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An alternative new casing material in the production of *Agaricus bisporus*

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ABSTRACT

The study was carried out to investigate the effects of using perlite together with vermicompost on yield and quality of white button mushroom. The research was conducted in the climate-controlled mushroom growing room, located in the faculty of agriculture of Akdeniz University. Peat (Control-1) and perlite (Control-2) used as casing soil, liquid vermicompost 1 (L1) (7.6 ml m^{-2}), liquid vermicompost 2 (L2) (15.2 ml m^{-2}), liquid vermicompost 3 (L3) (22.8 ml m^{-2}), solid vermicompost 1 (S1) (366 g m^{-2}), solid vermicompost 2 (S2) (732 g m^{-2}), solid vermicompost 3 (S3) (1098 g m^{-2}), liquid+solid vermicompost 1 (LS1) (3.8 ml m^{-2} + 183 g m^{-2}), liquid+solid vermicompost 2 (LS2) (7.6 ml m^{-2} + 366 g m^{-2}), and liquid+solid vermicompost 3 (LS3) (11.4 ml m^{-2} + 549 g m^{-2}) were applied into perlite as casing material. Parameters such as total mushroom yield, marketable mushroom yield, first two flushes of total yield of mushroom: 1st flush mushroom yield, 2nd flush mushroom yield, 3rd flush mushroom yield, earliness, average fruit weight, dry matter content, L, a* and b* color value were examined. As a result of the research, the highest total yield was obtained from S2 application with a value of 34.85 kg 100 kg^{-1} compost compared to Control-1. It was determined that liquid, solid and liquid+solid forms of applications mixed with perlite have the most positive effects on mushroom yield, yield was increased and approved an alternative potential to traditional casing soil. Due to the positive results obtained from the research, the results of the research were recorded in a register book on 26/06/2019 and 2019/09514, through an application made to the Turkish Patent Institute.

1. Introduction

The production amount of cultivated mushroom is 10242541 tons across the world (FAO 2019) and the *Agaricus bisporus* constitutes a big rate of this. The production rate of this was 49364 tons in Turkey (TUIK 2019). On the other hand, white button mushroom takes the first place in the cultivation of mushroom in our country as in many countries. Casing soil necessary for stimulation of primordia and then sporophore formation of A. bisporus (Noble et al. 2003). Commercially, casing soil is an absolute and necessary substance in the farming of button mushroom. The casing soil typically consists of black peat brought to the right pH with calcium carbonate. It has been postulated that the microflora of the casing layer is necessary for fruiting body formation because it consumes a metabolite of the mushroom mycelium that is inhibitory to mushroom formation (Visscher 1988; Noble et al. 1999). For high and quality yield the preferred casing soil contains properties such as high-water holding capacity, rich in organic material, low salt level, ease of gas exchange, soil crust layer will not be formed, and having pH 7.5 (Eren and Boztok 2013).

In general, the most common casing soil used in the cultivation of mushroom is peat. However, the reduction in peat resources, low quality of the existing peat beds, high price and transport cost and the demand for increase of mushroom cultivation made it crucial to search some alternative materials to replace peat and various researches have been done on this subject (Boztok 1984; Visscher 1988; Price 1991; Erkel 1992; Nair 1997; Baysal 1999; Demirer and Özer 2000; Gülser and Pekşen 2003; Çolak 2004; Kim et al. 2018; Kerketta et al. 2019).

In addition, there are a few scientific studies suggesting that it is recommended to mix different materials, as the peat adds amendment elements to the main material, so that the new mixture can give good results (Eren and Boztok 2013; Kim et al. 2018; Kerketta et al. 2019). Although, scientific and practical studies advise the quality of this, particularly in our country no alternative has been offered to the casing material which is traditionally used in the casing soil. There are also graduate theses related to this. Casing soil is an absolutely necessary material in the cultivation of mushroom (Shandiya 1989; Sharma et al. 1996; Sharma et al. 1999; Pardo et al. 2003). The studies conducted have always been important, but the recommended procedure and mixture have not permanently solved the problems arising from the casing soil resources in our country. Perlite was previously tested as casing material. Pure and mixed perlite were used as casing soil and successful results have not been achieved (Eren 2008; Eren and Boztok 2013; Çetin and Eren 2017). The production amount of perlite was 5690027600 tons according to 2021 data. It constitutes 74% of the world perlite reservation (MAPEG 2021). Organic wastes can be broken down and fragmented rapidly by earthworms, resulting in a stable nontoxic material with good structure which has a potentially high economic value as soil conditioner for plant growth. Vermicompost is a finely divided peat like material with excellent structure porosity, aeration, drainage and moisture holding capacity (Dominguez et al. 1997).

In this study, perlite was used as main casing material which may be an alternative to casing soil. Due to the positive results obtained from the research, the results of the research were recorded in a register book on 26/06/2019 and 2019/09514, through an application made to the Turkish Patent Institute.

2. Materials and methods

2.1. Material

The research was carried out at Akdeniz University Faculty of Agriculture (36° 53' 55.60" North latitude, 30° 38' 18.20" East longitude) in a climate-controlled mushroom production room. Perlite was used as the main material for casing soil in the study. Perlite is an acidic rock of volcanic origin which is obtained by breaking it to millimeter particles and subjecting to heat treatment between 800-1000°C. Perlite is light, sterile, aeration, high water holding capacity and high nutrient absorption capacity, inert, and neutral pH substrate. In addition to perlite, liquid and solid vermicompost as supplements were used in the study.

2.2. Methods

Compost was obtained from by a private compost production company in Antalya. Bags of 5 liter, having the size of 30x50 cm and about 2 kg weight, were filled. The bags were prepared based on random block design with 4 replications and each replication had 4 bags and total number was 44 bags. The growing room where research was carried out possessed moisture and heat insulation system, where the room had heating-cooling, ventilation, circulation, humidification and irrigation system infrastructure. The desired climate of the room was fully provided and was automatically controlled.

In order to complete the pre-development period of the mycelium, the temperature of the compost inside the bags was 25±1°C and the relative humidity of the room was kept 90% approximately for 14 days. Also, the internal temperature of the compost was monitored with a soil thermometer. The mycelium pre-development compost containing bags were covered about 4 cm height with alternative casing material, which include doses and form of vermicompost. In the research, commercial peat was used as a control casing soil. Perlite was used as an alternative casing material. However, the liquid, solid and liquid+solid forms of vermicompost in different doses were treated. During the creating of doses of vermicompost, recommended application doses in vegetables were taken as a reference from square of meter. The applied doses were created with study that we have already done. Accordingly, perlite as a substrate, three different forms and three doses of vermicompost into casing material and casing material were tested. Thus, the applications made; liquid vermicompost 1 (L1) 7.6 ml m^{-2}, liquid vermicompost 2 (L2) 15.2 ml m^{-2}, liquid vermicompost 3 (L3) 22.8 ml m^{-2}, solid vermicompost 1 (S1) 366 g m^{-2}, solid vermicompost 2 (S2) 732 g m^{-2}, solid vermicompost 3 (S3) 1098 g m^{-2}, liquid + solid vermicompost 1 (LS1) 3.8 ml m^{-2} + 183 g m^{-2}, liquid + solid vermicompost 2 (LS2) 7.6 ml m^{-2} + 366 g m^{-2}, liquid + solid vermicompost 3 (LS3) 11.4 ml m^{-2} + 549 g m^{-2}, traditional casing soil (Contro1-1) and pure perlite (Control-2).

Total mushroom yield, marketable mushroom yield, first two flushes of total yield of mushroom, first two flushes of marketable mushroom yield, average fruit weight parameters were determined. Yields for each flush and total yield (three flushes) for each treatment were expressed as kg 100 kg-1 compost. Additionally, the harvested mushrooms were examined for abnormalities in size and weight for marketable yield (%). Mushrooms were harvested, counted and weighed daily. At the end of each flush in the growing period, weight (g) of mushrooms with diameter of 3-5 cm per bag were determined. The yield of 2 kg of compost mushroom was determined by weighing it in "g" with a precision scale with a sensitivity of 0.01 g, and the values were calculated over 100 kg of compost. Earliness was determined by calculating the time until the first harvest in days. The dry matter content of mushrooms was taken from 2nd flush and kept in the oven at 70°C for 3 days and later the dry matter was weighted and determined by % calculation. L, a * and b * color values were measured by Minolta CR400 color chromometer.

3. Results

Total yield, marketable yield and two first flushes total yield is mentioned in Table 1. Also, pictures from study are given in Figures 1. Considering the total mushroom yield, the highest yield was obtained from solid vermicompost 1 (S1), solid vermicompost 2 (S2), and liquid+solid vermicompost 3 (LS3), in which the yield was 35.35 kg 100 kg^{-1} compost, 35.69 kg 100 kg^{-1} compost, and 34.52 kg 100 kg^{-1} compost, respectively. The lowest value was recorded as 22.88 kg 100 kg^{-1} compost and 22.73 kg 100 kg^{-1} compost from liquid vermicompost 1 (L1) and control 2 (perlite), respectively.

Table 1. Effects of different casing materials on button mushroom yield

Casing materials	Total yield (kg 100 kg^{-1} compost)	Marketable yield (%)	First two flush total yield(kg 100 kg^{-1} compost)
L1	22.88 c	100 a	16.98 d
L2	31.45 ab	100 a	25.66 c
L3	28.63 b	100 a	24.03 c
S1	35.35 a	100 a	30.32 ab
S2	35.69 a	96 a	31.22 a
S3	29.05 b	99.61 a	26.35 bc
LS1	32.93 ab	100 a	28.09 abc
LS2	31.18 ab	100 a	25.88 bc
LS3	34.52 a	100 a	26.72 abc
Control 1	33.16 ab	62.92 b	31.10 a
Control 2	22.73 c	100 a	16.45 d
LSD $_{(\%5)}$	5.16	11.46	4.61

Different letters in each column shows significantly differences at $P \leq 0.05$.

Figure 1. Alternative casing material: from left to right, top to bottom, Control-1; Control-2; L1; L2; L3; S1; S2; S3; LS1; LS2; LS3.

Apart from S2, S3 and control-1, the loss of marketable mushroom yield was not observed in all application, thus the data were recorded as 100%. The marketable mushroom yield was calculated for S2, S3 and control-1 as 96%, 99.61% and 62.92%, respectively. In the first two flushes of total yield, the highest values were obtained from S2 (31.22 kg 100 kg^{-1} compost) and control-1 (31.10 kg 100 kg^{-1} compost). However, the lowest values were obtained from L1 (16.98 kg 100 kg^{-1} compost) and control-2 (16.45 kg 100 kg^{-1} compost) applications. The 1st, 2nd, and 3rd flush yield of mushroom (kg 100 kg^{-1} compost) were given in Table 2. Considering the mushroom yield in the first flush, the highest values were obtained from S3 (22.03 kg 100 kg^{-1} compost) and control-1 (21.66 kg 100 kg^{-1} compost) applications. While the lowest values were obtained from L1 (8.35 kg 100 kg^{-1} compost) and control-2 (9.55 kg 100 kg^{-1} compost) applications. Considering the 2nd flush of mushroom yield, the highest values were achieved with L2 (12.52 kg 100 kg^{-1} compost) and L3 (12.23 kg 100 kg^{-1} compost) applications. While the lowest value was achieved with S3 (4.33 kg 100 kg^{-1} compost) application. In the 3rd flush of mushroom yield, the highest value was observed in LS3 (7.80 kg 100 kg^{-1} compost) application, while the lowest values were observed in S3 (2.69 kg 100 kg^{-1} compost) and control-1 (2.82 kg 100 kg^{-1} compost) applications.

Considering yield (g 2 kg^{-1} compost), earliness (days) and average fruit weight (g $number^{-1}$) were shown in Table 3.

Table 2. Effects of different casing materials on yield of *A. bisporus* according to flushes

Casing materials	1st flush yield (kg 100 kg^{-1} compost)	2nd flush yield (kg 100 kg^{-1} compost)	3rd flush yield (kg 100 kg^{-1} compost)
L1	8.35 e	8.64 ab	5.90 ab
L2	13.14 cde	12.52 a	5.79 ab
L3	11.8 de	12.23 a	4.59 ab
S1	20.15 ab	10.17 ab	5.04 ab
S2	20.86 ab	10.37 ab	4.47 ab
S3	22.03 a	4.33 c	2.69 b
LS1	18.83 ab	9.26 ab	4.85 ab
LS2	18.03 abc	7.85 bc	5.31 ab
LS3	16.36 bcd	8.87 ab	7.80 a
Control-1	21.66 a	9.44 ab	2.82 b
Control-2	9.55 e	6.91 bc	6.27 ab
LSD $_{(\%5)}$	4.9	4.17	ns

Different letters in each column shows significantly differences at $P \leq 0.05$.

Table 3. Effect of different casing materials on yield, earliness and average fruit weight of *A. bisporus*

Casing materials	Yield (g 2 kg^{-1} compost)	Earliness (Days)	MushroomWeight (g fruit body^{-1})
L1	457.62 c	41 ab	13.59 ab
L2	628.87 ab	40.25 bc	13.37 abc
L3	572.44 bc	42 a	14.22 ab
S1	707.03 ab	38.5 d	14.89 a
S2	713.71 a	38.25 d	14.46 ab
S3	580.96 abc	38.75 d	11.46 cd
LS1	658.60 ab	39.25 cd	13.39 abc
LS2	623.61 ab	39.5 cd	12.60 bc
LS3	690.37 ab	38.75 d	13.1 abc
Control-1	663.26 ab	35.5 e	10.33 d
Control-2	454.51 c	41.75 a	13.40 abc
LSD $_{(\%5)}$	138.77	1.41	2

Different letters in each column shows significantly differences at $P \leq 0.05$.

Considering the 2 kg mushroom yield, the highest value was obtained from S2 (713.71 g 2 kg^{-1} compost) application. The lowest values were obtained from L1 (457.62 g 2 kg^{-1} compost) and control-2 (454.51 g 2 kg^{-1} compost) applications. In earliness, the earliest harvest was obtained from control-1 (35.5 days) application, while the late harvest was achieved with L3 (42 days) and control-2 (41.75 days) applications. For the average fruit weight, the highest value was obtained with S1(14.89 g number^{-1}) and the lowest value was achieved with control-1 (10.33 g number^{-1}).

The dry matter contents were mentioned in Table 4. The highest dry matter content was achieved with S3 (7.77%), LS2 (7.76%) and control-2 (7.63%) applications. The lowest dry matter content was achieved with L3 (6.68%) application.

Parameters related to the mushroom color (L, a* and b*) are mentioned in Table 5. In terms of fruit color, the highest L values were obtained from S1 (93.5), S2 (93.24), LS3 (93.43) and control-1 (93.28) applications, while the lowest L values were obtained from L1 (91.29) and L2 (91.26) applications. The highest a* color value was observed in L2 (0.40) application and the lowest a* color value was observed in L3 (-0.10) application. Furthermore, the highest b* color value was recorded in L1 (11.58) application and the lowest value was recorded in L3 (8.38) application.

4. Discussion

The casing soil is one of the most important inputs affecting yield and quality in the cultivation of *A. bisporus* (Nair 1997; Pardo et al. 2003; Kerketta et al. 2019). As the conventional casing soil (peat) is not standard and based on the fact that the regions' and peat beds' different physical, chemical and biological properties directly affect the yield and quality of cultivated mushroom. In addition, casing soil (peat) obtained from the beds of lake causes the destruction and degradation of lake's beds (Price 1991; Sharma et al. 1996; Noble et al. 1999). On the other hand, our country is a great source of perlite material. It is a standard material in terms of ingredient and its effects are the same everywhere under optimum condition. To produce white button mushroom with this material, the fluctuations of the yield and quality of the mushroom will be eliminated or minimized.

Conventionally used peat (bed soil) has quite high potential to contain harmful and disease related ingredients. The primary source of *M. perniciosa* on most farms is contaminated casing soil. Generally, symptoms in the first flush indicate contamination of the casing soil. Spores of the pathogen may also survive on the surfaces of buildings, or may be carried in crop debris and, in this way, can contaminate crops. Once the pathogen is established in the crop, the main means of spread is

Table 4. The effects of different casing materials on mushroom dry matter content of *A. bisporus*

Casing materials	Dry matter content (%)
L1	6.98 bcd
L2	6.96 bcd
L3	6.68 d
S1	6.96 bcd
S2	7.28 abcd
S3	7.77 a
LS1	7.51 ab
LS2	7.76 a
LS3	6.78 cd
Control-1	7.39 abc
Control-2	7.63 a
LSD $_{(\%5)}$	0.63

Different letters in each column shows significantly differences at $P\leq0.05$.

Table 5. The effects of different casing materials on mushroom color

Casing materials	Color values		
	L	a*	b*
L1	91.29 c	0.39 ab	11.58 a
L2	91.26 c	0.40 a	10.43 ab
L3	92.98 ab	-0.10 c	8.38 c
S1	93.5 a	0.32 abc	9.42 bc
S2	93.24 a	0.015 abc	8.86 bc
S3	91.64 bc	0.16 abc	9.96 abc
LS1	92.81 ab	0.28 abc	9.90 abc
LS2	92.21 abc	0.34 abc	9.47 bc
LS3	93.43 a	-0.05 bc	9.38 bc
Control-1	93.28 a	0.22 abc	9.19 bc
Control-2	92.78 ab	0.13 abc	8.77 bc
LSD $_{(\%5)}$	1.39	ns	1.99

Different letters in each column shows significantly differences at $P\leq0.05$.

by water splash and by excess water running off the beds and bags (Atkins 1961; Fletcher et at. 1989; Karabulut et al. 2007). In recent years, the mushroom industry in Turkey and some other countries has been suffering from an epidemic of wet bubble disease (Gea et at. 1995; Fidan et al. 1998; Ilhan and Tezcan 2000). The presence of phorids must be avoided as the adults are vectors of the dry mould *Verticillium fungicola* (Preuss) Hassebrauk, recently named *Lecanicillium fungicola* (White 1981). The infestation of mushroom flies generally occurs as the compost cools and during the introduction of spawn into the compost (Jess et al. 2007). In addition, one of the most important sources of infestation is casing material (peat and limestone mixture) which is added as a surface layer (3-4 cm deep) on the colonised compost in order to facilitate sporophore formation (Erler et al. 2009). *Trichoderma species* (green mold) is a destructive fungal disease causing epidemics in *A. bisporus* cultivation. To control green mould, it should be good hygiene in mushroom farms and compost facilities. In addition, all phases of compost preparation should be properly performed and casing soil should be disinfected (Aydoğdu et al 2020).

However, perlite with vermicompost used as substrate in new casing material is a material which is sterile, especially very clean and has no risk of disease and harmful in transportation. In addition, a lot of advantages provided by the new casing material in the form of mixture are obtained. First of all, it has a sustainable property of an alternative casing material. Taking of the certificate for organic property is extremely high. In terms of disease and harmfulness, it is a great ingredient to eradicate the use of pesticides under optimum compost and growth chamber conditions. During the harvest of mushroom, the conventional casing soil of mushroom fruit can pollute it due to the influence of mud, which may open way to the decrease of quality of visual appearance of the product. The cleaning process lead the product to its physical damage and poor quality and may lose time due to labor-force. The new alternative casing has not got such problems. There is almost no licensed pesticide in button mushroom. As an alternative, it will bring a solution to compete the pesticide, will be environmentalist and permanent. In terms of human health and food safety, there will be no risk of pesticide residues remained on the fungus and thus the consumer will safely consume it. Due to limitation of pesticides use, the consumption of mushroom will increase. The consumer will get benefit, because of both producer and healthy product food. The problems (damage and degradation of lake beds) arisen from conventionally received casing material from the lake beds, will no longer exist. Since the conventional casing soil is heavy and it increases the cost of its transportation, while the new casing soil is lighter and will reduce shipping cost.

As a result, there are many studies for alternative casing material in the cultivated mushrooms (Gülser and Pekşen 2003; Pardo et al. 2003; Eren and Boztok 2013; Kerketta et al. 2019). However, in this study it was a new approach for casing soil, in which perlite together with vermicompost application were used.

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