Final Report for HDC

Project Title	Mushroom Quality: Use of bruisometer to determine which agronomic and environmental factors affect bruisability. I. Effects of compost depth, casing depth and compost duration.
Project Number	M 40
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Commercial benefits of the project

This project is aimed at providing new knowledge on which factors during the growing process cause mushrooms to be highly susceptible to bruising or more bruise resistant. Application of this knowledge will lead to the production and sale of high quality (less bruised) mushrooms which in turn may lead to commercial advantage as better price, contract retention and possibly increased sales.

Background and objectives

Quality is an important determinant affecting the competitiveness of the British mushroom industry. Discolouration, one of the main factors affecting quality, is caused either by ageing after harvest or bruising. Recently, a bruisometer has been designed and built (from HDC Projects M 19 and M 19a). This device can deliver a controlled amount of bruising force to a mushroom. It is known that mushroom bruisability varies from crop to crop and even within a crop, but it is not known which environmental or agronomic factors are affecting bruisability. A series of projects will seek to use the bruisometer to determine which environmental or agronomic factors can cause mushrooms to be susceptible to bruising. This project examines the effects of casing depth, compost depth and compost duration on bruisability.

Summary of results and conclusions

Initially, a strain trial was performed to identify the mushroom strain to be used for experimentation (the test strain). Eight different strains were grown under HRI Standard Operational Procedures. Mushrooms were harvested from three flushes, subjected to mechanical damage treatments and colour of the bruise was measured 2 hours later.

The test strain was selected but the experiment also showed that different strains have different degrees of bruisability. Flush number also affected the degree of mushroom bruising. Sometimes the order of best to worst flush number (in terms of bruise colour) was influenced by the strain type.

The crop experiment examined the effect of casing depth, compost depth and compost type on mushroom bruisability. Two casing depths were 25mm (shallow) and 50 mm (deep). Three compost depths were 40, 50 or 60 kg/tray. Different weights of compost were placed in 2 x 3 ft trays. Any effects could be due to either depth or density but as no effects were noted then this was not investigated further. Three different compost types were produced for the experiment, all with the same starting ingredients but with different durations of Phase I composting. These were type 1 (strawy, less degraded), type 2 ('normal') and type 3 (more degraded). These different treatments were applied to the growth of A15 mushrooms. The colour of bruised and unbruised regions of the mushrooms were measured and also the yield. The results can be summarised as follows:-

- Mushrooms grown on shallow casing were substantially less bruisable than those from deeper casing for second flush mushrooms.
- The strawy, less degraded compost resulted in less bruisable mushrooms.
- Compost depth had no effect on mushroom bruisability.
- Bruisability varied with flush number, with most strains being most vulnerable to bruising at flush numbers 1 and 2.
- Deeper casing and/or shallower compost resulted in higher yields.

The major agronomic influence on bruisability identified in this study is the depth of casing. At the moment, it is not known if this is an effect directly of the casing or whether it is an effect of water availability exhibited via the casing depth. This question will be examined in HDC project M 40a "Mushroom Quality; Use of the bruisometer to determine which agronomic factors affect bruisability. II. Effects of humidity, water potential of casing and casing type".

Action points for growers

This project (M40) is part of a series of HDC funded projects to establish all of the growing factors that can influence mushroom bruisability. This project examined the effects of compost depth, casing depth and compost duration. The particular growing system used by individual growers is a result of a combination of many factors (historical, farm design, availability of equipment, materials and labour) and if successful if unlikely to change radically due to any one report. However, if quality

problems are encountered or if farm procedures are to be overhauled then growers should note the main conclusions:-

1. Casing depth influences bruisability. Mushrooms grown on shallow casing were substantially less bruisable that those on deeper casing for the second flush mushrooms.
2. Strawy less degraded compost resulted in less bruisable mushrooms than more degraded composts.
3. Mushroom strain type can affect bruisability.
4. Growers do not need to be concerned with compost depth as that has no effect on mushroom bruisability.

Anticipated practical and financial benefits

This project is one of a series of projects which will examine all factors which might influence mushroom bruisabiity. From the work so far we can say that if farms have occasional or chronic quality problems of mushroom bruising, then growers should consider the mushroom strain grown, the depth of casing and type of compost as possible factors causing this problem. Reduction in the amount of bruising will lead to improved prices. The lost value of low quality mushrooms due to lost sales and down-grading resulting in lower returns can be estimated as a percentage of the total value of the crop as approx £15m. However, it should be appreciated that low quality can endanger the viability and sustainability of the entire business.

Science Section

Introduction

Quality is one of the main factors determining the competitiveness of the British mushroom industry. Mushrooms lose quality as a result of either 'senescence' (the process of natural deterioration in the hours and days after harvest), or mechanical damage (which results in rapid discoloration). HDC Project M 19 demonstrated that the mechanical process most damaging to mushrooms (in terms of bruising) is the process of 'slip-shear'. An example of slip-shear is when a finger slides over the surface of a mushroom with some downwards force. This occurs during picking and after harvest, when the mushrooms on the surface of the boxes and punnets are damaged as a result of the containers being tightly packed for transport and storage.

Bruising by slip-shear leads to discoloration, first reddish then brown. Although this browning reaction is biochemical, the differences between easily bruised and more difficult to bruise mushrooms are due to differences in their surface cellular arrangements rather than major biochemical differences. Certain combinations of growing conditions appear to lead to mushrooms which are either highly susceptible or resistant to bruising. The agronomic and environmental factors (flush, watering, casing, compost, humidity, strain and CO_2) which determine resistance or susceptibility are not known. This is because previously no machine has been available to exert a controlled amount of slip-shear force on to a mushroom (or any other item of produce).

HRI has been collaborating with the Mechanical Engineering Department of Coventry University in the design and building of two prototype bruisometers, devices to inflict a controlled amount of slip-shear force onto the surface of mushrooms. These bruisometers were released to HRI in June 1998. These bruisometers were validated (in HDC Project M 19a), i.e. they were shown that they could distinguish between mushrooms of different bruisabilities. Also the information of Project M 19a was used to make improvements to the design of the bruisometers. The collaboration with Coventry University has continued and the improved design bruisometer was handed to HRI in June 1999.

HRI and HDC are looking to identify the agronomic and environmental factors which cause mushrooms to be easily bruised. This knowledge will allow less bruised and therefore higher quality mushrooms to be grown. The factors to be examined over a series of projects will relate to compost, casing, watering and the environment (e.g. humidity, carbon dioxide level).

It was decided that the first project would examine compost and casing effects. In Project M 19, compost and casing depths were shown to profoundly affect mushroom texture. Mushrooms grown on deep casing and shallow compost were very soft. While bruisability does not necessarily correlate with texture, compost and casing depths are good candidates for key factors affecting bruisability. As part of the same experiment, mushrooms will be grown on different composts with different levels of degradation. The rationale behind this is the major difference in bruisability between first flush (often highly susceptible to bruising) and the remaining flushes. The hypothesis being considered is whether the flush differences are due to nutrition or nutritional availability.

Materials and Methods

Three main objectives were addressed in this project:

i. Identify a suitable test-strain of mushroom with moderate bruising characteristics.

ii. Assess the effects of casing depth and compost depth on mushroom bruisability.

iii. Assess the effects of compost degradation on mushroom bruisability.

The project is based around a strain trial and a crop experiment. Throughout all of the mushroom culture work, the Standard Operating Procedures of the HRI mushroom unit were applied (Willoughby and Gaze) unless stated otherwise.

Strain Trial

Spawn from eight white mushroom strains was obtained from a single spawn supplier. HRI formula III was separately inoculated and spawn-run with the eight spawn types. Four trays were spawned for each spawn-type. Each tray contained 50 kg of compost. After spawn-run the trays were cased in 50mm of casing containing compost inoculum relevant for each spawn.

Mushrooms were grown in the trays in a single growing room as per Standard Operating Procedures of the HRI Mushroom Unit. Twenty mushrooms were harvested of each strain for each of three flushes. For each strain-flush combination, ten mushrooms were subjected to a bruising treatment of 200g for 2 cycles and the remaining ten subjected to a 300 g for 3 cycles bruising treatment. The mushrooms were held in the growing room for 2 hours and then the colour of the bruise was measured at the top of the mushroom using a Minolta meter 503i.

Crop Experiment examining the effects of casing depth, compost depth and compost degradation

A factorial crop experiment was performed with: Two depths of casing (25 and 50mm) X Three depths of compost (expressed as weight of compost per tray, 40, 50 and 60 kg) X Three types of compost of different levels of straw degradation, i.e. 2 x 3 x 3 = 18 treatment combinations. The three composts were made at HRI using the same proportion of starting ingredients of straw, chicken litter and lime. Compost two is the normal formula III compost of HRI which received 14 days' composting at Phase I at that time of year. Compost one received 5 days' less composting (i.e. 9 days) and therefore had a strawy, less degraded appearance. Compost three received 5 days' additional composting (i.e. 19 days) and therefore had a heavier, more degraded appearance. The analyses of the compost at filling and at spawning are shown in Tables 1(a) and (b). After the differences in the duration of composting at Phase I between the composts, thereafter the composts were treated identically as per Standard Operating Procedures. Different weights of compost were placed in 2 x 3 ft trays. Any effects could be due to either depth or density but as no effects were noted then this was not investigated further.

Phase II composts were then spawned with A15 spawn and filled into trays at 40, 50 or 60 kg compost per tray. After spawn run, the trays were covered in casing by either 25 or 50 mm casing. The casing was supplied by L & P Peat containing 30% sugar beet lime and 70% peat. Eight trays (i.e. two stacks of four trays) were used for each compost depth - casing depth - compost duration combination.

The mushrooms were grown in a large growing room at HRI mushroom unit. The stacks of each treatment combination were placed in the growing room in two blocks (i.e. in two halves of the room), each block containing all 18 treatment combinations. The stacks were randomised within each block. Mushrooms were

harvested from each stack for each of the three flushes. Fifteen clean, white, blemish-free mushrooms were selected for each harvest per stack and subjected to the bruising treatment of 200g by 2 cycles. The mushrooms were placed cap uppermost into the growing room so that the bruise colour developed in the environment of the growing room. After two hours the colour of the mushrooms was measured in 5 positions; at the centre of the bruise, at two positions at the side of the bruise and at two positions on the unbruised part of the cap adjacent to the centre and side (figure 1).

The mushroom harvest, bruising and colour measurement were first performed on the mushrooms from the first block and then mushrooms from the second block. In this way, the blocking can account for the variability in space (within the growing room) and time of harvest and testing.

Statistical Analysis

Bruise colour data from the strain trial were statistically analysed by analysis of variance. For the crop experiment, the data were analysed by analysis of variance and analysis of co-variance where the bruise colour was compared with the colour of the non-bruised cap to eliminated any differences in non-bruised cap colour as a result of the treatments.

The Minolta meter produces three items of colour data:-

'L' - is a colourless or monochromatic scale of lightness to darkness where 100 is pure white and 0 is matt black.

'a' and 'b' are opponent colour scales.

'a' - refers to redress when the value is positive or greenness when negative.

'b' - refers to yellowness when value is positive or blueness when negative.

To identify treatment differences, the L value is mathematically transformed to degree of discoloration = $\log_{10}$ (100 - L). However, the values are presented as L values as the differences are proportionally greater and therefore more clearly followed.

Results and Discussion

Strain Trial

L - value (lightness to darkness; 100 = pure white, 0 = matt black)

A significant difference (at the 0.001 level) was found between flushes. Third flush mushrooms had the highest L value in the bruise (i.e. were least discolored) compared with first and second flush mushrooms (Table 2). Although on average there was no difference between first and second flush mushrooms, the interaction between strain and flush was highly significant (0.001 level) i.e. for some strains flush 1 was the more discolored while for other strains flush 2 had more discoloration (Table 3). Third flush mushrooms were consistently the least discolored.

The effects of different strains and the two bruising treatments were highly significant, both at the 0.001 levels (Table 4). The 300g by 3 cycles bruising treatment caused lower L values i.e. more discoloration that the 200g by 2 cycles. This is not surprising as more force was used for a longer duration.

For both cases, strain 7 had the least discolored bruise i.e. the highest L value. The statistical measure used here to identify differences is the Least Significant Differences or LSD. For these data the LSD is 1.7. So, if 1.7 is subtracted from the highest value of the 200g x 2 cycles treatment, i.e. for strain 7, 84.2, then the result is 82.5. Only two other strains fell within the range of 82.5 - 84.2. These were strains 2 and 8. If a similar exercise is performed for the 300g x 3 cycles data, then the range if 77.3 - 79 and a total of 5 strains fell within that range.

The interpretation made from the above is that the 300g x 3 cycles bruising treatment is too severe and subtle strain differences are being lost by overdamaging during bruising. In the following crop experiment only the 200g x 2 cycles bruising treatment was applied.

'a' value - redness

The effects of flush, strain and bruising treatment were all significant (0.001). On average flush 3 mushrooms were the least red when bruised followed by flush 2 and then flush 1 mushrooms. However, considerable flush x strain interactions were observed. In strain 1, second flush mushrooms were more red coloured than first flush mushrooms and in strain 6 no difference could be observed between any of the flushes (Table 5). For all other strains, flush 3 mushrooms were the least red followed by flush 2 and then flush 1.

The effects of strain and bruising treatment on the red colour of the bruise are shown in Table 6. Strain 7 had the least red colour when bruised by the 200g x 2 cycle treatment. The LSD is 0.51, so the strains with red colour, not significantly different from strain 7, are strains 2 and 8. For the 300g x 3 cycle treatment, strain 8 is the least red in colour on the bruise. Other strains within the range of strain 8 are strains 1, 2, 3, and 7.

'b' value - yellowness

Significant differences were observed in the yellowness of the bruised mushrooms from different flushes, strain and bruise treatments. First flush mushrooms were the most yellow after bruising (highest 'b' value), followed by second and then third flush mushrooms. Table 7 shows the yellowness of a bruise by strain and by flush number. The effects of strain and bruising treatment on the yellow colour of the bruise are shown in Table 8. Strain 7 is the least yellow when bruised by the 200g x 2 cycle treatment. Only one other strain (strain 2) fell within the range of its LSD. (i.e. 11.0 + 0.7). With the 300g x 3 cycles bruising treatment, strain 1 is the least yellow and all of the other strains fell within the range of the LSD (127 + 0.7).

Conclusions and comments of the Strain Trial

1. Mushroom bruisability differed with flush number. On average, first and second flush mushrooms had darker bruise colour ('L' value) than third flush mushrooms. In terms of redness and yellow ('a' and 'b' values), the bruise of first flush mushrooms had the strongest colour followed by second flush and then third flush mushrooms. However, there were some strain x flush interactions indicating that flush effects of bruisability is influenced by strain type.
2. Different strains have different bruisabilities. Consistently, strain 7 is amongst the least bruised of strains. It was decided that strain 7, A15, would be chosen as the test strain for future experiments. This is because it is a highly popular strain and therefore relevant for investigation. To work on an easily bruised strain would be less informative.

   Please note:- This strain trial was an exercise to determine the test strain and not an attempt to identify the best and worst strains. A15 is the strain normally grown at HRI and the growing regime for the growing room was optimised for strain 7. It

is quite possible that, if other strains were grown at their optimal conditions, then they may have been less bruisable.

3. The bruising treatment of 200g x 2 cycles was the more discrimatory treatment and so it was chosen as the test mechanical treatment for future experiments.

Crop Experiment

Data from the crop experiment examining the effects of casing depth, compost depth and compost type on bruising were statistically analysed by analysis of variance and analysis of co-variance. Analysis of variance was based on measurements from individual positions e.g. bruised top of mushroom, bruised side, unbruised top, unbruised side. The means from the data from bruised positions therefore represent the colour of the bruise but not taking into account whether the mushroom had a different colour as a result of the treatments before the bruising treatment. Analysis of co-variance compared the bruise colour with the unbruised colour for the same position (e.g. top or side) and therefore concentrated on the effect of bruising alone.

The trends of treatment effects for both types of analysis were similar. The results below will quote the analysis of co-variance as the effects are 'sharper' and relate only to the effects of bruising. However, it is worth noting that flush number significantly affected the colour of unbruised regions of the mushroom using analysis of variance (Table 9). Unbruised mushrooms from the second flush were the whitest mushrooms followed by first flush mushrooms and then third flush mushrooms which were considerably less white in colour.

L-value

Flush number had a major and significant effect (0.001) on the colour of the bruise (Table 10). Flush three mushrooms had the darkest bruise, followed by flush one mushrooms which were similar to but with a slightly darker bruise than second flush mushrooms (which were the lightest in colour).

Casing depth significantly affected bruise colour (0.001) with the shallower casing on average resulting in less bruised mushrooms than the deeper casing. However this overall average result should be considered with the finding that a significant interaction (0.001) occurred between casing depth and flush number. Examination of the data revealed that the effect of casing depth on bruising colour occurred only in second flush mushrooms (Tables 11 and 12). When examining the

bruise colour on both the tops and sides of the mushroom, there is no effect of casing depth on first or third flush mushrooms. However for the second flush mushrooms a clear and significant difference were identified. Second flush mushrooms grown on shallow casing bruised less than when grown on deeper casing. This difference could be detected by the eye (i.e. of the consumer).

A small but significant effect (0.01) was found for the compost type on mushroom bruisability. Mushrooms grown on type 1 compost (strawy and less degraded) were slightly lighter in colour when bruised than mushrooms grown on the other two composts (Table 13) for the bruise at the top only.

Compost depth had no great effect on mushroom bruisability.

'a' - value (Redness)

Mushrooms bruises had a low and positive 'a' colour value i.e. slightly red coloured. The bruises of third flush mushrooms were significantly more red in colour than of first or second flush mushrooms (Table 14).

As with the 'L' value above, there was a significant effect (0.001) on casing depth on the redness of the bruise. On average mushrooms grown on shallow casing were less red than those grown on deeper casing. However, as with the 'L' value, the effect was observed only in second flush mushrooms (Tables 15 and 16). No differences were observed in the redress of bruises from first or third flush mushrooms (i.e. the 'a' values are equal to or less than the LSD). However, the second flush mushrooms grown on shallow casing are significantly less red than if grown on deeper casing.

No major effects were found of compost depth or compost type on redness.

'b' - value (yellowness)

The average 'b' values of the bruise colour fell into the range of 11-14 indicating some yellowness. The bruises of first flush mushrooms were on average slightly more yellow than of second (the least yellow) and third flush mushrooms (Table 17). Mushroom grown on deeper casing were slightly but significantly less yellow than grown on shallow casing. This effect was largely observed in third flush mushrooms (Tables 18 and 19).

No consistent compost type or compost depth effects on yellowness of bruising were observed.

Yield

The average yield of mushrooms for the experiment for all treatments combined was 192 kg/tonne. This is less than the average for the HRI mushroom unit and is due to the fact that the 18 different treatment combinations were grown in a single growing room and so the growing conditions could not be optimised for any one treatment. Casing depth had a significant effect on yield (0.001), the deeper casing resulting in greater yield (Table 20). Compost depth also had a significant effect on yield (0.001) the shallower compost producing a greater weight of mushrooms (Table 20).

Conclusions and Comments from the Crop Experiment

1. The colour of the mushroom before and after a bruise differed with flush number. Overall second flush mushrooms were the lightest or the least discoloured either before or after the bruising treatment. First flush mushrooms were slightly more discoloured than from the second flush while third flush mushrooms were much more discoloured. This result is in contrast to the strain trial where third flush mushrooms were the least discoloured. Between the two experiments different strains and growing conditions (casing depth, compost depth and type) were used. This is, however, a further illustration of how growing conditions can influence bruisability.
2. Casing depth had a profound effect on mushroom bruisability for second flush mushrooms. Shallow compost resulted in less discoloration after bruising. At this point in time, it is not known whether this effect is directly a casing depth effect or whether it relates more to water availability.
3. Compost type had a minor effect on bruisability. Less degraded compost resulted in slightly less bruising colour.
4. Compost depth had no effect on bruisability. This was surprising as compost depth had a major influence on texture (tissue stiffness). This indicates that the agronomic and environmental factors which can influence texture do not necessarily have any influence on bruisability. This is presumably because texture is determined by the arrangement of cells throughout the entire depth of a mushroom while bruisability relates to the cellular arrangement at the surface only.

5. Discoloration at a bruise is largely due to general darkening with approximately equal contributions of more redness and yellowness.
6. Deeper casing and/or shallower composts result in higher yields.

References

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Figure 1 showing the 5 positions on the mushroom where colour was measured, three within the bruise area and two outside of the bruise.

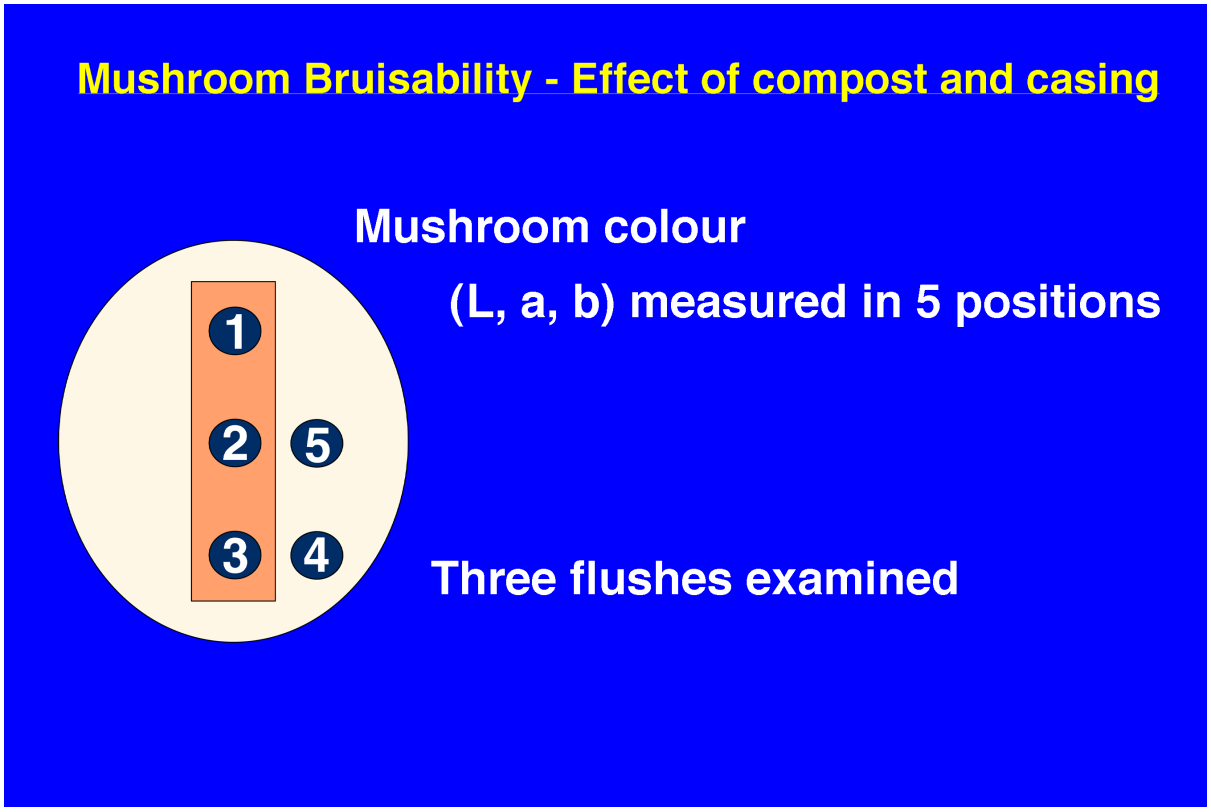

Table 1(a) Crop Experiment - compost analysis at filling

	Compost type		
	1	2	3
	'strawy, less degraded'	'normal'	'more degraded'
Water (%)	77.1	76.4	76.4
Nitrogen (%)	2.12	2.09	2.15
Ammonia/ammonium	0.20	0.21	0.21
PH	7.9	7.9	7.8
Ash (%)	20	21	20

Table 1(b) Crop Experiment - compost analysis at spawning

	Compost type		
	1	2	3
	'strawy, less degraded'	'normal'	'more degraded'
Water (%)	71.8	72.4	72.9
Nitrogen (%)	2.29	2.23	2.48
Ammonia/ammonium	0.067	0.097	0.083
PH	7.8	7.8	7.7
Ash (%)	27	27	25

Table 2. Strain Trial - the effect of flush number on bruise colour - 'L' (higher value of 'L' represents a white colour)

	Flush Number		
	1	**2**	**3**
Bruise colour - 'L'	77.7	78.0	83.2
			LSD = 0.39

Table 3. Strain Trial - effect of flush number and strain on discoloration (L) of bruise

Strain	Flush Number		
	1	**2**	**3**
1	74.8	75.8	83.2
2	77.0	79.7	85.1
3	78.5	77.3	84.0
4	79.1	75.7	80.6
5	73.8	76.4	83.9
6	79.5	79.3	80.8
7	80.1	79.9	84.8
8	78.5	79.9	83.4
			LSD = 2.1

Table 4. Strain Trial - the effects of strain and bruise treatment on bruise colour

Colour of Bruise - L (higher number represents whiter colour)

Strain Number	Bruise Treatment	
	200g x 2 cycles	**300g x 3 cycles**
1	81.3	74.6
2	83.1	78.1
3	81.6	78.3
4	81.9	75.0
5	80.3	75.8
6	81.8	78.0
7	84.2	79.0
8	82.8	78.4
		LSD = 1.7

Table 5. Strain Trial - effect of flush number and strain on redness ('a') of bruise

Strain	Flush Number		
	1	2	3
1	3.05	4.56	1.88
2	4.53	3.33	2.03
3	4.19	3.74	2.69
4	4.21	3.76	3.51
5	5.69	4.42	2.10
6	3.83	3.68	3.70
7	3.38	2.84	2.21
8	3.72	2.62	2.27
			LSD = 0.32

Table 6. Strain Trial - the effects of strain and bruising treatment on redness of bruise ('a')

Strain Number	Bruise Treatment	
	200g x 2 cycles	300g x 3 cycles
1	2.81	3.52
2	2.78	3.81
3	3.30	3.80
4	3.23	4.42
5	3.44	4.70
6	3.26	4.22
7	2.20	3.42
8	2.44	3.31
		LSD = 0.51

Table 7. Strain Trial - effect of flush number and strain on yellowness 'b' of bruise.

Strain	Flush Number		
	1	2	3
1	12.8	12.8	10.8
2	15.8	11.7	10.8
3	15.5	12.2	11.2
4	14.1	12.2	12.3
5	16.1	12.3	10.6
6	15.1	12.0	11.5
7	13.8	11.5	10.8
8	14.6	11.8	12.1
			LSD = 0.8

Table 8. Strain Trial - the effects of strain and bruising treatment on yellowness of bruise ('b')

Strain Number	Bruise Treatment	
	200g x 2 cycles	300g x 3 cycles
1	11.6	12.7
2	12.2	13.3
3	12.5	13.4
4	12.4	13.3
5	12.6	13.4
6	12.2	13.4
7	11.0	12.8
8	12.2	13.4
		LSD = 0.7

Table 9. Crop Experiment - effect of flush number on the colour 'L' of unbruised regions of the mushroom. Note the higher the value of L, the whiter the mushroom

Position on Mushroom Cap	Flush Number		
	1	**2**	**3**
Top of Mushroom	87.3	88.0	84.6
Side of mushroom	87.3	88.2	85.5
			LSD = 0.3

Table 10. Crop Experiment - effect of flush number on the colour 'L' of the bruise on mushroom caps

Position on Mushroom Cap	Flush Number		
	1	**2**	**3**
Top	78.8	79.6	76.2
Side	79.3	80.1	75.5
			LSD = 0.5

Table 11. Crop Experiment - effect of casing depth and flush number on colour of bruise 'L' on the tops of mushrooms

Casing Depth	Flush Number		
	1	**2**	**3**
Shallow	79.0	81.0	76.3
Deep	78.7	78.2	76.2
			LSD = 0.7

Table 12. Crop Experiment - effect of casing depth and flush number in colour of bruise 'L' on the sides of mushrooms.

Casing Depth	Flush Number		
	1	**2**	**3**
Shallow	79.5	81.5	75.5
Deep	79.1	78.8	75.5
			LSD = 0.6

Table 13. Crop Experiment - effect of compost type on colour of bruise 'L' on tops of mushrooms

	Compost type		
	1	2	3
	'strawy, less degraded'	'normal'	'more degraded'
L	78.7	78	78

LSD = 0.5

Table 14. Crop Experiment - effect of flush number on redness 'a' of mushroom bruise

Position on Mushroom Cap	Flush Number		
	1	**2**	**3**
Tops	1.14	1.18	2.04
Sides	1.01	0.88	2.09
			LSD = 0.12

Table 15. Crop Experiment - effect of casing depth and flush number on the redness 'a' of the bruise on tops of mushrooms

Casing Depth	Flush Number		
	1	**2**	**3**
Shallow	1.16	0.88	2.05
Deep	1.12	1.47	2.03
			LSD = 0.16

Table 16. Crop Experiment - effect of casing depth and flush number on the redness 'a' of the bruise on sides of mushrooms

Casing Depth	Flush Number		
	1	**2**	**3**
Shallow	0.98	0.46	2.01
Deep	1.04	1.31	2.17
			LSD = 0.16

Table 17. Crop Experiment - effect of flush number on yellowness ('b value) of bruise on tops and sides of mushrooms

Position on mushroom cap	Flush Number		
	1	**2**	**3**
Top	13.0	11.4	12.7
Side	13.2	11.4	12.8
			LSD = 0.2

Table 18. Crop Experiment - effect of casing depth and flush number on the yellowness, 'b', of the bruise on tops of mushrooms

Casing Depth	Flush Number		
	1	**2**	**3**
Shallow	13.2	11.3	13.0
Deep	12.8	11.5	12.3
			LSD = 0.3

Table 19. Crop Experiment - effect of casing depth and flush number on the yellowness, 'b', of the bruise on sides of mushrooms

Casing Depth	Flush Number		
	1	**2**	**3**
Shallow	13.3	11.4	13.2
Deep	13.2	11.5	12.3
			LSD = 0.3

Table 20. Crop Experiment - effect of casing depth and compost depth on mushroom yield (kg/tonne).

Casing Depth	Compost depth (kg/tray)		
	40	**50**	**60**
Shallow	189	175	163
Deep	224	209	189
			LSD = 8