom.

Keeping in view the importance of casing material, sterilization of casing material, casing thickness and their influence on button mushroom yield, the present investigation was planned with the following objectives:

1. To evaluate the effect of different casing materials on yield of button mushroom.
2. To evaluate the effect of different sterilization methods of casing material on yield of button mushroom.
3. To evaluate the effect of different depths of casing material on yield of button mushroom.

Chapter–2

REVIEW OF LITERATURE

Button mushroom (*Agaricus bisporus*) commonly known with different names *viz.*, common mushroom, table mushroom, button mushroom or white button mushroom is one of the most important edible mushroom. The relevant literature related to the present studies has been discussed under the following headings:

2.1 Casing material

The combination of farm yard manure (FYM) + loam soil (1:1 v/v) and farm yard manure + spent mushroom compost (3 years old) is commonly used as casing material in India for the cultivation of button mushrooms (Chang and Hayes, 1978; Vedder, 1978 and Shandilya and Agarwala, 1983). Different casing materials have been evaluated by Scientists world over.

Shandilya and Hayes (1977) recommended the use of farm yard manure (one and half year old cow dung and FYM) and loam soil (1:1, v/v) for casing mushroom beds which helped to improve the yield of button mushroom. Grapeli *et al*. (1987) reported early primordial appearance and more number of fruiting bodies when 40 per cent earthworm casting + 80 per cent inert material were used for casing. Tripathi *et al*. (1991) evaluated six different casing materials *viz.*, FYM, spent compost + 8 per cent calcium carbonate, FYM + rocky soil, garden soil, FYM + garden soil, FYM+ rocky clay soil. Highest yield of 853.00 and 968.33 g/polyethylene bag (50 x 30 cm) was recorded casing materials of spent compost + 8 per cent calcium carbonate and FYM, respectively.

Saini and Prashar (1992) evaluated seven casing materials *viz.*, FYM + waste compost + soil, FYM + soil, waste compost + soil, FYM + lime, Soil + lime, FYM + CCP, FYM and reported that FYM + waste compost + soil at a ratio of 2:1:1 provided the greatest yield of mushrooms (6.45 kg/100 x 50 x 15 cm tray) while lowest yield (1.92 kg/ tray) was obtained with FYM + lime (3:1). Mamta

(1997) evaluated five different casing materials *viz.*, FYM (2 years old), spent mushroom compost (3 years old), loam soil, forest soil and clay soil for their suitability as casing material. She reported that FYM was best casing material as it recorded minimum time for primordial formation (22-24 days) and maximum yield (13.45 kg/q compost).

In the study on evaluation of locally available agro/industrial wastes for their reuse as casing material, it has been observed that casing with coir pith alone gave a yield of 10.25 kg per 100 kg compost and was at par with two year old spent compost (Anonymous, 2004). Suman and Paliyal (2004) studied the effects of garden soil, farmyard manure (FYM; 2 years old), coconut coir pith (CCP), FYM + CCP (4:1, v/v), spent compost (2 years old) + FYM (1:1, v/v), spent compost + CCP (4:1, v/v) and FYM + garden soil (1:1, v/v; control) as casing materials for their performance as casing material of button mushroom. FYM + CCP had greater water holding capacity (180%), porosity (70%) and N (0.168%), P (0.020%), K (1.05%), Fe (0.028%), Mn (0.100%) and Zn (0.064%) contents and lower particle density (0.70 g/cm^3), bulk density (0.28 g/cm^3) and took minimum time for primordial formation *i.e* 12 and 15 days for the short and long methods of composting, respectively than other materials. The highest average yields (23.8 kg and 17.6 kg for the short and long methods of composting) were also obtained with FYM+CCP.

Dhar *et al*. (2006) conducted an experiment to evaluate the effect of commonly available eight casing materials *viz.*, SMC, CCP, FYM, Terracare-A, Terracare-B, Vermi compost and FYM + SMC to find out the most suitable casing material to be used in *Agaricus bisporus* cultivation and observed that coir pith was most suitable which resulted in fastest pinhead initiation (25 days) and maximum number of sporophores (12.33) and total yield (1112.3 grams per bag).

Peker *et al*. (2007) conducted an experiment to determine the effect of casing materials *viz.* peat of Caykara (PC) + forest soil (FS) (50+50; v/v) and peat of Bolu (PB) + peat of Agacbasi (PA) (50+50; v/v) on time taken for pin head

formation and button mushroom yield. Results showed that peat of Caykara (PC) and forest soil (FS) mixture (50+50; in volume) took minimum number of days for pin head initiation (12.50 days) than PB+ PA mixture (13.25 days). In terms of yield, a mixture of peat of Bolu and peat of Agacbasi gave the highest yield (1176.50 g per bag). Yigitbasi *et al*. (2007) conducted an experiment to determine the effect of casing materials *viz.*, Peat of Agacbasi, Peat of Bolu, Peat of Caykara, Perlite + Peat of Bolu, Perlite + Peat of Agacbasi, Perlite + Peat of Caykara on yield of button mushroom and reported that Peat of Caykara + perlite showed highest yield of 1676 grams/bag followed by Peat of Caykara (1537 grams/bag) while lowest yields were obtained from casing mixture of Peat of Bolu + Perlite (1277 grams/bag).

Pardo *et al.* (2008) completed a trial to assess the impact of various extents of combinations of coconut fiber (CF) essence and spent mushroom substrate (SMS). After compound and organic characterisation of the packaging substrates, qualitative and quantitative production parameters were assessed in button mushroom. An increase in the quantity of SMS diminished the quantity of sporophores and in general yield. Though first flush was postponed, mushroom size expanded and the mushrooms had a higher dry matter substance and a superior texture. Mixes of coconut fiber essence and SMS of 4:1 and 3:2 (v/v) gave biological efficiencies of 92.9 and 82.6 kg per 100 kg fertilizer, individually.

Estrada *et al*. (2009) observed an increase in yield by 141 per cent when casing was applied on the substrates as compared to non-cased substrates. They further observed that when casing and supplemented substrates were combined, the yield increased 179 per cent over non-cased/ non-supplemented substrates.

Chaudhary *et al*. (2009) conducted an experiment to determine the effect of casing materials *viz.*, FYM + spent mushroom substrate, FYM and FYM + vermi compost on yield of button mushroom. FYM + spent mushroom substrate was found to be the best casing material resulting in high yield and took minimum time for case run and produced superior fruit bodies. Ram and Holkar (2009)

reported maximum fruit body weight of button mushroom using casing mixture of coconut coir pith + vermi compost + FYM + sawdust + sand whereas maximum length of stalk was recorded in coconut coir pith + FYM + saw dust and highest yield in coconut coir pith + vermi compost + sand.

In order to use the agricultural by products (different wastes) to reduce peat consumption in casing soil for button mushroom production, an experiment was conducted by Dondge (2012) with treatments of casing soil and three replicates in a Completely Randomized Design. Results indicated that treatment of spent mushroom compost + north peat (4:6) produced highest yield (2093 g/bag) while lowest yield was obtained in loam soil + sand (4:3). Singh *et al.* (2013) conducted an experiment at SHIATS, Allahabad to determine the effect of certain casing materials on days required for pin head formation in button mushrooms. They evaluated a total of seven treatments *viz.* waste tea leaves (T_1), poultry manure ($T_{2)}$, vermi-compost (T_3), pigeon pea manure (T_4), cow dung (T_5), bavistin (T_6) and control (soil, T_0) and reported that minimum number of days required for pinhead initiation was recorded in treatment T_1, followed by T_3 and $T_{6.}$

Ayyub *et al*. (2014) conducted an experiment to investigate the agronomic performance of casing materials *viz.*, Swat peat, Abbottabad peat, spent mushrom compost, common soil and 45cm deep soil on different yield parameters in button mushroom and observed that Abbotabad peat and 45cm deep soil were at par in time taken for appearance of fruiting bodies with 3.5 and 3.6 days followed by Swat peat and common soil with 4.0 and 4.6 days, respectively. Spent mushroom compost was reported to take maximum days (5.25 days) for appearance of fruiting bodies. They further reported that highest yield was recorded with casing of Abbottabad peat (87.5 g/tray) whereas lowest yield was recorded with casing treatment of 45cm deep soil (43.75 g/tray).

Liaqat *et al.* (2014) evaluated five different materials *viz.*, spent mushroom compost, sand, canal basin soil, well decomposed FYM and local peat soil (peat)

for their suitability as casing material and recorded their effect on time to primordial formation, response time of primordial to reach at biological maturity, number of pinheads, number of fruit bodies, yield in each strain and biological efficiency. They reported that local peat soil proved best casing material in all parameters.

Chandra *et al*. (2014) evaluated seven casing mixture formulations and reported maximum number of sporophores (12.33/bag) and mention this at all places) in casing mixture of Coconut Coir Pith (CCP) + Vermi compost + Farm Yard Manure (FYM) + Saw dust (SD) + sand and minimum (5.67/bag) were obtained on casing mixture of Coconut Coir Pith (CCP) + Farm Yard Manure (FYM). Casing mixture Coconut Coir Pith (CCP) + Vermi compost + Farm Yard Manure (FYM) + Saw dust (SD) + Sand recorded the highest yield (320 g/bag) whereas CCP + FYM (250 g/bag) recorded lowest yield during harvesting of second flush. Maximum total yield (1112.26 g/bag) was observed in casing mixture, Coconut Coir Pith (CCP) + Farm Yard Manure (FYM). Casing mixture Coconut Coir Pith (CCP) + Vermi compost + Farm Yard Manure (FYM) + Saw dust (SD) + Sand and lowest yield (736.67 g/bag) from Coconut Coir Pith (CCP) + Farm Yard Manure (FYM). Casing mixture of Coconut Coir Pith (CCP) + Farm Yard Manure (FYM) + Saw dust (SD) recorded second highest yield (1033.67 g/bag).

Rehman *et al.* (2016) conducted an experiment to study the impact of various casing materials on the growth and yield of button mushroom. Results showed that Lahore compost (T_3) and FYM + sand +lime (T_2) were significantly different from the T_1 (Clay + Sand + lime) and T_0 (peat soil / control). Time taken for complete mycelial growth in T_3, T_2 and T_1 were 11.50, 10.75 and 9.50 days respectively. The maximum time taken for completion of mycelial growth was recorded in T_3 (19.25 days) and the minimum in control (10 days). Time taken to reach harvesting stage recorded in T_3, T_2 and T_1 were 14.75, 9.50 and 8.75 days respectively, furthermore T_1 and T_2 were similar to each other but dissimilar to

control and T_3. T_2 produced a maximum number of pinheads (15.50/bag), mature fruiting bodies (14.25/bag) and biomass (369.00 g/bag), followed by T_1 while control and T_3 were at par with regard to the number of mature fruiting bodies.

Barman *et al.* (2017) conducted an experiment to determine the effect of casing materials *viz.*, vermi compost (VS), garden soil (GS), tea waste (TW), Spent mushroom compost (SMC) and their combinations such as GS+ VS, TW+ VS and SMC+ VS on growth and development of *Agaricus bisporus* cultivated on paddy straw and dried tea leaf based composts. Growth parameters such as colonization days, time for pining, number of sporophores per bag, fruit body weight and yield rate were measured. The best result regarding fruit bodies number was reported to be in paddy straw based compost encased with vermi compost while lowest fruiting bodies were recorded in tea leaf based compost encased with SMC. They further reported that mixture of VS + SMC as casing matter gave better results as compared to SMC alone.

Kaur and Rampal (2017) carried out an experiment to examine the impact of various casing materials on the development and yield of *Agaricus bisporus*. Maximum total yield (1066.97 g/bag) was recorded from mixture of coconut coir pith + rice husk + formalin + red soil and lowest yield (607.93 g/bag) was obtained from FYM + sandy soil + Formalin. Kumar *et al*. (2017) assessed three casing materials *viz.,* garden loamy soil (GLS) + FYM (2:1), garden loamy soil (GLS) + FYM + waste tea leaves (2:1:1) and garden loamy soil (GLS) + FYM + slake lime (2:1:1) for assessing the impact of these materials on number of days needed for complete spawn run, fresh weight, number of sporophores per bag, B.E and BC ratio of *Agaricus bisporus*. They reported that mixture of GLS + FYM + waste tea leaves was best in all the boundaries with least number of days required for spawn run (17.62 days), maximum fresh weight of fruiting bodies (0.94 kg per bag), number of sporophores per bag (83.25), B.E (18.21) and BC ratio (1:2.08).

Yadav *et al.* (2017) carried out an investigation to study the impact of seven different casing materials *viz.*, soil+ cotton wastes (2:1), soil+ cotton wastes

+ jute coir pith (1:1:1), jute coir pith + soil (1:1), jute coir pith+ soil + sand (1:1:1), vermi compost+ sand + cotton wastes + soil (1:1:1:1), vermi compost+ saw dust+ cotton wastes + soil (1:1:1:1) and vermi compost+ cotton wastes + soil (1:1:1) on production and harvest quality of two strains of *Agaricus bisporus* (S-1 and S-2) and reported that jute coir pith + soil (1:1) gave better yields and influenced growth behaviour in both the strains while lowest yields and poor quality were obtained from vermi compost + cotton wastes + soil (1:1:1) and vermi compost+ saw dust+ cotton wastes + soil (1:1:1:1). Rasoul *et al.* (2018) evaluated eight casing materials *viz.*, peat soil, peat soil + vermi compost (2:1), peat soil + coco peat (2:1), peat soil + activated carbon (2:1), peat soil + spent mushroom compost (2:1), peat soil + vermi compost + activated carbon (2:1:0.5), peat soil + coco peat + activated carbon (2:1:0.5), peat soil + spent mushroom compost + activated carbon (2:1:0.5) to study their effect on growth and yield of button mushroom. They reported Results that peat soil + coco peat + activated carbon (2:1:0.5) resulted in the highest fruiting bodies number as well as yield of button mushrooms. They further reported that lowest duration between casing and first flush was with peat soil + coco peat (2:1) as casing material while longest duration was recorded with peat soil + spent mushroom compost (2:1) as casing material.

Kerketta *et al.* (2019) evaluated the effect of six different casing materials *viz.*, coco peat, vermi compost + coco peat (1:1), vermi compost + soil (1:1), coco peat + soil (1:1) vermi compost + coco peat + soil (1:1:1) and soil + FYM + sand (1:1:1) on growth and yield of button mushrooms and reported that the pinning was fastest in coco peat + soil and slowest in soil + FYM + sand. They further reported that yield attributing characters like stipe length, stipe diameter and cap diameter did not varied significantly with respect to casing materials.

Kumar *et al.* (2020) evaluated ten different casing materials *viz.*, FYM + Soil (2:1), FYM + Soil (1:1), FYM + Sand (2:1), FYM + Sand (1:1), FYM +Soil+ Ash (2:1:1), FYM + Sand +Ash (2:1:1), FYM + Soil + Sand (2:1:1), FYM + Ash

(3:1), FYM +Sand+ Ash (3:1:1/2) and Control (FYM only). They reported maximum fresh weight (1192.41 g/bag) of fruiting bodies was recorded in FYM + soil + sand (2:1:1), while it was 763.89 g/bag in case of control which increased by 56.6 per cent over control. They further reported that highest dry weight (173.42 g/bag) was recorded in FYM + soil + sand (2:1:1), followed by FYM + soil + ash (2:1:1) (154.3 g/bag) and FYM + sand + ash (3:1:1/2) (147.2 g/bag) while lowest dry weight (82.8 g/bag) was recorded in control (FYM).

2.2 Casing sterilization

Different sterilization methods for casing materials have been evaluated by scientists world-over. However, influence of different sterilization methods on yield has more widely been evaluated in other mushrooms like *Pleurotus* spp. where substrates directly bear the fruiting bodies and therefore some such references are also included here.

Singh *et al.* (1984) studied the effect of different sterilization methods *viz.*, chemical sterilization (formalin), dry heat and steam sterilization of casing material (soil) on yield of button mushroom. Steam sterilized of casing soil was reported to produce higher number of fruiting bodies as well as higher yield than the other two treatments.

Khan *et al.* (2011) evaluated three methods of sterilization *viz.*, lab autoclave, country style autoclave (2 hr), country style autoclave (1hr), hot water treatment (1/2 hr) and ordinary water (1/2 hr) for improvement in yield of *Pleurotus* species. Among these methods, highest yield was reported by sterilization of casing material with lab autoclave. It was further reported that substrate sterilized by lab autoclave recorded the highest yield in the first flush (1180.30 g/bag), followed by second flush (845.38 g/bag), third (540.53 g/bag) and fourth flush (279.39 g/bag).

Tiwari (2013) sterilized casing material (garden soil + FYM + sand, 2:1:1) by following methods *viz.*, formalin treatment (T_1), Bavistin treatment @ 0.1%

(T_2), 2% formalin + 0.1% bavistin (T_3) autoclaving [(Streaming under 15 *lbs* pressure for 15 minutes (T_4)] and Control (only water spray (T_5). It was reported that days required for fruiting were maximum (34.40 days) in T_1 followed by T_2 (33.50 days), T_4 (32.50 days), control (32.50 days) and T_3 (31.50 days). They further reported that average fruiting body weight (g) was maximum 10.95 gram in T_3 and minimum in control (8.65gram). The highest yield (18.20kg/100kg compost) was reported in treatment T_3 followed by T_1 while lowest yield was reported in control (10.60 kg/100kg compost).

An experiment was conducted by Akhter *et al.* (2017) who evaluated the impact of hot water treatment of rice straw on yield, yield attributes and contamination of *Pleurotus ostreatus*. The rice straw was subjected to hot-water treatment at 600°C, 800°C and 1000°C temperature. Each temperature was maintained for 1 hour, 2 hours and 3 hours, which were compared with untreated Control (without hot water treatment). It was reported that different dominant contaminants such as *Trichoderma harzianum*, *Coprinus* sp., *Aspergillus niger* and *penicillium* sp. were higher in non-treated spawn packets and 600°C treated packets. Better performance, such as biological efficiency was 57.44 per cent, the economic yield (280 g/bag), the highest average diameter of pileus (5.0 cm) and the highest average length of stipe (3.70 cm) was reported from the treatment 800°C for 3 hours.

Ahmad *et al.* (2020) carried out an experiment to investigate the impact of substrate sterilization technique and spawning method on yield and yield attributes of *Calocybe indica*. Seven different treatments *viz.*, Steam treatment of substrate and spawning in three layers (T_1), steam treatment of substrate and spawning thoroughly (T_2), autoclaving of substrate and top spawning (T_3), autoclaving of substrate and spawning in three layers (T_4), autoclaving of substrate and spawning thoroughly (T_5), hot water treatment of substrate and spawning in three layers (T_6) and Hot water treatment of substrate and spawning thoroughly (T_7) were evaluated. They reported that mycelium colonization,

substrate contamination, days to total harvest, yield and biological efficiency was significantly affected by substrate sterilization technique and spawning method. The faster mycelium colonization, no substrate contamination, highest yield and biological efficiency was recorded in substrate treated with hot water and inoculated in three layers (T_6).

2.3 Casing depth

Chakravarty (1976) evaluated three different casing depths *viz.*, 2.5 cm, 3.8 cm and 5.1 cm and obtained highest yield of 13.00 kg/100 kg compost from 5.1 cm depth followed by 3.8 cm (12.99 kg/100 kg compost). Lower yield of 11.01 kg/100 kg compost was obtained in 2.5 cm thickness which was significantly inferior to other two treatments**.**

Singh *et al.* (1984) conducted an experiment to observe the impact of casing material (soil) thickness *viz.*, 2.0, 2.5, 3.0, 3.5 and 4.0 cm on yield of button mushroom. Soil was steam sterilized before casing and highest yield and number of buttons were reported in 3.0 cm casing depth while lowest was reported in 4.0 cm casing depth.

Tripathi (1999) evaluated four casing depths *viz.*, 3 cm, 4 cm, 5 cm and 6 cm. Among these, 5cm recorded the highest yield (17.5 kg) per 100 kg of compost which was found statistically at par with 4 cm (15.4 kg/100 kg compost) and 3 cm (16.6 kg/100kg of compost) whereas 6 cm was reported to result in lowest yield of 12.6 kg per 100 kg of compost.

Pandey *et al*. (2007) conducted an experiment in Kanpur, India to determine the effective and optimum casing depths for maximum growth and production of button mushrooms. They evaluated different casing depths *viz*., 3, 4, 5 and 6 cm and reported highest yield (18.00 kg) with application of 4cm casing layer whereas 6cm casing gave the lowest yield (11.66 kg).

Amin *et al*. (2010) carried out an investigation to determine an appropriate thickness of casing materials for the cultivation of *Calocybe indica*.

They evaluated five different casing depths of casing material (cow dung and loamy soil) *viz.*, 1 cm, 2 cm, 3 cm, 4 cm and 5 cm and reported that 5 cm casing depth recorded highest number of fruiting bodies (7.75) and yield (431 g/packet) followed by 4 cm, 3 cm and 2 cm whereas 1 cm depth recorded lowest number of fruiting bodies (1.5) and yield (121.5 g/packet).

Tiwari (2013) conducted an experiment at JNKVV, Jabalpur on evaluation of effect of different casing depths on yield of button mushroom. He evaluated different casing depths *viz.,* 3, 4 and 5 cm and reported maximum number of fruiting bodies (74.30) at 5 cm casing depth whereas least number (49.00) was found at 3 cm casing depth. He further reported that maximum yield (917.6g/5kg compost) at 5 cm casing depth and lowest yield (430.33g/5kg compost) at 3 cm casing depth.

A trial was done by Nirupa and Kudada (2017) conducted an experiment to contemplate the impact of thickness of casing soil layer on various parameters *viz.,* commencement of fruiting bodies, number of pinhead and their turn of events, size and weight of sporophore, yield of fruiting bodies and B.E of *Calocybe indica*. Among various thickness of casing soil *viz.,* 1.0 cm, 1.5 cm, 2.0 cm, 2.5 cm, 3.0 cm, 3.5 cm, 4.0 cm and 4.5 cm assessed, casing soil having 2.0 cm thickness was accounted for to bring about most extreme number of pinhead, greatest size and weight of sporophores, BC ratio and B.E. Thickness of casing layer past 2.0 cm was accounted for to progressively diminish the mushroom yield and cause delay in the presence of sporophores.

Chapter–3

MATERIAL AND METHODS

The proposed research work entitled **"Studies on Different Aspects of Casing Material for Improvement in Yield of Button Mushroom (*Agaricus bisporus* L.)"** was conducted at Mushroom Technology-cum-Training unit, Division of Plant Pathology, Faculty of Agriculture, SKUAST-K, Wadura during the year 2020. The materials used and the methods adopted for achieving the specified objectives are discussed hereunder:

3.1 Evaluation of different casing materials

For evaluation of different casing materials, first and foremost important requirement was the preparation of compost and spawning.

3.1.1 Compost preparation

The compost used during the course of experimentation was prepared by 'Long Term Method' of composting as per the formula adopted by SKUAST-Kashmir (SK-3A). The composition of compost is given below:

Compost ingredients	Quantity
Wheat straw	300 kg
Poultry manure	200 kg
Wheat bran	50 kg
Molasses	12 kg
Linseed meal	7 kg
Urea	5 kg
Potash	2 kg
Gypsum	10 kg

(Munshi *et al*., 2010)

Wheat straw chopped into pieces of size 20 to 30 cm was spread in the form of loose heap on the cemented floor and wetted thoroughly for 48 hours. Wheat bran, linseed meal, urea and potash ingredients in the specified quantities were mixed in a heap and another heap of poultry manure was also piled near the composting site. Fifty litres of water was added to molasses in an iron tub and

stirred to get a uniform solution. All the ingredients except gypsum from the heaps were applied to wet straw layer by layer while raising the pile (1.5 × 1.0 × 2.0 m). Molasses solution from the tub was uniformly applied to layers while raising the pile for composting. Spray of water was done on daily basis so that pile does not dry up and contain sufficient moisture for microbial activity for decomposition. Periodic turnings were given as per the below given schedule:

Day	Activity/Turn
0 day	Raising of pile for composting
7th day	1st turning
14th day	2nd turning
21st day	3rd turning
28th day	4th turning
32nd day	5th turning
35th day	Final turning

(Munshi *et al*., 2010)

On 28th day, at 4th turning gypsum (10-15 kg) was added to maintain pH and remove the greasiness. The turning was given in such a manner that every portion of compost was uniformly decomposed. On 32th day, pile was opened and loosely arranged into a heap so that ammonical smell is lost and on 35th day pile was checked for its colour, pH and absence of ammonical smell and then spawned in trays.

3.1.2 Spawning

The plastic trays (50×30×15 cm) were filled with compost at the rate of 8 kg and spawned at the rate of 2 per cent (2 kg per 100 kg compost) in layers. After spawning, the top surface of each tray was covered with newspaper. The spawned trays were then kept in mushroom production room maintained at 25±2°C temperature and 85-90 per cent relative humidity. Water was sprayed on the surface of newspaper every day to prevent loss of moisture from the compost. After completion of spawn run (10-15 days), the newspapers were removed from the trays and casing was done.

3.1.3 Casing materials evaluated

Locally available and cost effective casing materials were evaluated which included:

1. Vermi compost
2. Soil + Cow dung (2:1)
3. Soil + Sand (2:1)
4. Soil + Local peat (Demb) (2:1)
5. Spent Mushroom Compost (SMC)

Casing materials were sterilized by autoclaving at a temperature of 121°C and 15 *lbs* pressure for 15 minutes. After sterilization, casing materials were applied at a depth of 5 cm over fully spawn run compost.

3.2 Evaluation of sterilization methods

To know the effect of different sterilization methods on different parameters of button mushroom yield, using casing material (soil + sand) in the ratio of 2:1, following sterilization methods of casing were evaluated *viz.,*

3.2.1 Formalin treatment (2%)

Chemical sterilization by application of formalin (2%) was carried out by treating the casing material placed on plastic sheet with 2 per cent formalin (50 ml/litre of water). Formalin was sprinkled in layers till saturation and then covered with another plastic sheet. The casing material was turned after 24 hours and then again covered tightly with plastic sheet. After 48 hours it was uncovered and stirred frequently to remove the traces of formalin fumes. The treated material was then stored in a nylon bag and used 2 days after the treatment.

3.2.2 Autoclaving

The casing material was autoclaved at 121°C temperature and 15 *lbs* pressure for 15 minutes.

3.2.3 Heat treatment (Local method)

The casing material was moistened and placed in a tub and covered with a lid. It was placed over a gas stove and using moderate flames heated for almost 4 hours so that it does not burn the organic matter in the soil.

3.2.4 Solarization

The casing mixture was spread over a plastic sheet to a depth of 5 cm and light spray of water was done. It was then covered by transparent plastic sheet and kept as such for 30 days. After that the sheet was removed and the material was used as casing.

After sterilization, the casing material (soil + sand) was applied on the spawned trays at a depth of 5 cm. After application, it was pressed gently and uniformly levelled.

3.3 Evaluation of casing depths

Casing material (soil + sand) in the ratio of 2:1 was applied on the spawned trays, pressed gently and uniformly levelled at the following depths with the help of a measuring scale.

a) 1.5 cm

b) 3.0 cm

c) 4.0 cm

d) 5.0 cm

e) 6.0 cm

During case run, a temperature of 25±2°C temperature and relative humidity of 85 to 90 per cent were maintained for a period of one week after casing (Tiwari, 2013). Each treatment was replicated four times in a completely randomised design.

3.4 Cropping room environment

After one week of casing, the temperature and relative humidity of the mushroom room were maintained at 15-18°C and 70-80 per cent, respectively. Very little or no ventilation was provided until the appearance of first pin heads (Tiwari, 2013). After that, normal ventilation was provided for a period of 3-4 hours a day to induce fruiting. Fine spray of water was done over the casing to maintain 70-80 per cent humidity (Tiwari, 2013).

3.5 Harvesting

First flush occurred almost 3 weeks after casing. Picking of mushrooms was done by gently twisting the mushroom head clockwise and anti-clock-wise and then pulled up softly. Mushrooms with many pin heads around, were harvested with the help of a sharp-edged knife in order to prevent any disturbance to nearby pinheads. When all the mushrooms of the harvestable size were picked up from the trays, the holes formed were filled up with the fresh sterilized casing.

3.6 Monitoring

The trays were monitored constantly for appearance of any contaminations or competitor moulds. Spray of insecticide (nuvan@1 ml/ litre) around the trays and on cemented floor in between the flushes was part of routine crop management operation.

3.7 Observations recorded

1. Time taken for case run.
2. Time taken for pinhead initiation.
3. Number of fruiting bodies per tray.
4. Average weight of fruiting body (g).
5. Yield (g)/kg of compost.

Same parameters were recorded in all the three objectives.

3.8 Statistical Analysis

Completely randomized design was utilized in present examination. All recorded data was subjected to online analysis by utilizing OPSTAT statistical software package for agricultural research workers (Sheoran *et al.*, 1998). Critical difference was determined at 5 per cent level of significance.

Chapter–4

EXPERMENTAL FINDINGS

The results of investigation entitled "Studies on Different Aspects of Casing Material for Improvement in Yield of Button Mushroom (*Agaricus bisporus* L.)" conducted at Mushroom Technology cum Training Centre, Division of Plant Pathology, FoA, Wadura during the year 2020 are presented under the following headings:

4.1 Effect of different casing materials on yield

Five locally available and cheap casing materials *viz.*, vermi compost, soil + cow dung (2:1), soil + sand (2:1), soil + local peat (Demb) (2:1) and spent mushroom compost (SMC) were evaluated to study their effect on case run, pinhead initiation, number of fruiting bodies, total yield (g), yield (g) per kg of compost and average weight of fruiting body (g).

4.1.1 Time taken for case run and pin head initiation

Time taken for case run and pin head initiation in all the casing materials varied significantly. Minimum time (**Table-1**) for case run (15.00 days) was recorded in soil + local peat followed by soil + sand (16.25 days), soil + cow dung (17.25 days) and vermi compost (18.50 days) whereas it took maximum time in spent mushroom compost (19.25 days).

Pinhead initiation (**Table-1**) took minimum days (20.50 days) in soil + local peat followed by soil + sand (22.50 days), soil + cow dung (24.00 days) and vermin compost (25.75 days) whereas maximum days (27.25 days) were taken by spent mushroom compost.

4.1.2 Number of fruiting bodies per tray

Significant differences were observed in number of fruiting bodies per tray on different casing materials. The data (**Table-1**) reveals that maximum number of fruiting bodies per tray were recorded in soil + local peat (105.00) followed by

soil + sand (100.00), soil + cow dung (84.00) and vermi compost (67.00) whereas spent mushroom compost resulted in lowest number of fruiting bodies per tray (57.00).

4.1.3 Yield per tray

All the casing materials resulted in significantly different button mushroom yield (**Table-1**). Highest yield per tray (1500.00 g) was recorded with soil + local peat (2:1) followed by soil + sand (2:1) (1300.75 g), soil + cow dung (2:1) (1000.25 g) and vermi compost (741.75 g). Spent mushroom compost resulted in lowest yield per tray (604.25 g).

The yield per kg of compost (187.50 g) was highest in soil + local peat (2:1) followed by soil + sand (2:1) (162.59 g), soil + cow dung (125.03 g) and vermi compost (92.71 g) whereas spent mushroom compost resulted in lowest yield per kg of compost (75.53 g).

4.1.4 Average weight of fruiting body

Significant differences were exhibited in the average weight of fruiting bodies formed on different casing materials. The data (**Table-1**) revealed that soil + local peat (2:1) resulted in maximum average weight of fruiting bodies (14.28 g) followed by soil + sand (2:1) (13.00 g) and soil + cow dung (2:1) (11.90 g). Spent mushroom compost resulted in the lowest average weight of fruiting bodies (10.60 g) which was however, statistically at par with the average weight of fruiting bodies (11.07 g) resulted by vermi compost.

Table-1 Effect of casing material type on growth and yield of button mushroom

Casing Material	Number of days taken		Number of fruiting bodies per tray*	Yield per Tray (g)*	Yield(g kg^{-1} compost)	Average weight of fruiting body (g)
	Case run*	Pinhead initiation*				
Vermi compost	18.50	25.75	67.00	741.75	92.71	11.07
Soil + Cow dung (2:1)	17.25	24.00	84.00	1000.25	125.03	11.90
Soil + Sand (2:1)	16.25	22.50	100.00	1300.75	162.59	13.00
Soil + Local peat (Demb) (2:1)	15.00	20.50	105.00	1500.00	187.50	14.28
Spent Mushroom Compost (SMC)	19.25	27.25	57.00	604.25	75.53	10.60
S.E(d)	**0.38**	**0.67**	**1.31**	**6.35**	**1.70**	**0.30**
C.D ($p \leq 0.05$)	**0.83**	**1.44**	**2.83**	**13.65**	**3.66**	**0.64**

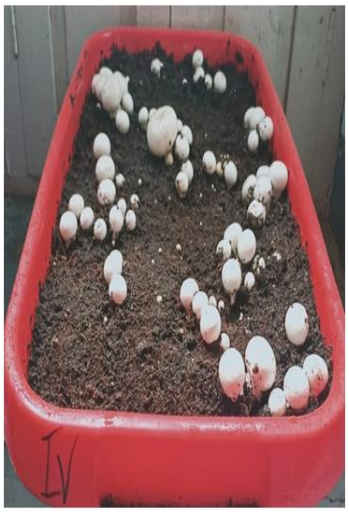
*Average of four replication

Soil + Demb (2:1)

Soil + Cow dung (2:1)

Soil + Sand (2:1)

Spent Mushroom Compost



Vermi compost

Plate 1: Sporocarps of *Agaricus bisporus* on different casing materials

4.2 Effect of different sterilization methods of casing material on yield of button mushroom

The casing material soil + sand (2:1) sterilized by four methods *viz.*, formalin (2%), autoclaving, heat treatment (local method) and solarization were evaluated to study their effect on case run, pinhead initiation, number of fruiting bodies, total yield (g), yield (g) per kg of compost and average weight of fruiting body (g).

4.2.1 Time taken for case run and pin head initiation

All the sterilization methods (**Table-2**) significantly impacted the time taken for case run and pin head initiation. The data revealed that minimum number of days for case run were recorded in casing material sterilized by autoclaving (16.00 days) followed by formalin (2%) (17.00 days) and heat treatment (19.25 days) whereas casing material sterilized with solarisation took maximum number of days (21.00 days) for case run. Similar trend was recorded in the initiation of pinhead formation. Earliest pinhead initiation was recorded in casing material sterilized by autoclaving (22.00 days) followed by sterilization with formalin (2%) (23.50 days) and heat treatment (25.00 days) whereas casing material sterilized by solarisation took maximum number of days for pinhead initiation (27.25 days).

4.2.2 Number of fruiting bodies per tray

Significant difference in number of fruiting bodies were recorded when the casing material was sterilized by sterilization methods The data (**Table-2**) revealed that maximum number of fruiting bodies per tray were recorded in trays where casing material was sterilized by autoclaving (100.00) followed by formalin (2%) (83.00) and heat treatment (64.00) while trays where casing material was sterilized by solarization recorded the lowest number of fruiting bodies (42.00) per tray.

4.2.3 Yield per tray

Significant differences in yield of button mushroom per tray were observed when casing material was sterilised by different sterilization methods. The data (**Table 2**) revealed that casing material sterilized by autoclaving resulted in the highest mean yield (1284.00 g/tray) followed by trays where casing material was sterilized by formalin (2%) which resulted in mean yield of 1000.50 g per tray and trays where casing material received heat treatment (697.75 g/tray). The lowest mean yield (430.00 g/tray) was recorded in trays where casing material was sterilized by solarization. Similar trend in yield of button mushroom was recorded. Mean button mushroom yield per kg of compost was highest in trays where casing material was sterilized by autoclaving (160.50 g) followed by chemical sterilization (125.06 g) and heat treatment (87.21 g) whereas lowest yield per kg of compost (53.75 g) was recorded in trays where casing material was sterilized by solarization.

4.2.4 Mean fruiting body weight

Significant differences were recorded in mean weight of fruiting bodies when casing material was sterilized by different sterilization methods. The data (**Table-2**) revealed that maximum average weight of fruiting bodies (12.70 g) was recorded in trays where casing material was sterilized by autoclaving followed by chemical sterilization (12.05 g) and heat treatment (10.90 g) while trays where casing material was sterilized by solarization resulted in the lowest average weight (10.23 g) of fruiting bodies.

Table-2 Effect of different sterilization methods of casing material on growth and yield of button mushroom

Sterilization methods	Number of days taken		Number of fruiting bodies per tray*	Yield per Tray (g)*	Yield (g kg^{-1} compost)	Average weight of fruiting body (g)
	Case run*	Pinhead initiation*				
Formalin (2%)	17.00	23.50	83.00	1000.50	125.06	12.05
Autoclaving	16.00	22.00	100.00	1284.00	160.50	12.84
Heat treatment	19.25	25.00	64.00	697.75	87.21	10.90
Solarization	21.00	27.25	42.00	430.00	53.75	10.23
S.E(d)	**0.33**	**0.48**	**1.15**	**5.98**	**2.39**	**0.29**
C.D ($p \leq 0.05$)	**0.74**	**1.07**	**2.54**	**13.17**	**5.28**	**0.64**

*Average of four replications

Autoclaving **Formalin (2%)**

Heat treatment **Solarization**

Plate 2: Sporocarps of *Agaricus bisporus* on casing mixture (soil +sand) sterilized by different methods

4.3 Effect of different depths of casing material on yield of button mushroom

Five different depths of casing material soil + sand *viz.*, 1.5 cm, 3 cm, 4 cm, 5 cm and 6 cm were evaluated to study their effect on case run, pinhead initiation, number of fruiting bodies, total yield (g), yield (g) per kg of compost and average weight of fruiting body (g).

4.3.1 Time taken for case run and pin head initiation

Different soil depths significantly influenced case run and pinhead formation in button mushrooms. Data (**Table-3**) revealed that case run was fastest (12.00 days) in trays where casing depth was 1.5 cm followed by casing depth 3 cm where case run took 15.5 days. However, pin head initiation took 28.00 days at 1.5 cm casing depth and 26.50 days at casing depth of 3 cm casing. At casing depth of 4 cm, case run was completed in 16.50 days but pin head initiation was earliest and recorded at 22.00 days which was, however, statistically at par with casing depth of 5 cm where case run was completed in 16.50 days and pin head initiation recorded at 22.00 days. Slowest case run (22.00 days) and pin head initiation (30.25 days) was recorded in 6 cm depth.

4.3.2 Number of fruiting bodies per tray

Significant difference in number of fruiting bodies was recorded when different soil depths different were applied to trays. The data (**Table-3**) revealed that maximum number of fruiting bodies per tray (91.00) were recorded at 5 cm casing depth which, however, was statistically at par with 4 cm casing depth where number of fruiting bodies per tray were 90.00. At 3 cm and 6 cm casing depths, number of fruiting bodies were 80.00 and 50.00 respectively while lowest number of fruiting bodies (46.00) were recorded at 1.5 cm casing depth.

4.3.3 Yield per tray

Significant difference was observed in button mushroom yield when different casing depths were applied to full spawn run compost trays. The data (**Table 3**) revealed that casing depth of 5 cm resulted in highest mean button

mushroom yields of 1010.25 g/tray, which, however, was statistically at par with casing depth of 4 cm where yield was 999.75 g per tray. At casing depth of 3 cm, mean button mushroom yield per tray was 864.00 g while at 6 cm casing depth, it was 510.00 g/tray. Lowest mean button mushroom yield (441.25 g/tray) was recorded at 1.5 cm casing depth. Similar trend was recorded in yield per kg of compost. Highest button mushroom yield per kg of compost (125.93 g/kg compost) was recorded in trays where casing depth was 5cm which however, was at par with trays with casing depth of 4 cm where mean yield was 125.46 g/kg. It was followed by casing depth of 3 cm and 6 cm with 108.00 and 63.75 g per kg of compost. The lowest mean button mushroom yield per kg of compost (55.15 g/kg compost) was recorded in trays where casing depth was 1.5 cm depth.

4.3.4 Average weight of fruiting body (g)

The data (**Table-3**) revealed that highest mean weight of fruiting bodies (11.10 g) was obtained from trays which received casing depth of 4 and 5 cm. It was followed by 3 cm and 6 cm casing depth where mean weight of fruiting bodies were 10.80 and 10.20 g respectively. Casing depth 1.5 cm resulted in lowest mean weight of fruiting bodies (9.59 g).

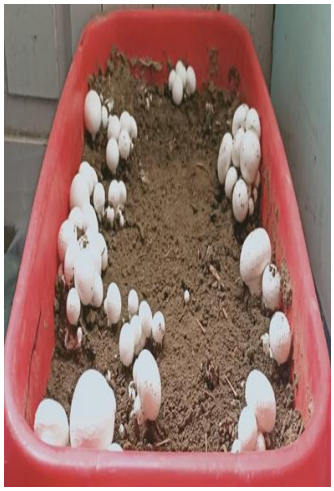
Table-3 Effect of casing material depths on growth and yield of button mushroom

Sterilization methods	Number of days taken		Number of fruiting bodies per tray*	Yield per Tray (g)*	Yield (g kg^{-1} compost)	Average weight of fruiting body (g)
	Case run*	Pinhead initiation*				
1.5cm	12.00	28.00	46.00	441.25	55.15	9.59
3 cm	15.50	26.50	80.00	864.00	108.00	10.80
4 cm	16.50	22.00	90.00	999.75	125.46	11.10
5 cm	17.00	22.50	91.00	1010.25	125.93	11.10
6 cm	22.00	30.25	50.00	510.00	63.75	10.20
S.E(d)	**0.57**	**0.74**	**1.00**	**4.93**	**1.91**	**0.27**
C.D ($p \leq 0.05$)	**1.22**	**1.59**	**2.15**	**10.61**	**4.12**	**0.59**

*Average of four replications

1.5 cm

3 cm



4 cm

5 cm

6 cm

Plate 3: Sporocarps of *Agaricus bisporus* at different casing depths

Chapter–5

DISCUSSION

One of the world's biggest challenges at present is food security. This problem is largely common in developing countries which have poor food production system and suffer from serious malnutrition. Such countries must find ways of improving food production so as to feed vastly increasing human population. Mushroom cultivation could be a possible option to mitigate malnutrition and improve the life style of the vulnerable people (Imtiaj and Rahman, 2008). Button mushroom cultivation is gaining popularity due to its low cost technology and easily availability of raw materials for its cultivation. In Kashmir valley, button mushrooms can be cultivated commercially anywhere as the essential environmental conditions required are easy to maintain and requisite raw materials (compost and casing material) are readily and locally available (Munshi *et al.,* 2010). Button mushroom has a requirement of two different substrates to produce sporophores, compost on which it grows vegetatively and the casing layer (Chaudhary *et al.,* 2009). It is normally believed that fruit bodies of button mushroom are produced when some stress is provided to vegetatively growing mycelium. By applying casing layer which is low in nutrition besides it creates conditions of stress necessary for induction of fruit bodies (Ratnoo and Doshi, 2012). Casing is important and pre-requisite for pinning in button mushroom cultivation and for high button mushroom yield.

The present investigation entitled "Studies on Different Aspects of Casing Material for Improvement in Yield of Button Mushroom (*Agaricus bisporus* L.)" was undertaken with the objectives to find out the most suitable casing material, sterilization method of casing material and casing depth for improving growth behaviour and yield potential of button mushrooms.

Various casing materials have been used by different workers in various parts of the world depending upon their suitability and availability. During present

investigation, five cheap and locally available casing materials *viz.*, vermi compost, soil + cow dung (2:1), soil + sand (2:1), soil + local peat (demb) (2:1) and spent mushroom compost were evaluated for their effect on growth and yield of button mushroom. Various parameters like time taken for case run, pin head initiation, number of fruiting bodies, yield and average weight of fruiting body were recorded. The time taken for case run and pinhead initiation varied in different casing materials and ranged from 15.00 to 19.00 days and 20.00 to 27.00 days, respectively. Soil + local peat took minimum time of around 15.00 days and 20.50 days for case run and pin head initiation, respectively whereas spent compost showed delayed results. It took maximum number of days for case run (19.25days) and pinhead initiation (27.25 days). Among all the casing materials evaluated, soil + local peat (2:1) recorded highest number of fruiting bodies (105.00 per tray) and yield (1500.00 g per tray) and highest average fruiting body weight (14.28 g) followed by soil + sand (2:1) (100/tray, 1300.75 g/tray and 13.00 g, respectively), soil + cow dung (2:1) (84/tray 1000.25 g/tray and 11.90 g), ver mi compost (67.00/tray, 741.75 g/tray and 11.07 g) whereas, lowest number of fruiting bodies (57.00 per tray), yield (604.25 g per tray) and average weight of fruiting bodies (10.60 g) were recorded in spent mushroom compost. The probable reason for minimum number of days required for case run, pinhead initiation, maximum number of fruiting bodies, yield and average weight of fruiting body might be the physico-chemical properties of casing material (bulk density, porosity, aeration capacity, water holding capacity, pH value and electric conductivity). The spent mushroom compost seem to be less favourable than other casing materials evaluated for button mushroom growth, pin head initiation and other yield parameters probably due to less water holding capacity, aeration and other characters that favoured the growth and fruiting in button mushrooms. The results of present examinations are in concurrence with the findings of Liaqat *et al*. (2014) who recorded highest yield of *Agaricus bitorquis* in a casing mixture of soil + local peat. Kaul (1978) has also described local peat as a good casing material and is being used by many growers in Kashmir due to its abundance and

easy availability. Our results are in corroboration with Fang (1990) and Kerketta *et al.* (2019) who recorded highest yield of button mushroom from soil + peat and soil + coco peat, respectively.

Casing materials [(soil +sand) 2:1 ratio] was sterilized by using different sterilization methods *viz.,* formalin (2%), autoclaving, heat treatment (local method) and solarization**.** A 5 cm thick casing layer was placed on the surface of compost after sterilization. Among these methods, casing material sterilized by autoclaving showed best results. It resulted in fastest case run (16.00 days), pinhead initiation (22.00 days), highest number of fruiting bodies per tray (100.00), total yield per tray (1284.00 g), yield per kg of compost (160.50 g) and average weight of fruiting body (12.70 g) followed by sterilization by formalin (2%) which resulted in case run, pinhead initiation, highest number of fruiting bodies per tray, total yield per tray, yield per kg of compost and average weight of fruiting body in 17 days, 23.50 days, 83.00, 1000.50 g, 160.50 g and 12.05 g, respectively. Third effective sterilization method was heat treatment which resulted in case run, pinhead initiation, highest number of fruiting bodies per tray, total yield per tray, yield per kg of compost and average weight of fruiting body in 19.25, 25.00, 64.00, 697.75 g, 87.21 g and 10.90 g. Sterilization by solarization was least effective and took maximum time for case run (21.00 days) and pinhead initiation (27.25 days), recorded lowest fruit number per tray (42), total yield per tray (430.00 g), yield per kg of compost (53.75 g) and average weight of fruiting body (10.23 g). Superiority of autoclaving as sterilization method over other methods in the present investigations may be due to the complete elimination of competitors and parasitic moulds and maintenance of moisture while in solarization low yield may be the result of the negative influence of competitive micro-organisms that have not been completely eliminated. Our results are in corroboration with Singh *et al. (*1984) who has also described autoclaving as best sterilization method for obtaining high yields in button mushroom followed by

formalin treatment. Kalita (2015) reported that substrates sterilized by autoclaving resulted in higher yields of oyster mushroom.

Thickness of casing layer is an important factor affecting the yield of button mushroom (Vijay and Gupta, 1988). Among different casing depths evaluated *viz.,* 1.5 cm, 3 cm, 4 cm, 5 cm and 6 cm, 5 cm casing depth was found to be most effective and statistically at par with 4 cm. Minimum number of days taken for case run were recorded in 1.5 cm (12.00) followed by 3 cm (15.5 cm), 4 and 5 cm (16.50 and 16.50, respectively) whereas maximum days for case run were recorded in 6 cm depth (22.00). However, pinhead initiation was fastest in 4 cm and 5 cm depth (22.00 and 22.00 days, respectively) followed by 3 cm (26.50 days), 1.5 cm (28.00 days) whereas delayed in 6 cm depth (30.25 days). 5 cm and 4 cm recorded highest number of fruiting bodies per tray (91.00 and 90.00, respectively) whereas lowest number fruiting bodies per tray was observed in 1.5 cm casing thickness (46.00). Similarly 5 cm and 4 cm recorded the highest total yield per tray (1010.25 g and 999.75 g, respectively), yield per kg of compost (125.93 g and 125.46 g, respectively) and average weight of fruiting body (11.10 g and 11.10 g, respectively) whereas lowest total yield (441.25 g), yield per kg of compost (55.15 g) and average weight of fruiting body (9.59 g) was observed in 1.5 cm casing thickness. 3 cm and 6 cm casing thickness showed intermediate results. The possible reason for 5 cm and 4 cm being most effective may be that these two depths provide enough stress necessary for fructification. On the other hand, 1.5 cm casing thickness does not provide enough stress necessary for fructification. In 6 cm casing thickness, vegetative mycelium has to cover a large distance to reach the surface of casing due to which it gets weak and some of the fruit bodies remain embedded in soil, thus yield reduces drastically. The results of present investigation are in agreement with the findings of Tiwari (2013) who evaluated three casing depths *viz.,* 5 cm, 4 cm and 3 cm and observed that 5 cm depth showed best results and resulted in fastest case run and pin head initiation, highest number of fruiting bodies and yield. The results of present investigations

are in agreement with investigations of Tripathi (1999) who evaluated four different casing depths *viz.*, 3 cm, 4 cm, 5cm and 6 cm and reported that 5 cm and 4 cm thickness showed best comparable results. Ghasemi *et al.* (2020) reported 4 cm casing thickness as best for optimum production of button mushrooms. The results of other scientists whose findings are in conformity with present findings are Chakravarty (1976) and Amin *et al.* (2010).

Chapter – 6

SUMMARY AND CONCLUSION

White button mushroom (*Agaricus bisporus*) also known as Khumbi and European mushroom is the most popular mushroom in the world and contributes around 40 per cent of world production of mushroom. *Agaricus bisporus* is an edible mushroom containing high protein and low fats, essential amino acids, vitamins and mineral elements required by human body. Button mushrooms are secondary decomposers that require nutritious and very selective composts for their vegetative growth. Button mushroom also require a casing layer that is applied to the fully colonised compost. Casing layer is one of the significant developing boundary and source of variation in production, quality and consistency of commercial cropping. The results of present investigation revealed that growth and yield of button mushroom varied significantly with different casing materials, sterilization methods and casing depths. Five locally available casing materials *viz.,* vermi compost, soil + cow dung (2:1), soil + sand (2:1), soil + local peat (demb), spent mushroom compost (SMC) were evaluated for number of days required for case run, pinhead initiation, total yield (g), yield (g/kg compost) and average weight of fruiting body (g). Casing material soil + local peat (2:1) was found best and took minimum time of around 15.00 days for case run and 20.50 days for pinhead initiation and recorded highest number of fruiting bodies per tray (105.00), total yield per tray (1500 g), yield per kg of compost (187.50 g) and average weight of fruiting body (14.28 g). On the other hand, spent compost (2:1) was least effective casing material among the different casing materials evaluated and took maximum number of days for case run (19.25) and pinhead initiation (27.25) and recorded the lowest total number of fruiting bodies per tray (57.00), total yield per tray (604.25 g), yield/kg of compost (75.53 g) and average weight of fruiting body (10.60 g).

Yield of button mushroom varied significantly with different sterilization methods of casing material [(soil + sand) 2:1]. Among the different sterilization

methods evaluated for sterilization of casing material *viz.*, autoclaving, formalin (2%) treatment, heat treatment (local method) and solarization, sterilization by autoclaving was most effective and resulted in fast case run (16.00 days) and pinhead initiation (22.00 days) and highest total number of fruiting bodies (100.00 per tray), total yield per tray (1284.00 g), yield/kg of compost (160.50 g) and average weight of fruiting body (12.70 g). Sterilization by solarization was least effective and resulted in slowest case run (21.00 days) and pinhead initiation (27.25 days) and lowest number of fruiting bodies per tray (42.00), total yield (430.00 g per tray), yield/kg of compost (53.75 g) and average weight of fruiting body (10.23 g).

The results of present studies revealed that growth and yield of button mushroom varied significantly with different depths of casing material. Among different casing depths evaluated *viz.*, 1.5 cm, 3 cm, 4 cm, 5 cm and 6 cm, casing depth of 1.5 resulted in minimum number of days for case run (12.00) followed by 3 cm (15.50), 4 cm and 5 cm (16.50 and 16.50) whereas 6 cm casing depth recorded maximum number of days for case run (22). Minimum number of days for pinhead initiation were recorded in 4 cm and 5 cm casing depths (22 and 22, respectively) followed by 3 cm depth (26.50), 1.5 cm (28) whereas 6 cm depth showed delayed results (30.25 days). 5 cm casing thickness resulted in highest number of fruiting bodies per tray (91.00), maximum yield per tray (1010.25 g), yield/kg of compost (125.93 g) and highest average weight of fruiting body (11.10 g). It was, however, statistically at par with 4 cm casing thickness where number of fruit bodies per tray, total yield per tray, yield/kg of compost and average weight of fruiting body were 90.00, 999.75 g, 125.46 g and 11.10 g, respectively. These were followed by 3 cm (80, 864.00 g, 108.00 g kg^{-1} and 10.80 g) and 6 cm (50.00, 510.00 g, 63.75 g and 10.20 g) whereas 1.5 cm was least effective *i.e* recorded lowest number of fruit bodies (46.00), yield (441.25 g), yield g kg^{-1} of compost (55.15) and average weight of fruiting body (9.59 g)

Overall, casing material comprising of soil + local peat (demb), casing

material sterilization by autoclaving and casing depth of 4 cm provided the best outcome and resulted in minimum case run days, minimum pin head initiation days and maximum number of fruiting bodies and highest yield.

LITERATURE CITED

Ahmed, M. F., Rahman, M. J., Islam, M. N., Ullah, M. J. and Sarker, N. C. 2020. Effect of Substrate Sterilization and Spawning Method on the Yield and Yield Attributes of Milky White Mushroom (*Calocybe indica*). *Universal Journal of Plant Science* **8**: 17-21.

Akhter, K., Salahuddin, M., Choudhary, M. and Aminuzzaman, F. M. 2017. Effect of Sterilization of Substrate by Hot Water Treatment on Prevalence of Contaminants and Yield Attributes of Oyster Mushroom (*Pleurotus ostreatus*). *Scholars Journal of Agriculture and Veterinary Sciences* **4**: 464-471.

Amin, R., Khair, A., Alam, N. and Lee, T. S. 2010. Effect of Different Substrates and Casing Materials on the Growth and Yield of *Calocybe indica*. *Mycobiology* **38**: 97-101.

Anonymous. 2004. Evaluation of locally available agro/industrial wastes and their use as casing material for *Agaricus bisporus*. *Annual* Report 2003-04 of AICMIP, NRCM, Chambaghat, Solan, H. P. pp. 15-16.

Anonymous. 2013. Fresh Mushrooms. *Mushroom Council*. n.d. *http: //en.m. wikipedia.org/wiki/Agaricus_bisporus*.

Ayyub, C. M., Khan, A. N., Rehman, A. and Akhtar, N. 2014. Evaluation Of Various Casing Materials For Enhancing Growth And Yield Of Button Mushroom (*Agaricus Bisporus*). *Pakistan Journal of Phytopathology* **26**: 125-132.

Bano, Z. and Rajarathnam, S. 1982. *Pleurotus* mushroom as nutritious food. **In**: *Tropical Mushroom Biological Nature and Cultivation Methods* (Eds. S. T. Chang and T. H. Quimio). *The Chinese University Press* **4**: 363-382.

Barman, S., Acharya, A., Chakraborty, U. and Chakraborty, B. N. 2017. Evaluation of the effect of different compost formulations and casing materials on button mushroom production. *International Journal of Nature and Science* **8**: 377-385.

Chakravarti, D. K. 1976. Casing thickness for mushroom production. *Indian Agriculturist* **20**: 91-94.

Chandra, R., Pandey, V. N. and Singh, H. B. 2014. Comparative evaluation of casing mixtures on the yield potential of button mushroom (*Agaricus bisporus*). *Proceedings of the 8th international conference on mushroom biology and mushroom products (icmbmp8)*.

Chang, S. T. and Hayes, W. A. 1978. Biology and Cultivation of Edible Mushrooms. Academic Press, New York, pp. 819.

Chang, ST and Miles, F. 1989. Edible Mushrooms and their Cultivation, Boca Raton, Florida, USA: CRC Press Inc.

Chang, S.T. and Miles, P.G. 1991. Recent trends in world production of cultivated edible mushrooms. *Mushroom Journal* **504**: 15-17.

Chaudhary, D. K., Agarwal, P. K. and Johri, B. N. 2009. Characterization of functional activity in composted casing amendments used in cultivation of *Agaricus bisporus*. *Indian Journal of Biotechnology* **8**: 97-109.

Colauto, N. B., Dasilvera, A. R., Daeira, A. F., Linda, G. A. 2011. Production flush of *Agaricus blazei* on Brazilian casing layers. *Brazilian Journal of Microbiology* **42**: 616-623.

Dhar, B. L., Ahlawat, O. P., Gupta, P. and Raj, D. 2006. Casing layer as related to mushroom yield and quality in *Agaricus bisporus* in India. *Mushroom Research* **15**: 111-117.

Dondge, V. S. 2012. Studies on some fungi in button mushroom cultivated in Akola (Amanantpur). *Recent Research in Science and Technology* **4**: 28-30.

Eger, G. 1972. Experiments and comments on the action of bacteria on sphorophore initation in *Agaricus bisporus*. *Mushroom Science* **8**: 719-725.

Estrada, A. R., Gasco, M. M. and Royse, D. J. 2009. Improvement of yield of *Pleurotus eryngii* var. *eryngii* by substrate supplementation and use of a casing overlay. *Bioresource Technology* **100**: 5270-5276.

Fang, K. W. 1990. Effect of different casing materials on the yield of mushroom (*Agaricus bisporus). Fujian Agricultural Science and Technology* **3**: 18.

Ghasemi, K., Emadi, M., Bagheri, A. and Mohammadi, M. 2020. Casing material and Thickness Effects on the Yield and Nutrient Concentration of *Agricus bisporus* **36**: 734-1009.

Grepeli, A., Galli, G. and Tomati, U. 1987. Evaluation of casing materials for enhancing button mushroom yield. *Agrochemicals* **31**: 457-462.

Hayes, W. A. and Sandilya, T. R. 1977. Casing soil and compost substrates used in the artificial culture of *Agaricus bisporus*, the cultivated mushroom. *Indian Journal of Mycology* **7**: 5-10.

Imtiaj, A. and Rahman, S. A. 2008. Economic viability of mushrooms cultivation to poverty reduction in Bangladesh. *Tropical and Subtropical Agro ecosystems* **8**: 93-99.

Jiskani, M. M., Pathan, M. A. and Wagan, K. H. 1999. Yield performance of Oyster mushroom *Pleurotus florida* (strain-PK401) on different substrates. *Pakistan Journal of Agriculture* **15**: 26-29.

Kalita, M.K. 2015. Impact of various sterilization methods on growth and yield of oyster mushroom (*Pleurotus florida)*. *International Journal of Agricultural Sciences* **11**: 104-107

Kaul, T. N. 1978. Casing. *Indian Mushroom Science* **1**: 147-164.

Kaur, A. P. and Rampal, V. K. 2017. Assessment of Casing Mixtures on Yield Potential and Quality of Button Mushroom (*Agaricus bisporus*) – On Farm Trial. *International Journal of Current Microbiology and Applied Sciences* **6**: 430-436

Kaur, A., Johl, P. P. and Sodhi, H. H. 2017. Evaluation of casing variables for cultivation of *Agaricus bisporus* strain U3 in Punjab, India. *Journal of Applied and Natural Science* **9**: 305-310.

Kerketta, A., Shukla, C. S. and Singh, H. K. 2019. Evaluation of different casing materials for growth and yield of button Musrhroom (*Agaricus bisporus* (L.) Sing.). *Journal of Pharmacognosy and Phytochemistry* **8**: 207-209.

Kesavan, P. and Swaminathan, M. 2008. Strategies and models for agricultural sustainability in developing Asian countries. *Philosophical Transactions of the Royal Society*: *Biological Sciences* **363**: 877–891.

Khajuria, R. 2005. Analysis of Entrepreneurial Behaviour of Mushroom growers in Jammu District of Jammu and Kashmir. Ph. D Thesis, Department Extension Education. Maharana Pratap University of Agriculture and Technology, Udaipur.

Khan, N. A., Abbas, M, Rehman, A., Haq, I. and Hanan, A. 2011. Impact Of Various Sterilization Methods Using Different Substrates For Yield Improvement Of *Pleurotus* Spp. *Pakistan Journal of Phytopathology* **23**: 20-23.

Kumar, B., Kumar, C., Kumar, M and Singh, V. K. 2017. Effect of waste tea leaf and slake lime in casing mixture on yield of white button mushroom [*Agaricus bisporus* (Lange) Imbach]. *International Journal of Current Science Research* **3**: 1452-1457.

Kumar, K., Biswas, S. K., Husain, A. and Kumar, S. 2020. Physical parameters of casing materials on yield parameter of white button mushroom [*Agaricus bisporus* (lange. Imbach)]. *International Journal of Chemical Studies* **8**: 2820-2824.

Liaqat, M. R., Ali, M. A., Khan, N. A., Kashif, M. and Khan, H. U. 2014. Influence of Different Casing Materials on the Growth and Yield of Thermo-Tolerant Strains Of *Agaricus bisporus. Pakistan Journal of Phytopathology* **25**: 101-104.

Mamta, S. 1997. Effect of different casing materials on the yield and quality parameters of *Agaricus bitorquis* (Quel.) Sacc. Ph. D thesis, Department Plant Pathology. College of Horticulture, Solan, H. P.

Mehta, B. K., Jain, S. K., Sharma, G. P., Doshi, A. and Jain, H. K. 2011. Cultivation of button mushroom and its processing: An techno-economic feasibility. *International Journal of Advanced Biotechnology and Research* **2**: 201-207.

Munshi, N. A., Dar, G. H., Ghani, M. Y., Kauser, S. and Mughal, N. 2010. Button Mushroom Cultivation. pp. 1-6.

Nirupa, K. and Kudada, N. 2017. Effect of casing soil thickness on growth and yield of milky mushroom (*Calocybe indica*). *Journal of Pharmacognosy and Phytochemistry* **7**: 3619-3623.

Pandey, M., Pandey, U. N., Verma, N and Sukla, H. P. 2007. Yield response of

Agaricus bisporus in relation to different casing thickness. *Progressive Agriculture* **7**: 162-172.

Pardo, A., De Juan, J., Pardo, J. and Pardo, J. E. 2011. Assessment of different casing materials for use as peat alternatives in mushroom cultivation and Evaluation of quantitative and qualitative production parameters. *Spanish Journal of Agricultural Research* **2**: 267-272.

Pardo, G. A. and. Pardo, J. E. 2008. Evaluation of casing Material made from spent mushroom substrate and coconut fiber pith for use in production of *Agaricus bisporus* (Lange) Imbach. *Spanish Journal of Agricultural Research* **6**: 683-690.

Peker, H. E., Baysal, E., Yigitbasi, O. N., Simsek, H., Colak, M and Toker, H. 2007. Cultivation of *Agaricus bisporus* on wheat straw and waste tea leaves based compost formula using wheat chaff as activator material. *African Journal of Biotechnology* **6**: 400-409.

Rasooul, R., Sadrabadi, R. and Janpoor, J. 2018. Evaluation of the Effect of Different Composition of Casing Soil on the White Button Mushroom (*Agaricus bisporus* Lange) Yield and Quality Traits. *Journal of Horticultural Sciences* **32**: 137-148.

Ratnoo, R. S. and Doshi. A. 2012. Use of vermi compost as casing material for cultivation of *Agaricus bisporus* (Lange) Sing. *International Journal of Agricultural Sciences* **8**: 390-392.

Rehman, M. K., Ali, M. A., Hussain, A., Khan, A. and A Khan, A. M. 2016. Effect of Different Casing Materials on the Production of Button Mushroom (*Agaricus bisporous* L.). *Journal of Environmental and*

Agricultural Sciences **7**: 55-61.

Royse, D. J., Baars, J. and Tan, Q. 2017. Current Overview of Mushroom Production in the World. *Edible and Medicinal Mushrooms*. pp. 5-13.

Saini, L. C and Prashar, R. D. 1992. Casing media in relation to the yield of white button mushroom (*Agaricus bisporus*). *Agricultural Science Digest* **12**: 13-14.

Shandilya, T. R. and Agarwala, R. K. 1983. *Indian Journal of Plant Pathology* **1**: 34-37.

Shandilya, T. R. and Hayes, W. H. 1977. Available elements in some casing soils. *Indian Mushroom Sciences* **2**: 10-15.

Sheoran, O. P., Tonk, D. S., Kaushik, L. S., Hasija, R. C. and Pannu, R. S. 1998. Statistical software package for agricultural research workers. recent advances in information theory. statistics and computer applications by D. S. Hooda and R. C. Hasija Department of Mathematics Statistics, CCS HAU, Hisar pp. 139-143.

Singh, P., Simon, S. and Lal, A. 2013. Effect of different casing materials on the yield of *Agaricus bisporus* (Lange) Imbach. *Bioved* **24**: 13-16.

Singh, R. N., Jain, V. B., Bhandari, T. P. S. and Singh, G. 1984. Effect of depth and method of sterilization of casing soil on yield of button mushroom. *Progressive Horticulture* **16**: 129-132.

Suman, B. C. and Paliyal, S. S. 2004. Farm Yard Manure and coconut coirpith as a casing material for production of *Agaricus bisporus*. *Mushroom Research* **13**: 54-58.

Taherzadeh, L. and Jafarpour, M. 2013. The Effect of Different Casing Soils on

Quantitative Indices *Blazei* Mushroom (*Agaricus blazei*). *International Journal of Agriculture and Crop Sciences* **5**: 656-661.

Tiwari, G. P. 2013. Comparative efficacy of various compost on the growth and seasonal production of *Agaricus bisporus* (Lange) Imbach, by long term process. Ph. D Thesis, Department Plant Pathology. Jawaharlal Nehru Krishi Vishwa Vidyalaya, College of Agriculture, Jabalpur (M. P).

Tripathi, K., Upadhyay, C. J. and Singh, R. K. 1991. Effect of different casing material on the growth and yield of button mushroom. *Progressive Horticulture* **23**: 141-143.

Tripathi, P. 1999. *Studies on button mushroom (Agaricus bisporus) for production*. Ph. D thesis, Department of Horticulture. C. S. J. M. Kanpur University, Kanpur, U. P.

Vedder, P. J. C. 1978. **In**: *Biology and Cultivation of Edible Fungi*. Academic Press, New York, pp. 377-392.

Vijay, B., Gupta, Y. and Chaudhary, R. C. 1988. Effect of casing thickness on yield of *Agaricus bisporus*. *Recent Development in the Cultivation Technology of Edible Mushrooms* **1**: 85-87.

Yadav, M. K., Chandra, R., Yadav, S. K., Dhakad, P. K., Srivastava, A. K., Dwivedi, P. K. and Naik, S. 2017. Comparative Evaluation Of Locally Available Casing Materials For Quantitative And Qualitative Effect On Two Strains Of *Agaricus Bisporus* (Lange). *Biochemical and Cellular Archives* **17**: 133-139.

Yigitbasi, O. N., Baysal, E., Colak, M,. Toker, H., Simsek, H. and Yilmaz, F. 2007. Cultivation of *Agaricus bisporus* on some compost formulas and locally available casing materials. Part II: Waste tea leaves based compost

formulas and locally available casing materials. *African Journal of Biotechnology* **6**: 109-115.

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Faculty of Agriculture, Division of Plant Pathology, Wadura,
Sopore-193201

CERTIFICATE

Certified that all the corrections/amendments as suggested by External Examiner, during Viva-Voce examination held on 26th of March, 2021 have been incorporated in the manuscript entitled **"Studies on Different Aspects of Casing Material for Improvement in Yield of Button Mushroom (*Agaricus bisporus* L.)"** submitted by **Ms. Sumila Gul (Regd. No. MSA-2018-1233).**

(Dr. M. Najeeb Mughal)
Chairman
Advisory Committee