J. Appl. Hort.,5(1):11-15, January-June, 2003

Performance of composted vine shoots as a peat alternative in casing materials for mushroom cultivation

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Abstract

Agronomic behaviour of composted vine shoots as casing material in the cultivation of different hybrid strains of mushroom, *Agaricus bisporus* (Lange) Imbach, was studied with an aim to find an alternative to peat, which is normally used as a structural and water holding corrector of mineral soils used as casing material. According to the main production parameters measured (number of mushrooms produced, unitary weight, yield and earliness), composted vine shoots performed similar to peat-based casing materials. However, the possibilities of their use are limited due to the appearance of spots caused by *Trichoderma spp.* on the fruit bodies. The scratching technique consists of creating an open structure in the casing layer to enable uniform and abundant fructification. In general, for the different casing types used, this technique has a positive effect on fructification. This practice induces a higher total yield of mushrooms, although of smaller size, and it facilitates the apparition and harvest of the first flush.

Key words: *Agaricus bisporus*, cultivated mushroom, casing layer, composted vine shoot, peat alternative

Introduction

A compost which is completely colonised by mycelium will not on its own produce mushrooms. It is therefore necessary to modify the compost to initiate fructification. The casing layer is the material used as a top covering of the compost and it is here that the ecological modification that involves the changes from the vegetative to the reproductive growth phase takes place, and where fructification occurs.

Peat constitutes the most widely used material as casing for mushroom cultivation throughout the world. Its water-holding capacity and structural properties are widely accepted as ideal for the purposes of casing (Yeo and Hayes, 1979). However, problems associated with its use, especially as regards its availability, the depletion of reserves and the alteration of ecosystems, have led to the search for alternative materials (Price, 1991). Any material which is to be considered as an alternative to peat for use in mushroom casing should have the following properties: similar performance characteristics at least equal to peat, competitive cost, stable quality, continuity of supply, freedom from pests and diseases and ease of handling (Border, 1993).

Of the great variety of materials that alone or in combination have been used as casing in mushroom growing, either commercially or experimentally, only very few have proved to be of practical application in commercial cultivation. Some of them have only been used at the experimental level to study some of their characteristics or certain aspects of fructification, while many others have been discarded for diverse reasons. The yield and quality of the resulting mushrooms, availability and cost are the decisive factors in choosing a casing material (Pardo *et al.*, 1999a).

In the mushroom growing area of Castilla-La Mancha (Spain), between 40000 and 45000 t of mushrooms (45-50% of total Spanish production) is produced every year. In this zone, the casings used at the moment are based on mineral soils of different origins as base material, to which different types of peats are usually added as structural and water holding correctors (Pardo *et al.*, 1999a). In Castilla-La Mancha, 8.1% of the world total vineyard are cultivated and the enormous production of vine shoots constitutes a problem for the farmers, who usually burns them in the field. However, the composting of vine shoots could provide a material with high porosity and water-holding capacity, which are requirements for mushroom casing (Lobo, 1985; Pardo *et al.*, 1999b). The elimination of an agricultural waste together with the above characteristics should be taken into consideration in the search for peat substitutes for use in casing mixtures in mushroom cultivation (Pardo *et al.*, 1999a).

Casing material has to be open-textured for uniform and abundant fructification to be achieved and to prevent an excess of carbon dioxide during fructification and harvesting. In light of this, the 70's saw the introduction of deep 'scratching' or 'ruffling', a practice that can be manually carried out by means of a board with nails (Visscher, 1988). The process, which is recommended for dense materials which are compacted during the vegetative phase, consists of mixing all the casing layer with the mushroom mycelium, which is growing in it, about a week after casing. The result of this procedure is a more open structure, which facilitates the interchange of CO_2 (Van Gils, 1988) and ensures that all the mycelium appearing at the surface is at the same development stage, giving a much more even spread of the primordia over the entire bed surface (Vedder, 1989).

This work evaluates the agronomic behaviour of composted vine shoots as an ingredient of the casing layer for growing mushrooms, as a substitute for different types of peat usually used. The effect of scratching on the performance of casing materials based on peat and vine shoots was also examined.

Materials and methods

Binary mixtures of mineral soils (80%, v/v) as base material mixed with each of the studied materials (20%, v/v) were used as casings. These materials were: German *sphagnum* peat (Protorf), black peat from the coastal formations southeast of Torreblanca (Castellón, Spain) and a compost of vine shoots (Pardo *et al.*, 1999b).

Three experiments were carried out using three different commercial mushroom strains: Pla 8.9 (mid-range hybrid strain), Blancochamp BL-40 (smooth white hybrid strain) and Gurelan 45 (large off-white hybrid strain). A spawn rate of 12 g kg^{-1} fresh mushroom compost was used. Wheat straw based commercial mushroom cultivation substrates were used (moisture: 65.9-68.9%; pH: 7.24-7.53; N: 2.20-2.36% and C/N ratio: 18.4-19.6).

Tests were carried out in a 20 m^3 experimental walk-in growth chamber, provided with a humidification system, a heating/cooling system and internal air circulation/outside ventilation. In this way, the temperature, relative humidity and carbon dioxide level were controlled automatically.

The experimental design used was a 3 x 2 Equilibrated Factorial Plan, with 4 repetitions (randomised blocks with two factorial factors). The first factor, with three levels, was the casing type. The second factor, with two levels, was the application or not of the scratching technique. Repetitions corresponding to four blocks were placed in two levels on both sides of the crop chamber. The experimental trays (16 L in volume, 870 cm^2 in area) were filled with 6 kg of pressed compost (450 kg m^{-3}). The volume of the casing was 2.61 L per tray, giving a depth of 3 cm.

Three separate growth cycles were carried out according to the growth chamber conditions (air temperature, relative humidity and carbon dioxide concentration) suggested for each of the selected strains (CIES, 2000). A spawn run period of 14 days was used, and disinfectant (formaline, 18 mL m^{-2}), insecticidal (diflubenzuron 25%, 3.6 g m^{-2}) and fungicidal (prochloraz 46%, 0.62 g m^{-2}) treatments were applied after casing. The casing was deeply scratched after 7 days of casing run, and ventilation was carried out 11 days after casing to stimulate primordia formation. The total growth cycle lasted 79-80 days.

The casing was moistened to between 60% and 70% of its water-holding capacity, by regular and uniform watering with between 0.5 L m^{-2} and 1.5 L m^{-2}, depending on necessity, and according to the usual cultivation technique (Wuest, 1982).

Mushrooms were harvested every day at their optimal commercial stage of development, corresponding to morphogenetic stages 2, 3 and 4, according to the classification established by Hammond and Nichols (1976). The quantity of mushrooms produced daily in each tray was weighed with an accuracy of 1g. The number of mushrooms obtained was counted. The cropped mushrooms were separated according to size and defects into three groups: large first quality mushrooms (> 40 mm), medium first quality mushrooms (15-40 mm), and mushrooms with defects in size, colour or disease symptoms (non-marketable production). The size of the mushrooms, expressed as unitary weight (g), was determined from the yield and the number of harvested mushrooms. Biological efficiency, expressed in g kg^{-1} compost dry matter, was determined from the yield per m^2. Earliness was expressed as the number of days between casing and the harvesting of the first flush, with the daily relative production being weighted.

For the statistical analysis the software Statgraphics Plus v. 2.1 (Statistical Graphics Corp., Princeton, NJ, USA) was used. To resolve the variability of the experimental results into independent components, a variance analysis was carried out with the "ANOVA Multifactor" of the Statgraphics option "Analysis of Variance", based on a significance level of 5%. To establish significant differences the Tukey-HSD test (p=0.05) was used.

Results and discussion

Tables 1-3 show the mean values obtained for the quantitative production parameters considered in Experiments 1 to 3, respectively, for the three types of casings used.

The number of mushrooms harvested per m^2 is an indicator of fructification level. The casing which included *sphagnum* peat showed the lowest values in all three experiments (Tables 1 to 3). Casing with composted vine shoots gave values between 1345 and 1884 mushrooms per m^2, which is between the values obtained with the two types of peats in Experiments 1 and 3 and the highest value of Experiment 2. Regardless of scratching, this technique increased the number of mushrooms harvested in the three experiments, although this increase was only significant in Experiments 1 and 2. The interaction scratching-type of casing showed that the effect of scratching is the same, independent of the experiment and type of casing (Fig. 1). The highest level of fruiting, and consequently the greatest number of mushrooms produced, was achieved in Experiments 1 and 2 with scratching. These experiments, in which composted vine shoots were included in the casings, provided between 1670 and 2121 mushrooms per m^2, respectively (Fig.1).

Generally, mushroom yield and mushroom size are inversely related. In all three experiments, the heaviest mushrooms were obtained with the casing containing *sphagnum* peat. The weight varied between 12.56 and 15.46 g, depending on the experiment. The scratching technique produced significantly smaller fruit in Experiments 1 and 2 (Tables 1 to 3). Scratching diminished mushroom weight in all three types of casing in the three experiments (Fig. 2). The biggest mushrooms were obtained using the Gurelan 45 strain (Experiment 3), using the casing with *sphagnum* peat, independently of whether the scratching technique was applied (15.39 g) or not (15.53 g). However, the casing containing composted vine shoot provided similar values to those obtained with the black peat casing (Fig. 2).

As regards the quantitative yield, the best results were obtained with the casing containing black peat in Experiment 1 (18.26 kg m^{-2}) and with the casing containing composted vine shoots in Experiments 2 and 3 (22.18 and 18.72 kg m^{-2}, respectively), although the differences were not significant at p=0.05 (Tables 1 to 3). Scratching resulted in an increase in yield of 2.2 to 6.6%, in

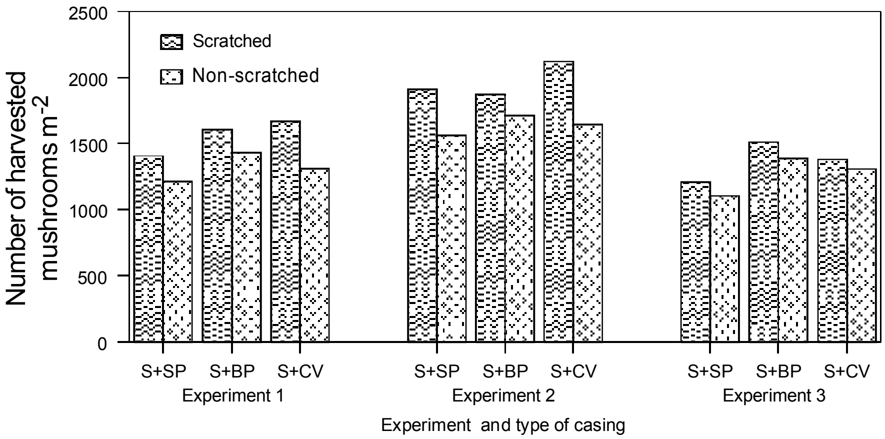

Fig 1. Interaction scratching-casing type on the number of harvested mushrooms per m^2 in the three experiments.
Exp. 1: Pla 8.9 strain; Exp. 2: Blancochamp BL-40 strain; Exp. 3: Gurelan 45 strain
S+SP: Soil + Sphagnum peat (4:1, v/v)
S+BP: Soil + Black peat (4:1, v/v)
S+CV: Soil + Composted vine shoots (4:1, v/v)

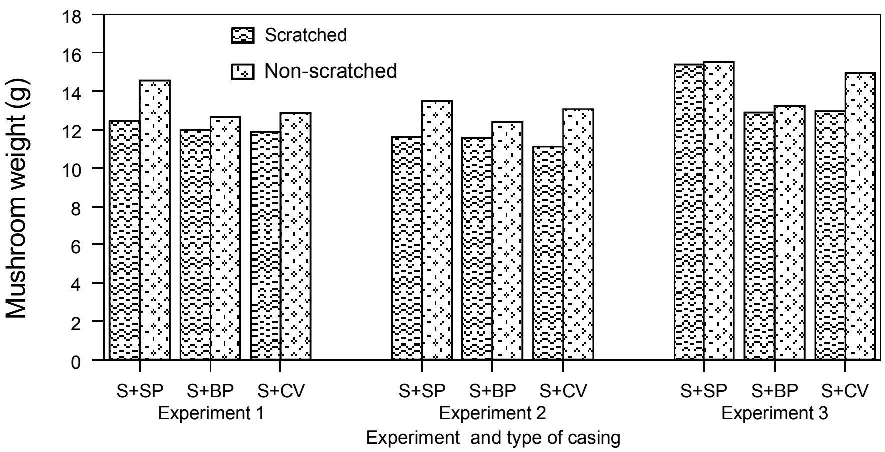

Fig 2. Interaction scratching-casing type on the mushroom weight in the three experiments.
Exp. 1: Pla 8.9 strain; Exp. 2: Blancochamp BL-40 strain; Exp. 3: Gurelan 45 strain
S+SP: Soil + Sphagnum peat (4:1, v/v)
S+BP: Soil + Black peat (4:1, v/v)
S+CV: Soil + Composted vine shoots (4:1, v/v)

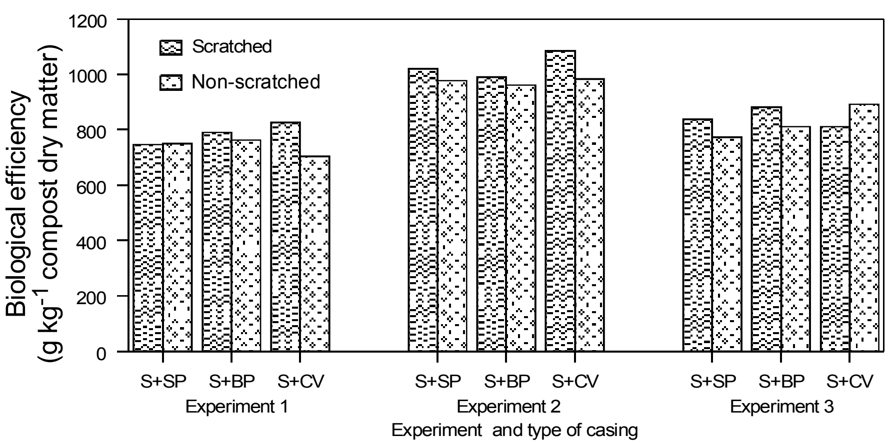

Fig 3. Interaction scratching-casing type on the biological efficiency in the three experiments.
Exp. 1: Pla 8.9 strain; Exp. 2: Blancochamp BL-40 strain; Exp. 3: Gurelan 45 strain
S+SP: Soil + Sphagnum peat (4:1, v/v)
S+BP: Soil + Black peat (4:1, v/v)
S+CV: Soil + Composted vine shoots (4:1, v/v)

the three experiments, although this increase was significant only in Experiment 2 (Tables 1 to 3). When the production was divided into categories, the high proportion of commercially unacceptable mushrooms obtained in the casing with composted vine shoots (more than 20% of the total production in Experiment 2) was of note (Table 2). These mushrooms had brown spots caused by *Trichoderma* spp., a microparasitary fungus (Fletcher *et al.*, 1989; Harvey, 1982). Table 4 shows the effects of the interaction between scratching and casing type on yield and commercial category in each experiment. In general, the scratching technique increased the total commercial production, while reducing the quantity of large mushrooms produced, which is not a disadvantage for mushrooms destined for the preserve industry. In the casing that contained composted vine shoots (Experiments 1 and 2), similar yields of large mushrooms were obtained whether or not the scratching technique was applied (5.01 and 4.92 kg m^{-2} respectively, in Experiment 1; and 5.10 and 5.12 kg m^{-2}, respectively in Experiment 2). Thus, the increases observed in the yield of marketable mushrooms as a consequence of scratching (14.6 and 6.8% for the Experiments 1 and 2) were linked almost entirely with an increase in the number of medium-sized mushrooms (diameters of 15-40 mm). In Experiment 3, a reduction in the total commercial yield of 8.4% was produced when the composted vine shoot casing was scratched. However, the quantity of medium-sized mushrooms harvested increased. The quantity of non-marketable mushrooms did not show significant differences as a consequence of scratching with any of the types of casing in any of the experiments (Table 4).

Biological efficiency is established from the yield per m^2 and the density of the compost in the trays. So, all the considerations about the total yield in the behaviour of the different types of

Table 1. Mean values of quantitative production parameters from Experiment 1 (Pla 8.9 strain)(*)

	Number of mushrooms m^{-2}	Mushroom weight (g)	Mushroom yield (kg m^{-2})					Biological efficiency (g kg^{-1} compost dry matter)	Earlines (days from casing)
			Marketable mushrooms			Non-marketable mushrooms	Total mushroom yield		
			Large size (> 40 mm)	Medium size (15- 40 mm)	Total marketable				
Casing 1 (S+SP)	1312 b	13.51	5.54	11.86	17.39	0.18	17.58	747.5	27.1 ab
Casing 2 (S+BP)	1519 a	12.32	4.85	13.25	18.09	0.17	18.26	776.5	27.6 a
Casing 3 (S+CV)	1491 ab	12.37	4.97	12.39	17.36	0.63	17.99	765.1	26.8 b
Scratched	1560 a	12.11 b	4.77	13.36 a	18.13	0.39	18.51	787.4	26.6 b
Non-scratched	1321 b	13.36 a	5.46	11.64 b	17.10	0.27	17.37	738.7	27.7 a
Mean	1441	12.73	5.12	12.50	17.61	0.33	17.94	763.0	27.1

Table 2. Mean values of quantitative production parameters from Experiment 2 (Blancochamp BL-40 strain)(*)

	Number of mushrooms m^{-2}	Mushroom weight (g)	Mushroom yield (kg m^{-2})					Biological efficiency (g kg^{-1} compost dry matter)	Earlines (days from casing)
			Marketable mushrooms			Non-marketable mushrooms	Total mushroom yield		
			Large size (> 40 mm)	Medium size (15- 40 mm)	Total marketable				
Casing 1 (S+SP)	1737	12.56	6.97	14.26	21.23 a	0.18 b	21.41	998.1	24.8 b
Casing 2 (S+BP)	1792	11.97	5.91	14.98	20.89 a	0.03 b	20.92	975.2	24.4 b
Casing 3 (S+CV)	1884	12.09	5.11	12.50	17.60 b	4.58 a	22.18	1034.1	25.9 a
Scratched	1968 a	11.43 b	5.56	14.77	20.33	1.79	22.12 a	1031.2 a	23.9 b
Non-scratched	1640 b	12.98 a	6.43	13.06	19.48	1.40	20.89 b	974.0 b	26.1 a
Mean	1804	12.20	5.99	13.91	19.91	1.60	21.50	1002.4	25.0

Table 3. Mean values of quantitative production parameters from Experiment 3 (Gurelan 45 strain)(*)

	Number of mushrooms m^{-2}	Mushroom weight (g)	Mushroom yield (kg m^{-2})					Biological efficiency (g kg^{-1} compost dry matter)	Earlines (days from casing)
			Marketable mushrooms			Non-marketable mushrooms	Total mushroom yield		
			Large size (> 40 mm)	Medium size (15- 40 mm)	Total marketable				
Casing 1 (S+SP)	1158 b	15.46 a	7.70 a	9.88 b	17.58	0.17 b	17.75	806.9	27.4
Casing 2 (S+BP)	1448 a	13.05 b	5.20 b	13.29 a	18.50	0.11 b	18.61	845.8	28.1
Casing 3 (S+CV)	1345 ab	13.96 ab	5.30 b	11.34 ab	16.65	2.08 a	18.72	851.1	27.3
Scratched	1366	13.74	5.72	12.14	17.86	0.70	18.56	843.6	26.7 b
Non-scratched	1268	14.57	6.41	10.87	17.29	0.88	18.16	825.7	28.5 a
Mean	1317	14.16	6.07	11.51	17.57	0.79	18.36	834.6	27.6

(*) Values followed by a different letter within a column and factor are significantly different at 5% level according to Tukey's test
S+SP: Soil + *Sphagnum* peat (4:1, v/v); S+BP: Soil + Black peat (4:1, v/v); S+CV: Soil + Composted vine shoots (4:1, v/v)

casing and the scratching effect can be applied to it. The best results were obtained in Experiment 1 in the casing with black peat (776.5 g kg^{-1} compost dry matter), and in the casing with composted vine shoots in Experiments 2 and 3 (1034.1 and 851.1 g kg^{-1} compost dry matter, respectively), although there were no significant differences in any case (Tables 1 to 3). Scratching increased biological efficiency by 2.2 to 6.6% in the three experiments, although to a more significant extent in Experiment 2 (Tables 1 to 3). When analysing the interaction between scratching and casing type, the high values obtained for this parameter in the three experiments are of note. In Experiment 2, particularly, the Blancochamp BL-40 strain provided values of between 960.8 and 1084.2 g kg^{-1} compost dry matter, depending on the casing type and the application or not of the scratching technique. For this variety, the crop is favoured by the casing containing composted vine shoots and the application of scratching (Fig. 3).

Finally, the effect of casing type on earliness depends on the variety in question. In Experiments 1 and 3 (Tables 1 and 3), use of casing with composted vine shoots led to an earlier harvest of the first flush (by 0.1 to 0.8 days). On the contrary, in Experiment 2, delays of 1.1 to 1.5 days were observed with the composted vine shoots compared with the casings containing peat. Scratching had a positive action, significant in all three experiments, decreasing by 1.1 to 2.2 days the period between the application of the casing and the harvest of the first flush (Tables 1 to 3). With Blancochamp BL-40 strain, used in Experiment 2, harvesting of the first flush was more than 2 days earlier than with the varieties used in Experiments 1 and 3 (Tables 1 to 3). As far as earliness is concerned, the interaction scratching-casing type showed that the effect of scratching was the same for the three types of casing in the three experiments, although the level of significance differed.

Table 4. Effects of interactions between scratching and type of casing on the yield of different commercial categories in each of the experiments (*)

		Pla 8.9 strain			Blancochamp BL-40 strain			Gurelan 45 strain		
		S+SP	S+BP	S+CV	S+SP	S+BP	S+CV	S+SP	S+BP	S+CV
Large size mushrooms	Scratched	4.75	4.55	5.01	6.20	5.39	5.10	7.81	5.25	4.12 a
(kg m^{-2})	Non-scratched	6.33	5.15	4.92	7.73	6.44	5.12	7.59	5.16	6.49 b
Medium size mushrooms	Scratched	12.65	13.90	13.53	15.37	15.86	13.09	10.50	14.13	11.80
(kg m^{-2})	Non-scratched	11.07	12.59	11.26	13.16	14.11	11.91	9.27	12.46	10.89
Total marketable	Scratched	17.39	18.45	18.54	21.57	21.24	18.19	18.30	19.37	15.92
mushrooms(kg m^{-2})	Non-scratched	17.40	17.74	16.18	20.89	20.54	17.02	16.86	17.62	17.38
Non-marketable	Scratched	0.15	0.16	0.86	0.30	0.00	5.07	0.16	0.00	1.93
mushrooms (kg m^{-2})	Non-scratched	0.22	0.18	0.41	0.07	0.06	4.09	0.19	0.22	2.23
Total mushroom	Scratched	17.54	18.61	19.40	21.86	21.24	23.26	18.46	19.37	17.84
yield(kg m^{-2})	Non-scratched	17.62	17.92	16.59	20.96	20.61	21.10	17.05	17.84	19.60

(*) Values followed by a different letter within a column and class are significantly different at 5% level according to Tukey's test
S+SP: Soil + *Sphagnum* peat (4:1, v/v); S+BP: Soil + Black peat (4:1, v/v); S+CV: Soil + Composted vine shoots (4:1, v/v)

Composted vine shoots, used to improve structural and water holding characteristics of the mineral soil casing in mushroom cultivation, performed comparably with peat with regard to the quantitative production parameters considered. Regardless of the casing type used, scratching, in general, had a positive effect on fructification. It increased the number and yield of mushrooms produced m^{-2}, although they were of smaller size and individual weight. It also slightly brought forward the harvesting time of the first flush. The potential for substituting peat in mushroom casing with composted vine shoots is limited due to the appearance of spots caused by *Trichoderma* spp. on part of the fruit bodies. However, a controlled composting process and the application of a thermal and/or chemical treatment before mixing might inhibit the disease and provide the mushroom sector with a cheap material. Environmentally, there is also the advantage of using an abundant organic by-product instead of non-renewable peat resources.

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