INTERIM REPORT MAY 1995

HDC PROJECT NUMBER M20a

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The effects of casing materials and casing management techniques on the yield and quality of mushrooms

December 1994 - April 1995

Contents

	Page
Summary	1
Recommendations for future work	2
Future Experiments	3
Introduction	4
Materials and Methods	5
Cropping procedure	5
Mushroom cleanness and dry matter content	6
Casing treatments	6
Properties of casing materials	7
Results	7
Properties of peat sources	7
Conductivity and pH of casing materials	9
Physical Properties of casing materials	9
Moisture content of casing during cropping	10
Mushroom growth and yield	16
Mushroom dry matter content	16
Mushroom cleanness	17
Discussion	23
References	25
Photographs	

Summary

Following a survey of UK casing materials and practices, a controlled experiment was conducted to examine the most important trends and factors which emerged. This initial experiment should be regarded as preliminary results only; further experiments are needed to confirm the effects which were found. Four peat sources (two bulk extracted and two milled peats) and two lime sources (sugar beet lime and fine grade chalk) were compared. All of the peat/lime mixtures were examined at two different depths (45 and 55 mm) and at two different moisture levels. A milled black peat and a less decomposed bulk extracted peat were found to be almost equally suitable for casing in terms of mushroom yield and cleanness. When the effects of peat source, casing depth and moisture content were combined, relatively large difference in yield became apparent. The highest yielding individual treatment (milled black peat, 45 mm depth, lower moisture) yielded 348 kg/t compared with 255 kg/t for the lowest treatment (bulk black peat, 55 mm depth, higher moisture). A bulk brown peat with the lower moisture regime resulted in the cleanest mushrooms. No significant differences between sugar beet lime and fine grade chalk in terms of mushroom yield, cleanness or dry matter content were found when used at an inclusion rate of 100 kg/m^3 casing.

The bulk brown peat resulted in a significantly higher casing water retention than the other peat sources, and the sugar beet lime resulted in a significantly higher water retention than fine grade chalk. However, no relationships between physical or chemical properties of the casing and the yield or cleanness of the mushrooms were found. Pinhead formation was much greater in the milled brown peat/lower moisture treatment, resulting in a larger number

of smaller mushrooms than the other treatments.

The results of this experiment showed that the influence of growing conditions, particularly the time of airing, on the yield and cleanness of mushrooms may be at least as great as the effect of the casing materials. Although it was not apparent from the casing survey that the time of airing was varied in relation to the materials used, future experiments should include at least two airing times.

Recommendations for future work

1. This experiment has demonstrated significant differences in yield and cleanness between peat sources; future experiments should therefore concentrate on a range of peat types and sources.

2. No significant differences between fine grade chalk and sugar beet lime were found when used at 100 kg/m^3 casing. These materials should also be compared at a higher inclusion rate, as used in Dutch type casing mixtures (20% by volume, or about 250 kg/m^3 casing).

3. Casing depth and moisture content were found to influence the performance of all the casing mixtures, those factors should therefore be retained in further casing comparisons.

Future Experiments

In this series of experiments, the variables in the next experiment are:

a)	Peat source	i)	Brown (milled, partially dried and re-wetted)
		ii)	Black (milled, partially, dried and re-wetted)
		iii)	Brown (bulk, ex-bog, wet)
		iv)	Black (bulk, ex-bog, wet)
b)	Lime source	i)	Fine grade chalk (superfine)
		ii)	Sugar beet lime
c)	Rate of lime addition	i)	100 kg/m^3 casing (12:1 vol)
		ii)	260 kg/m^3 casing (3:1 vol)
d)	Time of airing	i)	6.5 days after casing
		ii)	7.5 days after casing
e)	Casing moisture	i)	1-2% below maximum water retention
		ii)	3-4% below maximum water retention

f) Control casing (Nooyen) aired after 6.5 and 7.5 days.

A commercial Phase II compost and strain Hauser A12 will be used. Spawned casing (Growmaster) will be used for all the treatments.

Evaluation will be by:

i) Yield
ii) Size grade
iii) Cleanness
iv) Dry matter content
v) Occurrence of panning and weed moulds
vi) Mycelial growth and colonization

Casing peat and mixtures will be assessed for pH, conductivity, water retention, bulk density and air filled porosity.

Introduction

In an HDC funded survey of UK casing materials and practices (Noble & Gaze, 1994) a wide range of casing materials (peat and lime sources) and casing practices were found. There was a significant trend for blacker, more decomposed peats to produce cleaner mushrooms. Blacker peats also resulted in more uniform sporophore distribution and less 'panning' although they were generally more expensive than brown peats. The factor in the survey which was most closely correlated with mushroom yield was casing depth, with the optimum in the range 45-55 mm. Casing moisture content increased with casing depth and peat blackness. The independent effects of chalk/lime source could not be clearly identified from the survey since sugar beet lime was generally used with black peats.

Due to the large number of different materials used on the farms and limited replication of individual types, no conclusions could be drawn regarding the best type of casing material within a particular category of blackness. Of particular interest was the difference between 'wet', bulk extracted peats and the partially dried, milled peats.

The technique of spawned casing (caccing) was used on 83% of the casings, and where this was practised, most farms 'aired' the growing rooms 5-7 days after casing. However, other environmental conditions in the growing rooms varied widely.

The aims of the present experiment were:

i) to determine if the trends found in the survey could be repeated under controlled conditions.

ii) to determine the effects of individual factors on mushroom yield and quality, in order to clarify the complexity of interactions of casing factors.

Materials and Methods

Cropping procedure

The experiment was conducted in a controlled environment cropping room using wooden trays (0.9 x 0.6 x 0.2 (deep) m). Each tray contained 50 kg compost spawned with the strain Hauser A12 and supplemented with Betamyl 1000 at 1% w/w. Fourteen days after spawning, the trays were cased with casing material which contained Hauser 'Growmaster' casing spawn (caccing), at a rate of 4 kg/m^3 casing. Casing materials were wetted and mixed before application in a mechanical mixer for 1-2 minutes depending on the material and desired moisture content. The compost temperature was maintained at 25°C (due to the smaller than commercial size trays, the air temperature could be maintained at 21-23°C; for larger trays, a higher compost temperature than 25°C will be required before airing). Fresh air was introduced into the growing room after 6.5 days to obtain a CO_2 concentration of 0.09-0.10% v/v; air temperature and relative humidity were maintained at 17°C and 90% respectively.

All the trays were watered immediately after the casing was applied. Further waterings to the higher and lower casing moisture treatments were adjusted to maintain the desired moisture levels. This was achieved by determining the moisture content of 4 x 200 g samples taken from each treatment at 2-3 day intervals.

Ten days after airing, the mycelial growth in the trays was assessed on a 1 (weak growth) to 5 (strong growth) scale. Mushrooms were picked as large buttons (diameter 30-40 mm) over a 27 day period (3 flushes), with the first flush being picked *c.* 17 days after application of the casing.

Mushroom cleanness and dry matter content

Before each flush was picked, the mushrooms on each tray were assessed for cleanness on a 0 (clean) to 5 scale (Noble & Gaze, 1994). After picking, three containers of 30 mushrooms from each tray from the first three flushes were assessed for cleanness (Photos 1-3). The percentage dry matter of 20 mushrooms from each tray from the first three flushes were determined according to Burton & Noble (1993).

Casing treatments

1. Peat sources
   - (i) Bulk extracted, wet dug (blackness 2.5 'brown')
   - (ii) Bulk extracted, wet dug (blackness 5 'black')
   - (iii) Milled (blackness 2.5 'brown')
   - (iv) Milled (blackness 4 'black')

2. Chalk/lime sources
   - (i) Chalk, superfine grade, 95% ≤ 20 microns
   - (ii) Sugar beet lime

Chalk or sugar beet lime were added at 100 kg/m^3 to achieve a casing pH of 7.6-7.8.

3. Casing moisture content

   (i) Maintained at 1-2% below the maximum water retention level

   (ii) Maintained at 3-4% below the maximum water retention level

4. Casing depth

   (i) 45 mm (ii) 55 mm

Properties of casing materials

Peat sources were assessed for decomposition according to 'blackness' on a modified von Post scale of 1 (young, pale) to 5 (decomposed, black) (Noble & Gaze, 1994). The following properties were determined on the peat sources and mixed samples of the casing materials: air filled porosity (AFP), bulk density (air dried material and at field capacity), water retention and pH (Anon, 1990).

Results

Properties of peat sources

The bulk extracted peats had a lower pH and conductivity but a higher ash content (non organic matter) than the milled peats (Table 1). Before mixing, moisture content, AFP and water retention were higher in the bulk peats than in the milled peats. Dry bulk density was higher for the blacker, more decomposed peats (bulk or milled) than for the brown peats.

Table 1 Properties of peat sources used in the casing materials

Peat source	pH	Conductivity µS	Moisture* %	Ash % of d.m.	A.F.P. + %	Dry bulk density, g/l	Water retention, %w/v
Bulk "brown"	5.6	58	89.6	7.7	6.5	149	92.9
Bulk "black"	4.9	72	88.7	5.7	6.3	303	92.0
Milled "brown"	3.6	94	66.2	2.2	4.2	154	86.0
Milled "black"	3.5	92	80.2	1.8	5.5	238	88.3

* Before addition of water
+ Air filled porosity

Conductivity and pH of casing materials

There were no significant differences in pH resulting from the use of different peat or lime sources, or different casing moisture contents. The pH of the casing did not change significantly during the growing period (Table 2). The conductivity of casings prepared with the different peat sources were similar before application, but casing prepared with sugar beet lime had a higher conductivity than that prepared with chalk (Table 2). The conductivity of all the casing treatments increased during cropping, but this increase was most pronounced in the bulk brown peat and 'drier' casing treatments.

Physical properties of casing materials

The AFP of casings prepared with the bulk peats was higher than that of casings prepared with the milled peats (Table 3). The lower moisture treatment also had a higher AFP than the wetter treatment. With the exception of casing prepared with milled brown peat, the AFP of the casing increased slightly during the growing period. Due to the lower AFP, the bulk density of milled peat casings was higher than that of bulk peat casings. The lime source did not affect the AFP but casing prepared with sugar beet lime had a significantly higher water retention and lower bulk density than casing prepared with chalk (Table 3).

The water retention of the bulk peat casings was significantly higher than that of the casings prepared with milled peat (Table 3). Within a particular peat type (bulk or milled) the browner peat casings had a slightly higher water retention than the black peat casings. During the growing period, the water retention of the bulk peats declined slightly whereas that of the milled peats remained unchanged.

Moisture content of casings during cropping

The effects of peat source, casing depth and chalk/lime source on casing moisture content are shown in Figures 1 - 3 respectively. These largely followed the same trend as the maximum water retention shown in Table 3. The bulk brown peat casing had the highest moisture content during cropping, whereas the milled peats had significantly lower moisture contents (Figure 1). There was no significant difference in moisture content between the two casing depth treatments. The 'wet' casing moisture treatment had, on average, a 2.5% higher moisture content than the 'dry' moisture treatment (Figure 2). The sugar beet lime casings had a significantly higher moisture content than the casings prepared with fine grade chalk (Figure 3).

Table 2 Effect of casing treatments on pH and conductivity, before application and after cropping

Treatment mean	Casing pH		Casing conductivity µS	
	Before	After	Before	After
Peat				
Bulk "brown"	7.69	7.62	304	600
Bulk "black"	7.60	7.59	310	491
Milled "brown"	7.76	7.74	275	384
Milled "black"	7.70	7.69	275	441
Lime source				
Sugar beet lime	7.71	7.67	339	510
Chalk	7.67	7.66	242	448
Moisture				
"Wet"	7.67	7.70	287	446
"Dry"	7.70	7.63	295	512

Table 3 **Effect of casing treatments on physical properties, before application and after cropping**

Treatment mean	Air filled porosity %		Bulk density g/l		Water retention % w/v	
	Before	After	Before	After	Before	After
Peat						
Bulk "brown"	9.7	10.9	603	-	84.5	83.3
Bulk "black"	8.0	11.3	644	-	82.3	80.3
Milled "brown"	5.9	3.8	679	-	78.4	79.0
Milled "black"	5.2	6.1	699	-	77.3	77.3
Lime source						
Sugar beet lime	7.1	8.0	639	-	82.5	81.3
Chalk	7.3	8.0	673	-	78.8	78.6
Moisture						
"Wet"	6.2	8.0	694	-	80.9	81.2
"Dry"	8.2	8.0	618	-	80.3	78.7

Fig. 1 Peat type and casing moisture content

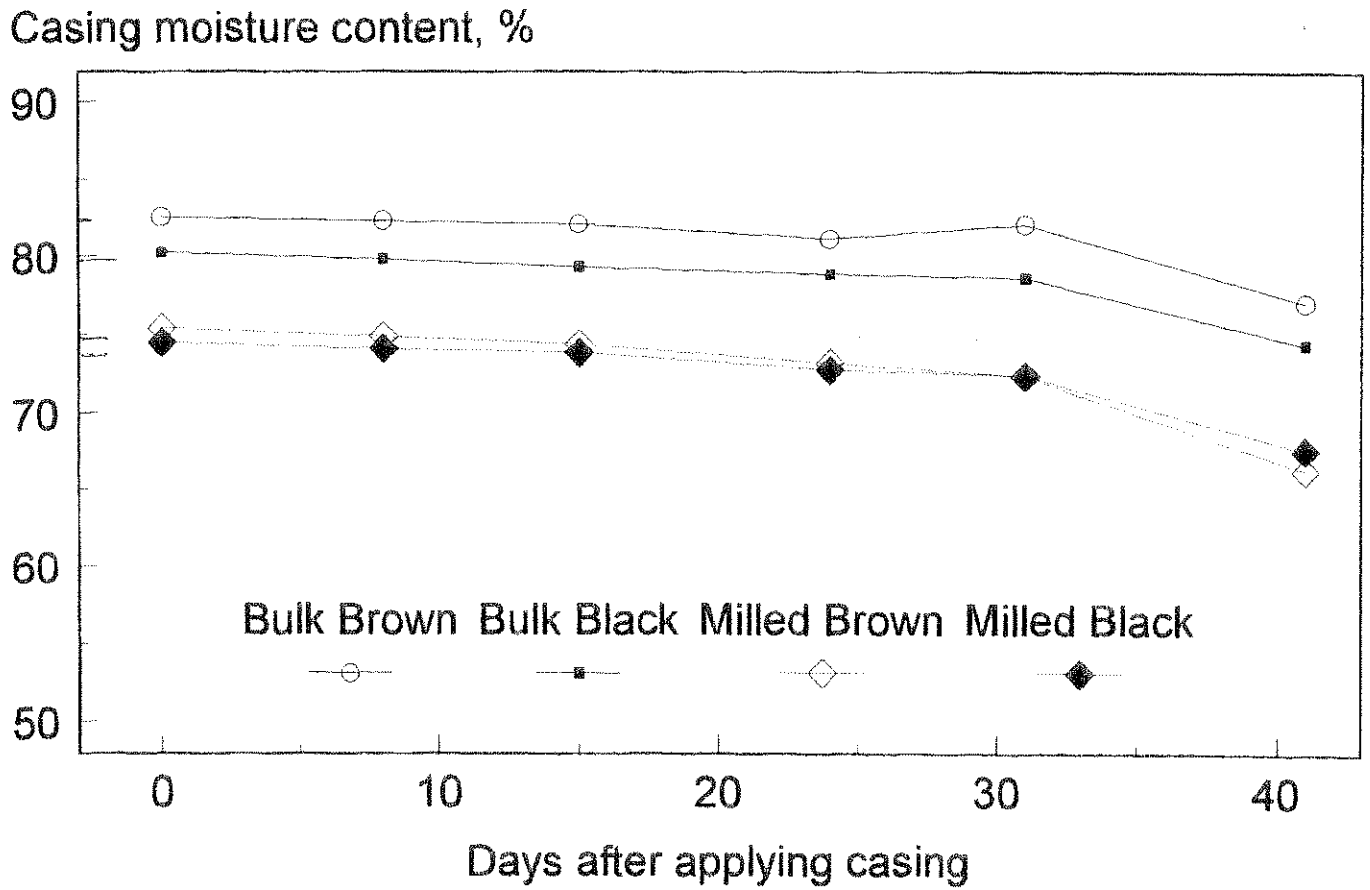


Fig. 2 Depth and moisture content of casing

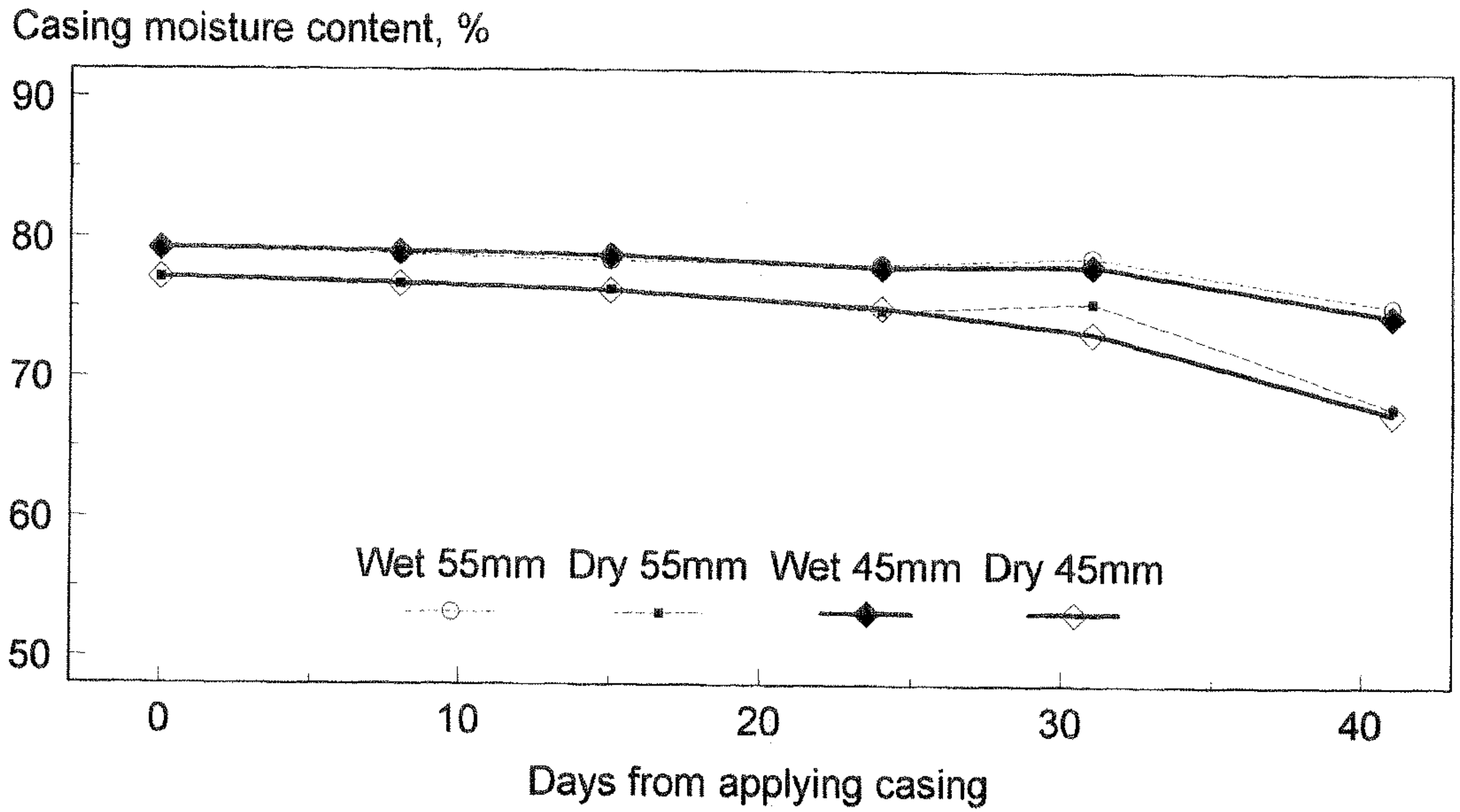
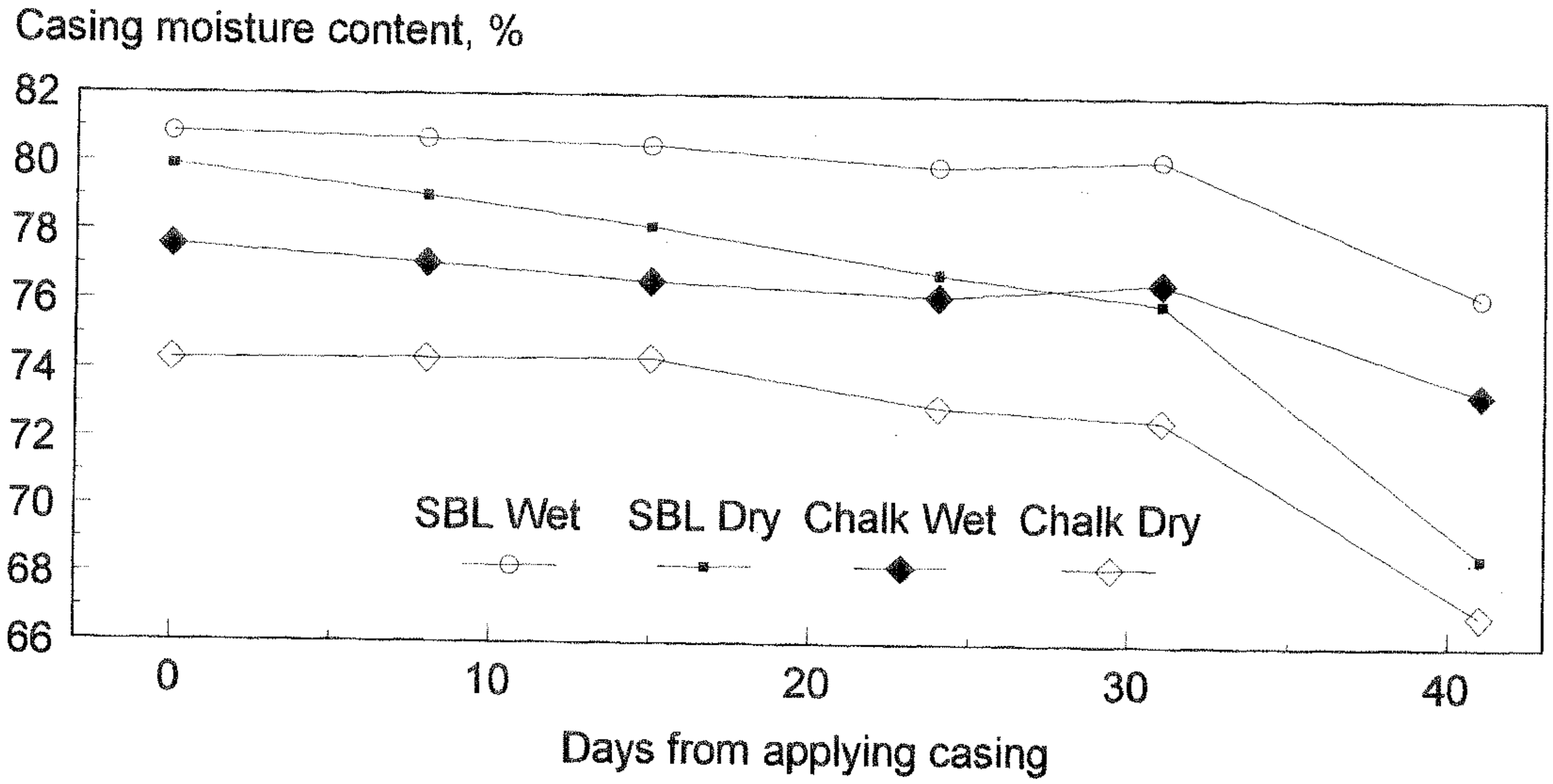


Fig 3. Effect of chalk type on casing moisture content



Mushroom growth and yield

Mycelial growth was stronger in the brown peat casings than in the black peat casings (Table 4). Growth was much stronger in the drier casing moisture treatment than in the wetter regime. The bulk brown peat and milled black peat resulted in a significantly higher mushroom yield than the bulk black peat (Table 5). The lower moisture level and shallower casing layer (45 mm) yielded slightly higher than the higher moisture level and deeper (55 mm) casing layer respectively (Table 5). When the effects of peat source, casing depth and moisture content were combined, relatively large differences in yield became apparent. The highest factorial treatment (milled black peat, 45 mm depth, lower moisture) yielded 348 kg/t compared with 255 kg/t for the lowest (bulk black peat, 55 mm depth, higher moisture) Appendix 1. Pinhead formation was much greater in the milled brown peat/lower moisture treatment, resulting in a larger number of small mushrooms compared with the other treatments (Table 4). There was no significant difference in yield between the lime sources.

Mushroom dry matter content

The bulk brown peat resulted in a lower dry matter content than the other peat sources (Table 6). The higher moisture level and shallower casing treatment resulted in lower dry matter contents than the lower moisture level and deeper casing treatments respectively. The individual treatment which resulted in the highest dry matter content was a bulk black peat casing, 55 mm depth and the drier moisture regime (Appendix 2). The lime source did not significantly affect the dry matter content of the mushrooms.

Mushroom cleanness

The bulk black peat resulted in significantly dirtier mushrooms than the other peat sources and this difference became more pronounced after picking (Tables 7 and 8). The lower moisture level resulted in significantly cleaner mushrooms than the higher moisture level (Table 7 and 8). There were no significant effects of lime source or casing depth on mushroom cleanness. Before picking, the first and third flushes were cleaner than the second flush (Table 7). However, this difference was not evident after picking (Table 8). The treatment which resulted in the cleanest mushrooms was bulk brown peat casing with the lower moisture regime (Appendices 3 and 4).

Table 4 Effect of peat and lime sources and casing depth and moisture level on mycelial growth

Treatment mean	Mycelial growth (1= weak ; 5 = strong)	L.S.D. *(P=0.05)*
Peat		
Bulk "brown"	3.9	
Bulk "black"	2.6	0.5
Milled "brown"	3.1	
Milled "black"	2.6	
Lime source		
Sugar beet lime	2.8	0.3
Chalk	3.3	
Moisture		
"Wet"	2.1	0.3
"Dry"	3.9	
Casing depth		
45mm	3.1	0.3
55mm	3.0	

Table 5 Effect of peat and lime sources and casing depth and moisture level on mushroom yield and dry matter content

Treatment mean	Dry matter, %	Small buttons, %	Mushroom yield kg/tonne	L.S.D.(yld) *(P=0.05)*
Peat				
Bulk "brown"	6.9	12.2	314	
Bulk "black"	7.2	11.4	290	16
Milled "brown"	7.1	17.4	306	
Milled "black"	7.1	12.8	322	
Lime source				
Sugar beet lime	7.1	13.9	.307	10
Chalk	7.1	13.0	308	
Moisture				
"Wet"	7.0	13.1	302	10
"Dry"	7.2	13.8	314	
Casing depth				
45mm	6.9	12.7	320	10
55mm	7.2	14.2	296	

Table 6 Effect of peat and chalk/lime sources and casing depth and moisture level on the dry matter content (%) of the first three flushes of mushrooms

Treatment mean	Flush 1	2	3	Mean	L.S.D. * (P=0.05)
Peat					
Bulk "brown"	7.1	6.7	6.9	6.9	0.2
Bulk "black"	7.3	7.2	7.2	7.2	
Milled "brown"	7.2	7.0	7.0	7.1	
Milled "black"	7.1	7.0	7.2	7.1	
Lime source					
Sugar beet lime	7.2	6.9	7.1	7.1	0.1
Chalk	7.2	7.0	7.1	7.1	
Moisture					
"Wet"	7.1	6.9	6.9	7.0	0.1
"Dry"	7.2	7.0	7.3	7.2	
Casing depth					
45mm	7.0	6.8	7.0	6.9	0.1
55mm	7.4	7.1	7.2	7.2	
Flush mean	7.2	7.0	7.1	-	

* Least significant difference between the means of 3 flushes within a treatment category

Table 7 Effect of peat and chalk/lime sources and casing depth and moisture level on the cleanness (before picking) of the first three flushes of mushrooms (1 = cleanest)

Treatment mean	Flush 1	2	3	Mean
Peat				
Bulk "brown"	3.9	4.1	3.6	3.9
Bulk "black"	4.0	4.3	4.0	4.1
Milled "brown"	3.8	4.0	3.7	3.8
Milled "black"	4.0	4.3	3.6	4.0
Lime source				
Sugar beet lime	3.9	4.1	3.7	3.9
Chalk	4.0	4.2	3.8	4.0
Moisture				
"Wet"	4.1	4.4	4.0	4.2
"Dry"	3.8	3.9	3.4	3.7
Casing depth				
45mm	4.0	4.2	3.8	4.0
55mm	3.8	4.1	3.6	3.8
Flush mean	3.9	4.2	3.7	-

Table 8 Effect of peat and chalk/lime sources and casing depth and moisture level on the cleanness of picked mushrooms from the first three flushes (1 = cleanest)

Treatment mean	Flush 1	2	3	Mean	L.S.D. * *(P=0.05)*
Peat					
Bulk "brown"	3.9	3.8	4.0	3.9	0.2
Bulk "black"	4.7	4.7	4.7	4.7	
Milled "brown"	4.3	4.2	4.3	4.3	
Milled "black"	3.9	4.0	4.2	4.0	
Lime source					
Sugar beet lime	4.2	4.2	4.3	4.2	0.2
Chalk	4.2	4.1	4.3	4.2	
Moisture					
"Wet"	4.6	4.4	4.5	4.5	0.2
"Dry"	3.9	3.9	4.2	4.0	
Casing depth					
45mm	4.3	4.2	4.4	4.3	0.2
55mm	4.2	4.1	4.3	4.2	
Flush mean	4.2	4.2	4.3	-	

* Least significant difference between the means of 3 flushes within a treatment category

Discussion

The use of sugar beet lime did not significantly affect the yield, cleanness or dry matter content of mushrooms compared with a fine grade chalk used at the same inclusion rate. Visscher (1988) reported that sugar beet lime gave the casing a denser structure resulting in a smaller number of larger mushrooms. However, sugar beet lime was added to the casing at 20-25% v/v (compared with 8% v/v in the present experiment) and it is possible that a similar affect would be achieved using an equivalent proportion of fine grade chalk. No effect of sugar beet lime on the size of mushrooms was found in the present experiment. The effects of adding sugar beet lime at 20-25% v/v should be compared with adding a similar amount of fine grade chalk in a further experiment.

Significant differences in the physical and chemical properties of different peat sources were found. The most reliable measure of the decomposition of the peat (which relates to peat 'blackness') was the dry bulk density of the material. There were an insufficient number of peat sources to determine if there were any significant relationships between physical or chemical properties and mushroom yield. The highest yields were obtained from a bulk 'brown' peat and a milled 'black' peat which had differing physical and chemical properties. Rainey *et al.* (1986) found a positive relationship between air filled porosity (AFP) and mushroom yield, although they investigated wide ranges in AFP (18 to 45% v/v) and casing materials, including peat, granulated bark and pumice. Flegg (1961) and Kalberer (1990) showed that the electrical conductivity and water potential of the casing layer influence the yield and dry matter content of the mushrooms.

Unlike the casing survey and a previous experiment at HRI Littlehampton (Noble & Gaze, 1995), no relationship between casing blackness and mushroom cleanness was found. A milled black peat and bulk brown peat resulted in significantly cleaner mushrooms, although deep pinning occurred in all the treatments.

A greater mushroom yield was obtained from the shallower (45 mm) and lower moisture content treatments. The higher moisture content treatment also resulted in dirtier mushrooms. Observations of mycelial growth in the casing indicate that the time of airing of the wetter treatments should be delayed (for the rate of caccing material used).

The shallower (45 mm) casing layer resulted in a lower dry matter content of the mushrooms than a deeper (55 mm) layer. Kalberer (1985) however found that mushroom dry matter content decreased with greater casing depth, but compared a greater difference (30 mm against 60 mm).

The results of this experiment have shown that the influence of the growing conditions, particularly the time of airing, on the yield and cleanness of the mushrooms may be at least as great as the effect of the casing materials. Although it was not apparent from the casing survey that the time of airing was varied in relation to the materials used, future experiments should include at least two airing times.

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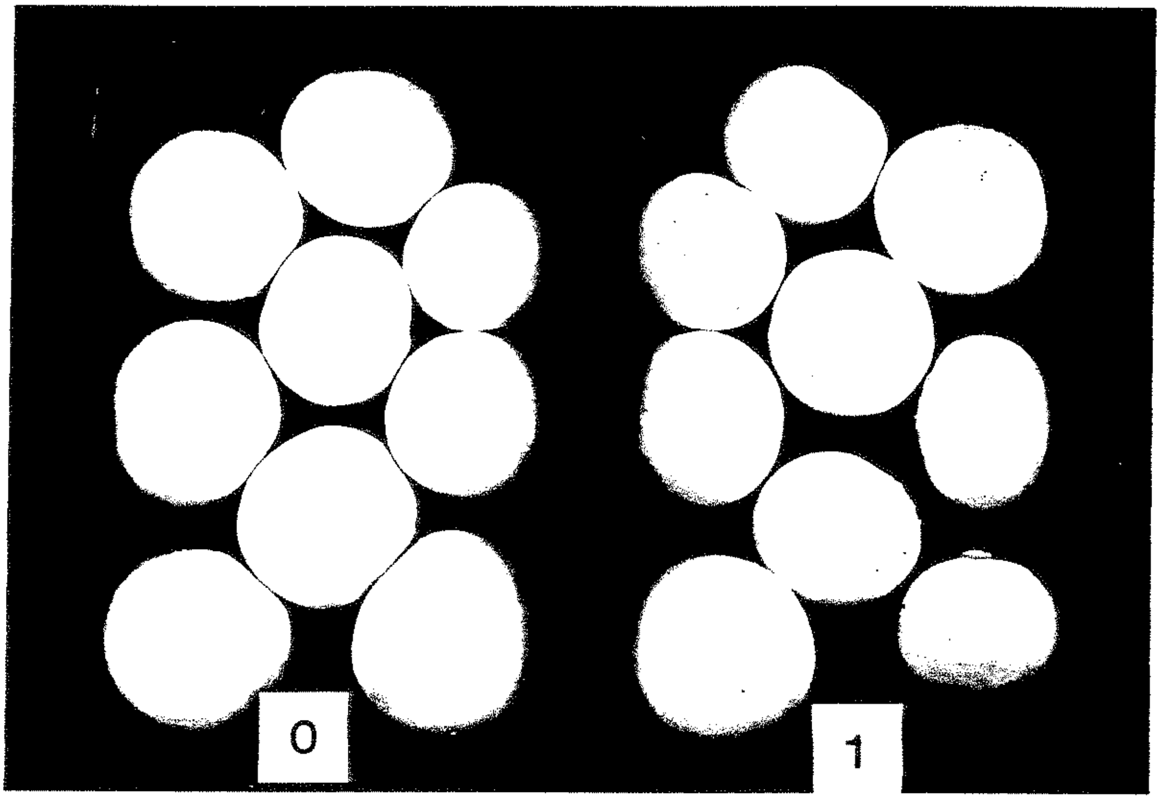

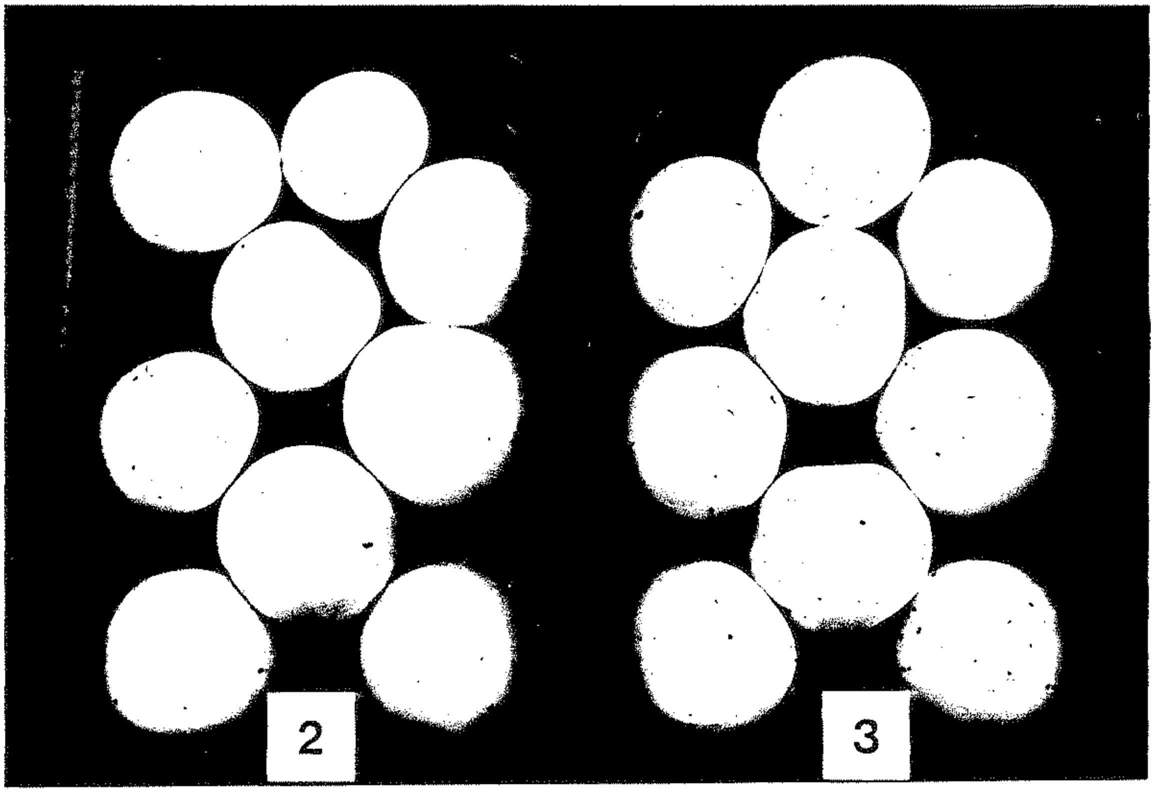

Photos 1 & 2 Mushroom cleanness scale (points 0 - 3)

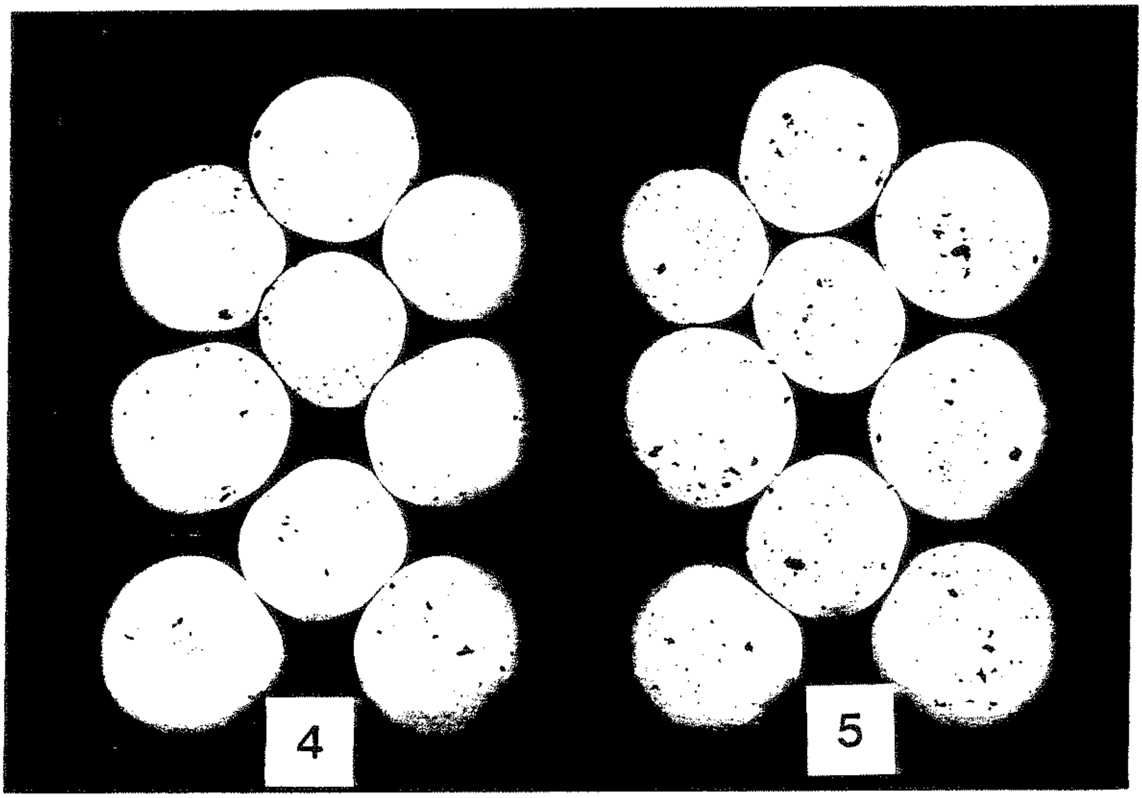

Photo 3 Mushroom cleanness scale (Points 4 &5)

Appendix 1 Effect of individual peat, casing depth and moisture treatments on mushroom yield, kg/tonne

Depth:	45 mm		55 mm	
Moisture:	Wet	Dry	Wet	Dry
Peat source				
Bulk "brown"	322	322	316	295
Bulk "black"	291	320	255	293
Milled "brown"	300	324	294	304
Milled "black"	331	348	304	304

Each value is the mean of chalk and sugar beet lime treatments

Appendix 2 Effect of individual peat, casing depth and moisture treatments on mushroom dry matter content, %

Depth:	45 mm		55 mm	
Moisture:	Wet	Dry	Wet	Dry
Peat source				
Bulk "brown"	6.7	6.9	6.9	7.2
Bulk "black"	7.1	7.1	7.4	7.4
Milled "brown"	6.9	7.0	7.1	7.2
Milled "black"	6.8	7.0	7.3	7.3

Each value is the mean of chalk and sugar beet lime treatments

Appendix 3 Effect of individual peat, casing depth and moisture treatments on mushroom cleanness before picking

Depth:	45 mm		55 mm	
Moisture:	Wet	Dry	Wet	Dry
Peat source				
Bulk "brown"	4.0	3.9	3.9	3.5
Bulk "black"	4.4	4.0	4.2	3.8
Milled "brown"	4.1	3.7	3.9	3.7
Milled "black"	4.2	3.8	4.0	3.8

Each value is the mean of chalk and sugar beet lime treatments
1 = cleanest; 5 = dirtiest

Appendix 4 Effect of individual peat, casing depth and moisture treatments on mushroom cleanness after picking

Depth:	45 mm		55 mm	
Moisture:	Wet	Dry	Wet	Dry
Peat source				
Bulk "brown"	4.3	3.8	4.0	3.7
Bulk "black"	5.0	4.3	5.0	4.4
Milled "brown"	4.7	4.1	4.4	4.0
Milled "black"	4.2	3.9	4.2	3.8

Each value is the mean of chalk and sugar beet lime treatments
1 = cleanest; 5 = dirtiest