Project title:	Relationship between Laboratory Resistance and Practical Control of *Dactylium dendroides*
Report:	Final Report (July 1998)
Project number:	M 30
Project leader:	Helen Grogan HRI Wellesbourne Warwick CV35 9EF
Location:	HRI Wellesbourne
Project Co-ordinator:	Mr Harold Linfield Chesswood Produce Ltd Chesswood Nurseries Thakeham Pulborough W Sussex RH20 3EL
Date commenced:	July 1997
Date completed:	July 1998
Keywords:	*Dactylium*, fungicides, efficacy, chemical control, resistance

CONTENTS Page No

PRACTICAL SECTION FOR GROWERS

Summary

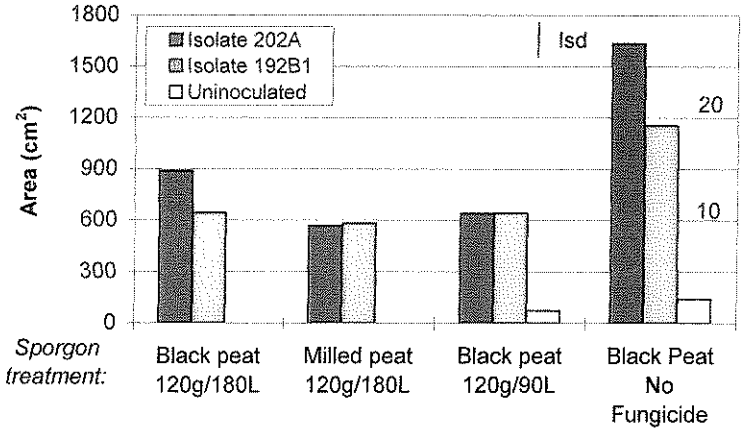
This project was commissioned to examine the efficacy of the fungicides Sporgon, Bavistin and Hymush in controlling *Dactylium* caused by two isolates with different fungicide resistance profiles in order to relate laboratory results to practical control. All British isolates screened in the recent HDC survey (M 14a) showed an ability to tolerate Sporgon at moderate concentrations under laboratory conditions and were termed "partially-resistant" to Sporgon. Eighty percent (80%) of isolates were "partially-resistant" to Bavistin and "totally-resistant" to Hymush (characterised by isolate 192B1). Twenty percent (20%) of isolates were "sensitive" to Bavistin but were "partially-resistant" to Hymush (characterised by isolate 202A). Cropping experiments were carried out using these two isolates to represent the two groups in conjunction with different application treatments of the fungicides Sporgon, Bavistin and Hymush.

Sporgon did not prevent spotting or cobweb symptoms from developing when two "partially-resistant" isolates were used to infect a crop, but it significantly reduced the area of cobweb which developed despite a high inoculum load at pinning. It may be more effective under lower inoculum loads but it cannot be relied upon to give total control. "Partially-resistant" best describes these isolates in relation to practical control by Sporgon.

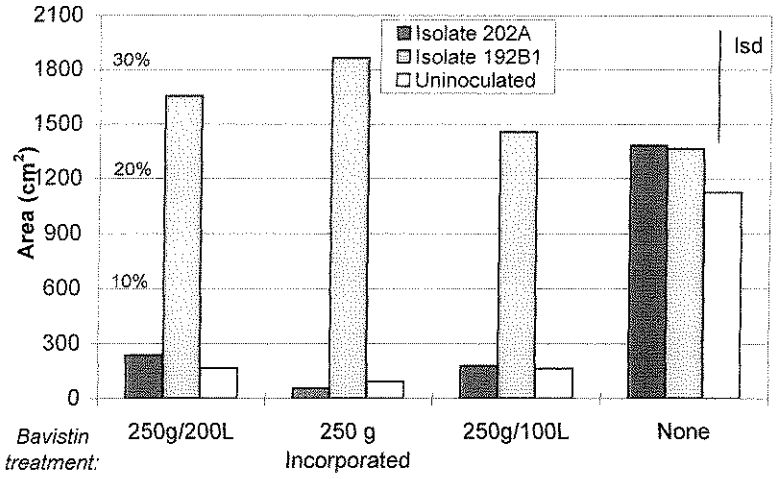
Bavistin was very effective against the sensitive isolate 202A (following inoculation at pinning), preventing both spotting and cobweb symptoms from developing well into the second flush. Its efficacy is likely to be reduced in the latter stages of the crop as the concentration of the active ingredient falls during the cropping period. Isolate 192B1, which was "partially-resistant" to Bavistin under laboratory conditions was not controlled at all by Bavistin under cropping conditions with massive spotting and cobweb developing by the end of the second flush. This type of isolate should now be known as "Bavistin-resistant". These isolates are also totally Hymush resistant.

Hymush was very effective against isolate 202A which was "partially-resistant" to Hymush under laboratory conditions. It did not prevent spotting symptoms from developing but it reduced their number significantly. Hymush applied at casing (230g/100m^2), followed by two interflush applications (85g/100m^2) resulted in very little spotting or cobweb developing, despite the introduction of a very high inoculum load at pinning. This type of isolate should now be known as "Hymush-sensitive".

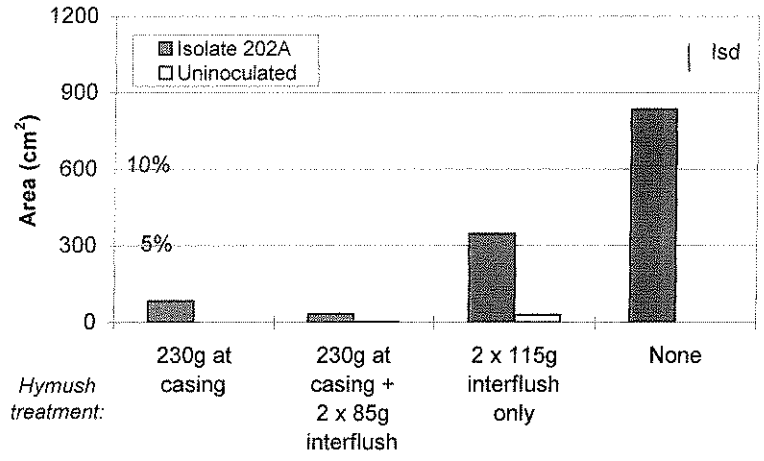
Area of cobweb at the end of 2nd flush following different Sporgon and inoculation treatments.



Area of cobweb (end of 2nd flush) following different inoculation and Bavistin treatments



Area of cobweb (end of 2nd flush) following different inoculation and Hymush treatments



Action points for growers

Successful disease control depends on a complex combination of measures involving (i) good hygiene measures to reduce inoculum loads; (ii) knowledge of the fungicide sensitivity of the offending pathogen; (iii) knowledge of the persistence of a given fungicide in the casing over time; (iv) confidence in fungicide application techniques to ensure good coverage of the casing; (v) choice of the most appropriate fungicide for the offending pathogen. The following are a number of practical points which may help to put the results presented in this report into an integrated control strategy.

1. The greatest source of *Dactylium* inoculum is a small, un-noticed, patch of cobweb on the casing which is inadvertently watered at the end of a flush. This releases millions of dry spores into the air which can cause massive spotting and cobweb symptoms in subsequent flushes. Be extra vigilant prior to watering events, particularly if you suspect *Dactylium* may be present. Deal with areas of cobweb carefully, minimising spore disturbance. Use strong but flexible tissue to gently cover areas prior to salting or disinfecting.

2. The fungicide resistance profile of pathogens (in this case *Dactylium*) needs to be clearly established to determine the choice of chemical to be used.

3. Be aware that the concentration of Bavistin in the casing will decrease during cropping to near zero by the end of the second flush (M14a).

4. Be aware that the concentration of Sporgon will be reduced to about half the amount applied by the end of the third flush. In view of this, and the partially-resistant nature of *Dactylium* isolates, always apply two 120g/100m^2 doses (M26).

5. Ensure that the full rate is of fungicide is being applied based on the label rates/100m^2. Incorrect dosing and application can markedly reduce the actual concentration of fungicide in the casing compared to the target concentration. Have the casing tested if you are unsure.

SCIENCE SECTION

Relationship between Laboratory Resistance and Practical Control of *Cladobotryum (Dactylium) dendroides*

1. Introduction

Work already commissioned by the HDC (Project M 14a) has shown that a significant number of British *Dactylium* isolates are completely resistant to Hymush while at the same time, being only partially resistant to Bavistin and Sporgon (Grogan & Gaze, 1996). A smaller number of isolates were more sensitive to both Hymush and Bavistin but they, too, were also partially resistant to Sporgon. These observations were based on laboratory tests so it is important to relate them to the performance of the fungicides in a cropping situation.

In the past, *Verticillium fungicola* developed complete resistance to the benzimidazole fungicide benomyl, active ingredient in Benlate, rendering the product ineffective against this pathogen (Fletcher & Yarham, 1976). If pathogens demonstrate a high degree of resistance under laboratory conditions then the fungicide in question is unlikely to be effective in a cropping situation. Thus, it is unlikely that Hymush will control highly-resistant isolates of *Dactylium*. However, resistance to fungicides is not always total and different degrees of resistance can be observed. In such cases the efficacy of a fungicide may be reduced, resulting in a reduction in the level of control obtained. Thus, we could perhaps expect isolates which are partially resistant to fungicides in the laboratory, to be at least partially controlled by such fungicides in a cropping situation.

Lack of control by a fungicide however, does not always imply a degree of resistance in the pathogen. Fletcher *et al.* (1980) showed that a *Mycogone* isolate, which was still sensitive to benomyl, was not controlled by this chemical due to an accelerated loss of the active ingredient from casing. This phenomenon was recorded for a farm which had a high level of benomyl-degrading bacteria. Benomyl was shown to gradually disappear from unamended casing by day 28 after application, but if a population of benomyl-degrading bacteria was added it had disappeared by day 3 after application, leaving the casing and mushrooms unprotected from even benomyl-sensitive pathogens. Recent work commissioned by the HDC (Project M 14a - Part 2) demonstrated that carbendazim, the active ingredient in Bavistin, also disappeared over a 17-27 day period so we might expect Bavistin-sensitive isolates to be capable of emerging at this stage in the cropping cycle.

There is no information relating to the efficacy of currently used fungicides against the newly evolved "resistant", and "partially-resistant" isolates of *Dactylium* and this report was commissioned to provide data on this subject.

Cropping experiments were carried out using two isolates with different fungicide resistance profiles in conjunction with the fungicides Sporgon, Bavistin and Hymush in order to see what degree of control could be expected from these chemicals against *Dactylium* isolates with a known laboratory response to the fungicides in question.

2. Materials and Methods

2.1 Fungicides

The three fungicides Sporgon, Bavistin and Hymush were used in this study. The concentration of active ingredient in each product is given in Table 1.

Table 1. Fungicides used in experiments

Fungicide	Active ingredient	%	Tested against :
Sporgon 50WP	Prochloraz manganese	46% w/w	Isolate 202A
			Isolate 192B1
Bavistin DF	Carbendazim	50%	Isolate 202A
			Isolate 192B1
Hymush	Thiabendazole	60%	Isolate 202A

2.2 Isolates

Two isolates were used in this study: isolate 192B1 *(Cladobotryum dendroides)* and isolate 202A *(Cladobotryum mycophilum)*. The fungicide resistance profiles of these two isolates are shown in Figures 1 and 2. Under laboratory conditions, isolate 192B1 is partially resistant to Bavistin and Sporgon but completely resistant to Hymush while isolate 202A is partially resistant to Sporgon and, to a lesser extent, Hymush, but it is very sensitive to Bavistin.

2.3 Inoculum

A spore-suspension inoculum was prepared for each *Dactylium* isolate by flushing sporulating cultures with sterile water. The resultant suspensions were then filtered through sterile cotton wool to remove mycelial debris. The concentration of spores was calculated using a haemocytometer and suspensions were diluted to give spore concentrations in the region of 1 x 10^6 spores/ml.

2.4 Inoculation

The spore suspension inocula were applied between Days 11-13 using a 'Hozelok Spraymist' sprayer holding 500 ml. Spraying technique was calibrated to enable a 4 ml aliquot of suspension to be sprayed onto the casing surface of each tray. This delivered approximately 4 million spores to each 0.6m^2 tray. Each isolate was applied separately using separate sterilized sprayer units. Control plots received 4 ml of sterile water. No water was applied to

the casing on days 11, 12 or 13 but the equivalent of between 2-4 litres/m^2 was applied between days 14 and 16. *Dactylium* expression was recorded as (a) weight of spotted mushrooms and (b) number and area of colonies on the casing.

Figure 1. Response of *Dactylium* Isolate 192B1 to three fungicides *invitro*

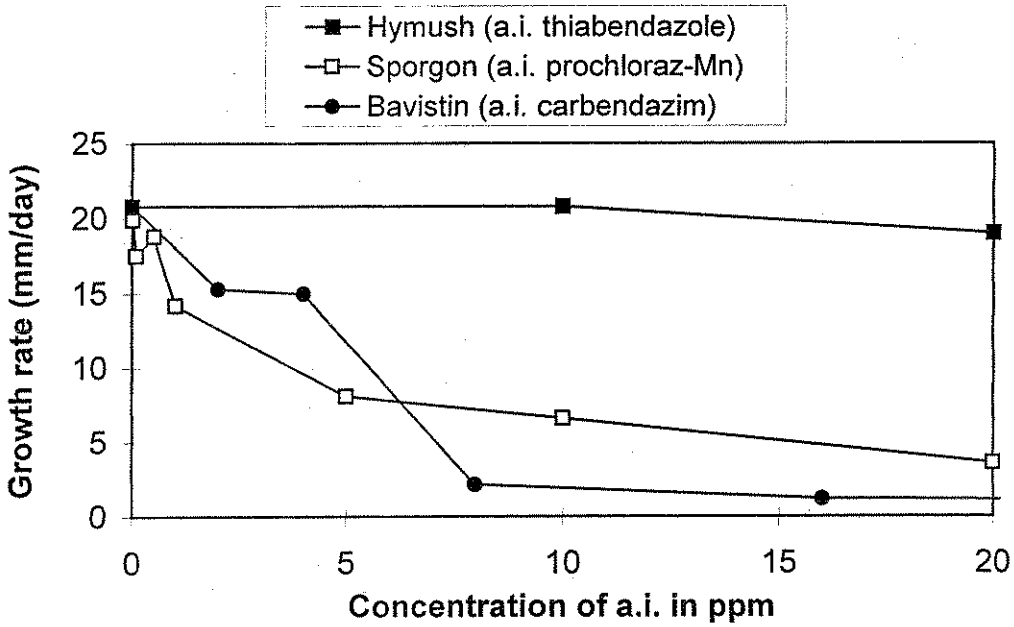
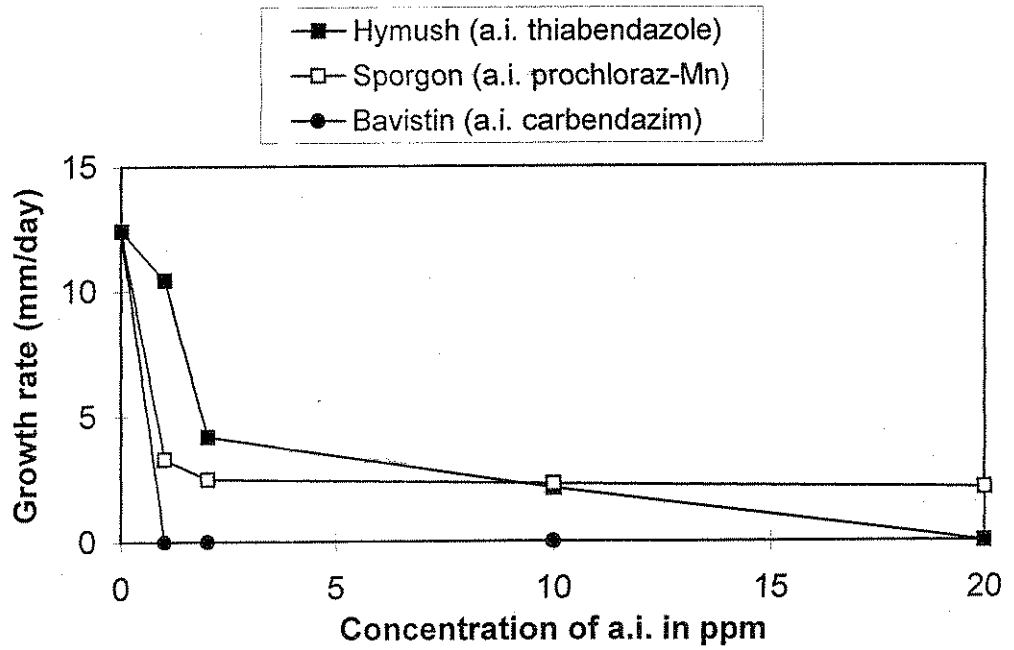


Figure 2. Response of *Dactylium* isolate 202A to three fungicides *invitro*



2.5 Crop details

Compost produced by the HRI Mushroom Unit was used for three cropping experiments. Compost no. 16/97 was used for the Hymush experiment and Compost 17/97 was used for the Sporgon and Bavistin experiments. Wooden trays, measuring 91cm x 61cm x 17cm (l x b x h) were filled with 50 kg of spawned (Sylvan A12) compost and spawn run for 17 days at 25°C. Trays were cased to 4-5 cm with a black peat/sugar beet lime casing (Tunnel Tech English) and case-run at 25°C. One treatment in one cropping house used a sphagnum peat and sugar beet lime casing mix prepared by the HRI Mushroom Unit (300-litre bale Shamrock Peat moss; 75kg Bumpacrop lime; 50 litres water). Crops were aired on Day 7 after casing over a three day period, by which time the air temperature was reduced to 18°C. Inoculation of plots took place on Days 11-13. Two or three flushes were harvested from each crop, depending on the extent of disease development following inoculation. Mushrooms were harvested as either healthy or spotted. Diameters of cobweb patches were measured at the beginning and end of each flush. Cobweb patches were salted at the end of each flush prior to watering.

2.6 Fungicide treatments

Fungicides were applied at a number of different rates as outlined in Table 2. A separate cropping house was used for each fungicide as it was impossible to accommodate all fungicide treatments in one house. All rates used, except one, follow label recommendations. Bavistin applied in 100 litres/100m^2 is not on the label. This application was included to see if it gave enhanced control by concentrating the active ingredient in the upper layer of casing in view of the knowledge that Bavistin disappears steadily from casing immediately after application (HDC project report M 14a - Part 2).

2.7 Statistical design

Six replicate trays were prepared for each treatment. For the Sporgon house, a total of 12 treatments in all were prepared consisting of three isolate categories (isolates 192B1, 202A, None), and four fungicide application treatments (Table 2) giving 3 x 4 = 12 treatments. Plots were positioned according to a randomized block design, consisting of 6 blocks each with 12 trays, with one replicate of each treatment per block. Data were analysed by Analysis of Variance (ANOVA) and the least significant difference between means was calculated according to the formula:

$$(\text{lsd}) = (\text{sed}) \times t_{(p = 0.05,\ \text{d.f.})}$$

(lsd = least significant difference; sed = standard error of deviation; d.f. = residual degrees of freedom).

Table 2. Fungicide treatments applied to crops inoculated with two isolates of *Dactylium dendroides*.

Fungicide Treatment	Rate of application	Time	Casing type
Sporgon			
1.	None		
2.	120 grams/100m^2 in 180 litres water	at casing	Black peat/sbl
and	120 grams/100m^2 in 180 litres water	after 1st flush	
3.	120 grams/100m^2 in 180 litres water	at casing	Sphagnum/chalk
and	120 grams/100m^2 in 180 litres water	after 1st flush	
4.	120 grams/100m^2 in 90 litres water	at casing	Black peat/sbl
and	120 grams/100m^2 in 90 litres water	after 1st flush	
Bavistin			
1.	None		
2.	250 grams/100m^2 incorporated into mix	at casing	Black peat/sbl
3.	250 grams/100m^2 in 200 litres water	at 1st watering	Black peat/sbl
4.	250 grams/100m^2 in 100 litres water	at casing*	Black peat/sbl
Hymush			
1.	None		
2.	230 grams/100m^2 in 200 litres water	at casing	Black peat/sbl
3.	230 grams/100m^2 in 200 litres water	at casing	Black peat/sbl
and	85 grams/100 m^2 in 200 litres water	after 1st flush	
and	85 grams/100 m^2 in 200 litres water	after 2nd flush	
4.	115 grams/100m^2 in 200 litres water	after 1st flush	Black peat/sbl
and	115 grams/100m^2 in 200 litres water	after 2nd flush	

* This is not a label-recommended application

3. The Efficacy of Sporgon against two *Dactylium* isolates

3.1 Yield Results - (Sporgon)

Mushrooms were harvested over only two flushes due to the extent of disease within the crop. The average total yield (of spotted and unspotted mushrooms) for the uninoculated treatment with no fungicide was 241 kg/tonne compared with 259 and 264 kg/tonne for inoculated, Sporgon-treated black peat casing (Figure 3). Only 150 kg/tonne was recorded from the Sporgon-treated milled-peat casing type. This significantly lower yield is most due to panning of the casing in the first flush which considerably reduced the first flush yield.

Both *Dactylium* isolates caused an average yield reduction of 20 to 36% which was due to a reduction in cropping area following the salting of established cobweb patches on the bed (Figure 3). Further losses in marketable yield due to spotting were recorded, irrespective of Sporgon treatment, with from 34 to 84 kg/tonne occurring on Sporgon-treated casing compared with a slightly higher loss of 85 to 104 kg/tonne occurring when no fungicide was applied (Figure 4). The average yield from all uninoculated plots was 238 kg/tonne compost for two flushes of which 22% was spotted, mostly in the second flush. Inoculated plots yielded 176 kg/tonne (isolate 192B1) and 179 kg/tonne (isolate 202A) of which 40% were spotted in both 1st and second flushes. In addition, the third flush was lost due to the amount of disease in the house which resulted in the crop being terminated early.

Sporgon did not prevent the development of spotting symptoms by isolate 192B1 or isolate 202A in either the first or second flush. Mushrooms in all uninoculated plots developed spotting symptoms in the second flush due to spread of the disease within the house.

3.2 Cobweb symptoms (Sporgon)

Following inoculation with a suspension of *Dactylium* spores, both isolates, 192B1 and 202A, produced 3 to 11 cobweb patches/tray by the end of the first flush on Sporgon treated casings (data not shown), rising to up to 13 to 18 patches/tray by the end of the second flush (Figure 5). Both isolates caused similar numbers of patches on the same casing/Sporgon treatment. In the absence of Sporgon, the numbers were not much different at the end of the first flush, (4 to 11 patches/tray; data not shown) but were slightly higher at the end of the second flush at 21 to 24 patches/tray. This represents approximately 24-35% fewer colonies on Sporgon-treated casing. Sporgon therefore had a slight, but significant effect on the number of cobweb patches developing. When the area of disease was calculated, cobweb covered a significantly smaller area (approx. 10% of the casing surface) on Sporgon treated casings than on casing containing no fungicide (approx. 20-25% of the casing surface) (Figure 6). This represents 48

Figure 3. Total yield of mushrooms (2 flushes) following different inoculation and Sporgon treatments

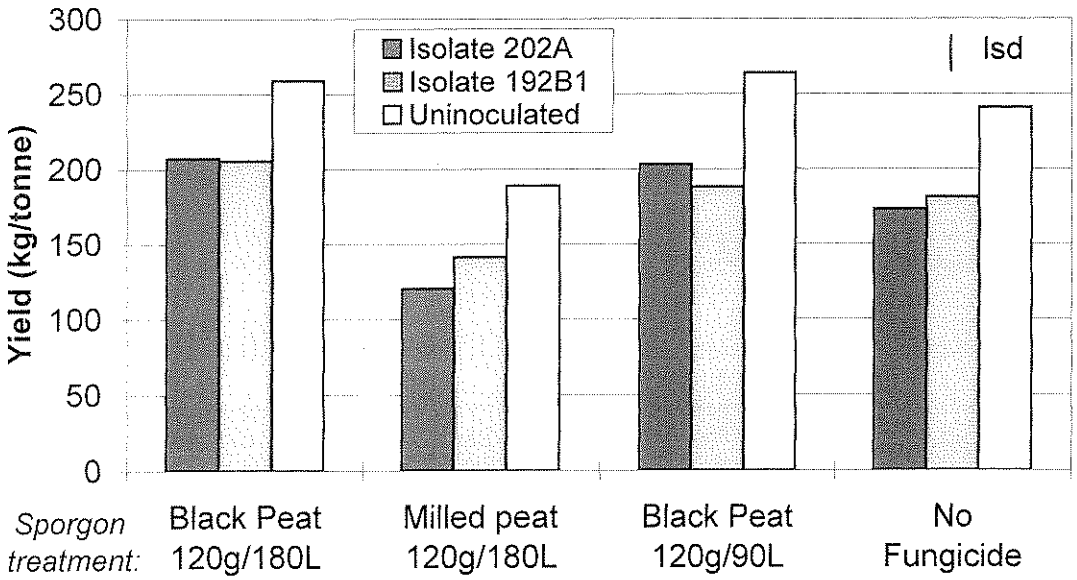


Figure 4. Yield of spotted mushrooms (2 flushes) following different inoculation and Sporgon treatments

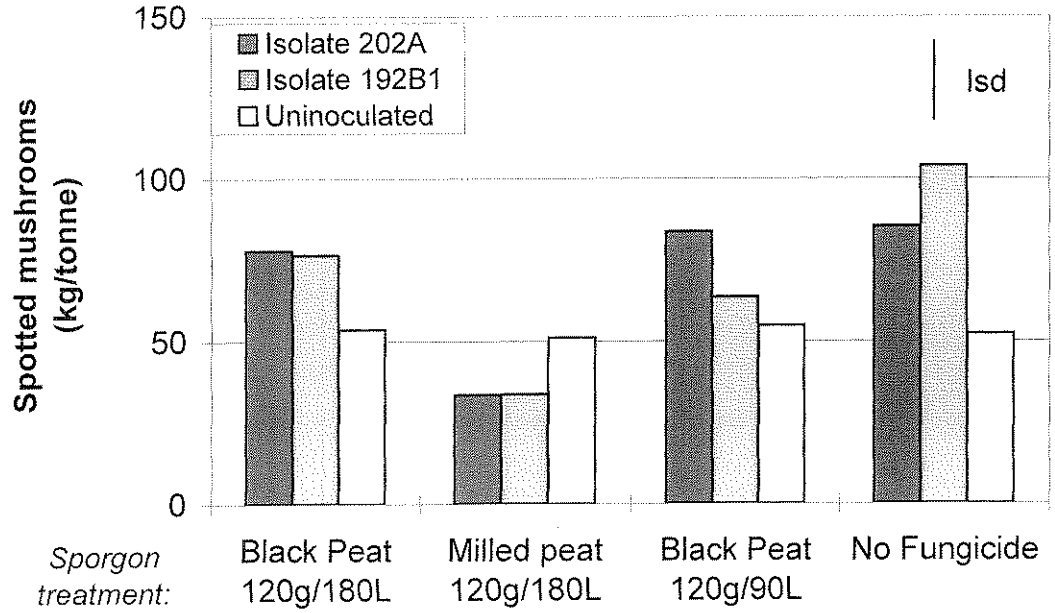


Figure 5. Number of Cobweb patches (end of 2nd flush) following different inoculation and Sporgon treatments.

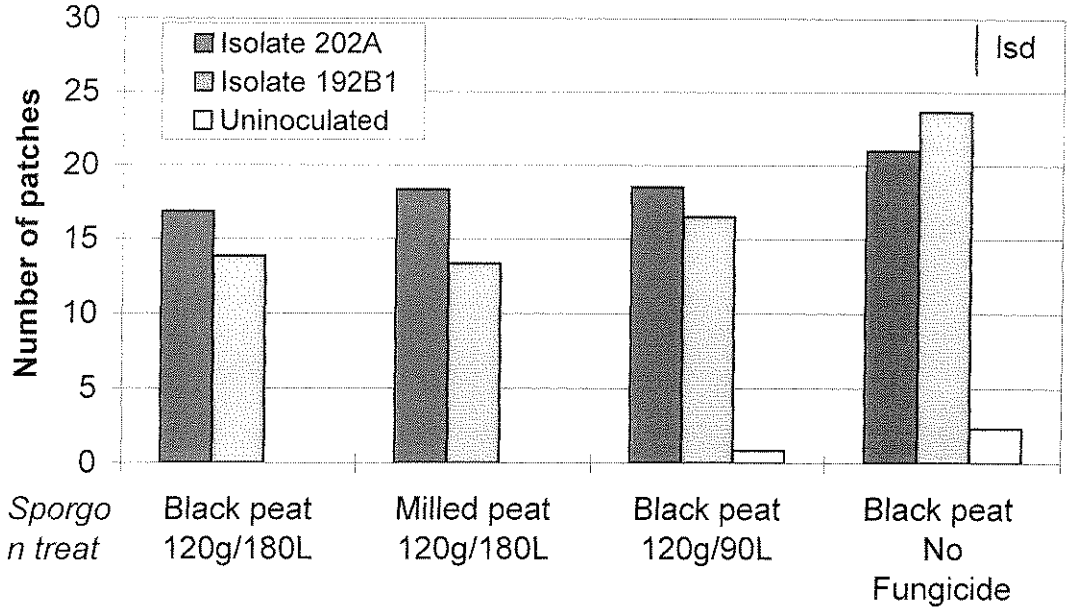
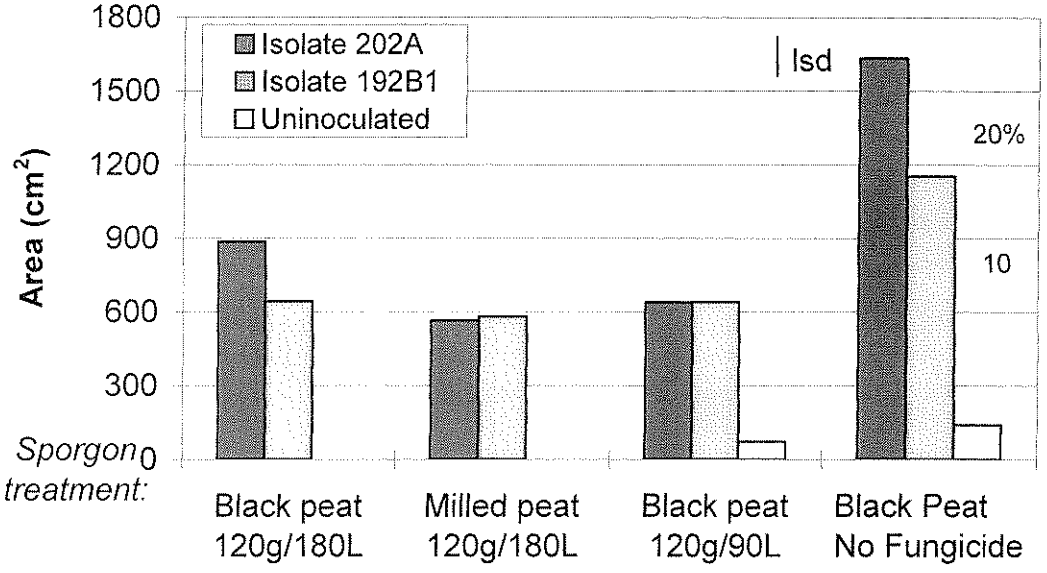


Figure 6. Area of cobweb at the end of 2nd flush following different Sporgon and inoculation treatments.



to 61% less cobweb on the bed. Sporgon therefore significantly reduced the growth of cobweb on the casing. All Sporgon treatments gave very similar results. Trays which had not been inoculated remained free of cobweb at the end of the first flush but some patches had emerged on some trays by the end of the second flush.

3.3 Conclusions

There was very little difference between two isolates of *Dactylium* in terms of their effects on yield, spotting symptoms or the number of cobweb patches emerging.

The application of Sporgon to casing did not prevent the development of either spotted mushrooms or cobweb in the first flush. Sporgon slightly reduced the number of cobweb patches emerging by 24 to 35%, and significantly reduced the area of cobweb on the beds by about 48 to 61% but its effect was not sufficient to prevent either spotting symptoms or cobweb patches emerging on uninoculated, Sporgon-treated plots in the second flush. These findings indicate that Sporgon may be of only limited against *Dactylium*, particularly if the inoculum load is high. It may give some degree of protection if inoculum levels are lower.

4. The Efficacy of Bavistin against two *Dactylium* isolates

4.1 Yield Results (Bavistin)

Mushrooms were harvested over only two flushes due to the extent of disease within the crop. The average total yield (of spotted and unspotted mushrooms) for the uninoculated treatment with no fungicide was 248 kg/tonne and for uninoculated, Bavistin-treated plots were from 221 to 236 kg/tonne (Figure 7).

Only *Dactylium* isolate 192B1 caused a reduction in total yield of 15 to 28% (Figure 7) which was due to a reduction in cropping area following the salting of established cobweb patches on the bed. At the end of the first flush no spotted mushrooms were present on Bavistin-treated plots inoculated with isolate 202A, compared with 74 kg/tonne (68%) spotted mushrooms from Bavistin-untreated plots (Figure 8). Thus, Bavistin prevented the development of spotting by isolate 202A. However, Bavistin treatment of casing did not prevent spotting by isolate 192B1 and an average of 47 kg/tonne (42%) of all 1st flush mushrooms harvested were spotted, irrespective of whether Bavistin had been applied or not (Figure 8).

By the end of the second flush, spotted mushrooms were harvested from every plot, irrespective of any treatment, due to cross contamination (Figure 9). Spotted mushrooms from 22 Bavistin-treated plots inoculated with 202A were sampled to determine if the spotting was due to isolate 202A or was due to cross contamination from plots treated with isolate 192B1. Tissue from the spotted mushrooms was excised and subcultured to obtain the organism causing the symptom. All the cultures were then tested for their response to Bavistin to determine if the profile was that of the inoculated organism 202A, or the other isolate in the experiment, isolate 192B1 (see Figures 1 and 2, page 4). All isolates tested had the Bavistin-profile of isolate 192B1. Thus it is reasonable to assume that Bavistin was still protecting mushrooms in the second flush from spotting by isolate 202A.

Because of the high level of cross contamination in the second flush from 192B1-inoculated plots, it is difficult to exclude the distinct possibility that some of the spotted mushrooms recorded from 202A-inoculated plots with no Bavistin applied were caused by isolate 192B1. There was insufficient time to determine what proportion of spotting was due to each isolate.

Figure 7. Total yield of mushrooms (2 flushes) following different inoculation and Bavistin treatments

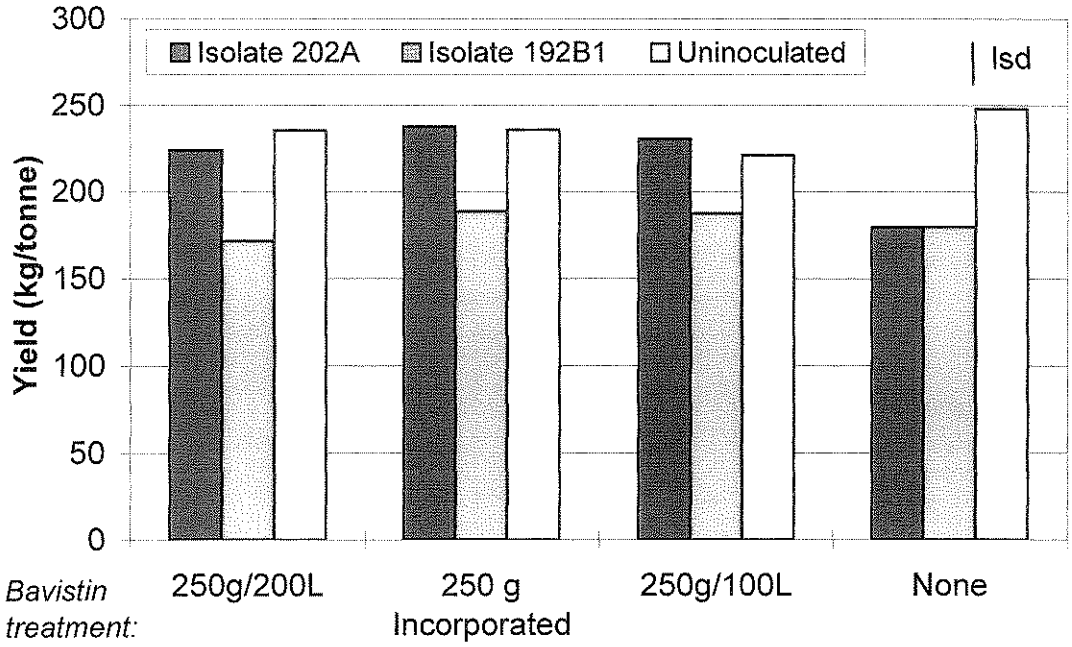


Figure 8. Yield of spotted mushrooms from 1st flush following different inoculation and Bavistin treatments

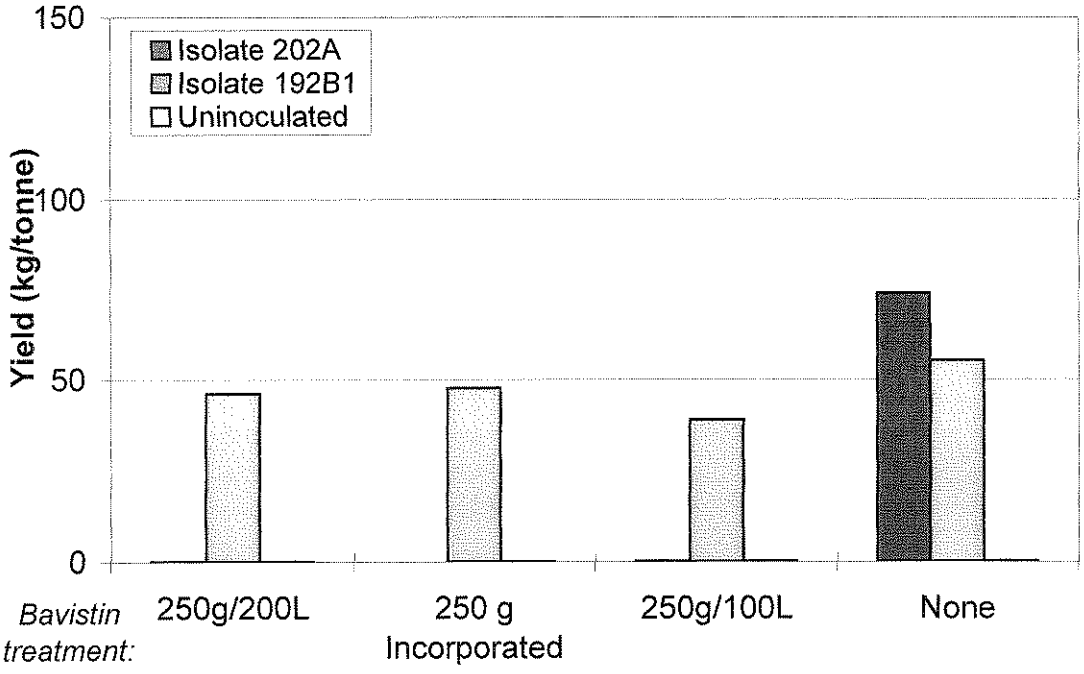
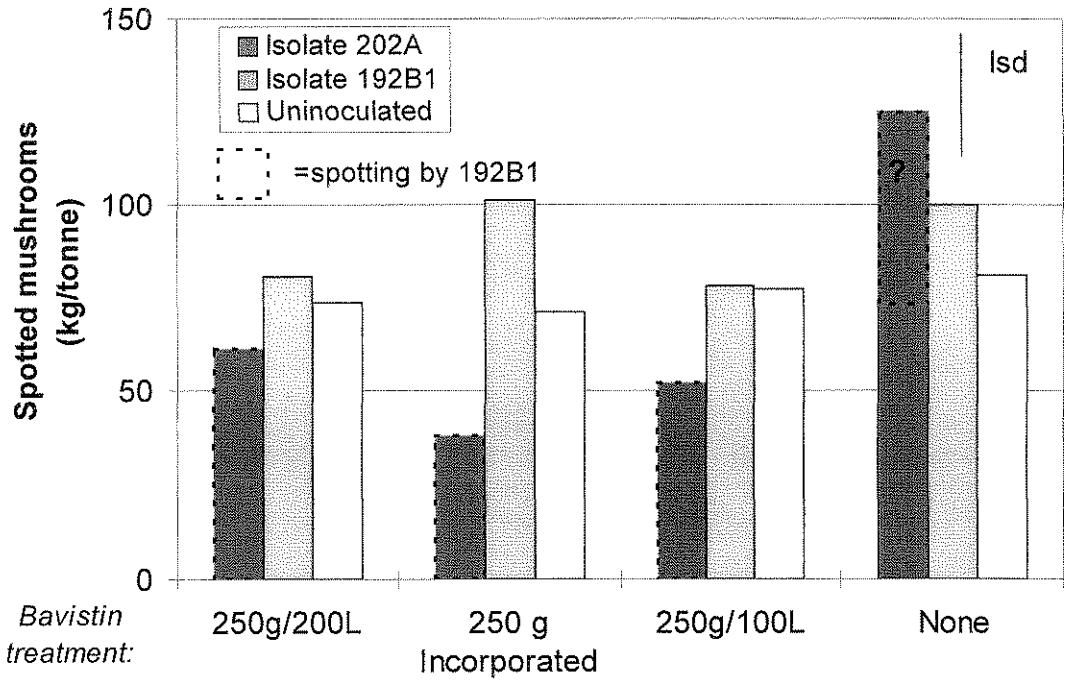


Figure 9. Yield of spotted mushrooms (2 flushes) following different inoculation and Bavistin treatments



4.2 Cobweb symptoms (Bavistin)

The development of cobweb patches by the end of the first flush followed a very similar pattern to the development of spotting symptoms described above. No cobweb was present on Bavistin-treated casing inoculated with isolate 202A but an average of two patches per tray had developed on Bavistin-treated casing inoculated with isolate 192B1. Four to five patches of each had also developed on plots which had not received any Bavistin (data not shown). By the end of the second flush (Figure 10), the number of patches had risen dramatically on 192B1-inoculated plots to 15 - 18 patches/tray, irrespective of Bavistin treatment while only 2 - 4 patches/tray had emerged on 202A inoculated plots which had been Bavistin-treated compared with 15 patches/tray in the absence of Bavistin. Sixteen cobweb patches were sampled from Bavistin-treated, 202A-inoculated, plots in order to determine if they were due to either isolate 202A, or 192B1 as a result of cross contamination. Fifty percent (50%) of the cultures obtained were isolate 202A, and 50% of them were isolate 192B1 thus Bavistin is not totally controlling isolate 202A by the end of the second flush.

A very similar picture emerged when the area of cobweb on the casing was calculated. Small areas of isolate 192B1 had developed on Bavistin-treated casing by the end of the 1st flush, but not on Bavistin-treated casing inoculated with isolate 202A (not shown). Similarly, by the end of the second flush, large areas of casing were covered with isolate 192B1 compared to relatively small areas of isolate 202A (Figure 11). Both isolates grew equally well in the absence of Bavistin.

4.3 Conclusions

Bavistin is very effective against sensitive isolates of *Dactylium*, as represented by isolate 202A, preventing both spotting and cobweb symptoms well into the second flush. However, some cobweb growth on casing is likely to occur at the end of the second flush, when the concentration of Bavistin in the casing is falling (see HDC report M 14a).

Bavistin is completely ineffective against partially-resistant isolates, as represented by isolate 192B1. Therefore, cobweb isolates which are partially resistant to Bavistin *in vitro* should be considered as completely resistant under cropping conditions.

There were no significant differences in disease expression due to different application treatments. Thus, under a high inoculum load, applying Bavistin applied in 100 litres/100m^2 confers no advantage.

Figure 10. Number of cobweb patches (end of 2nd flush) following different inoculation and Bavistin treatments

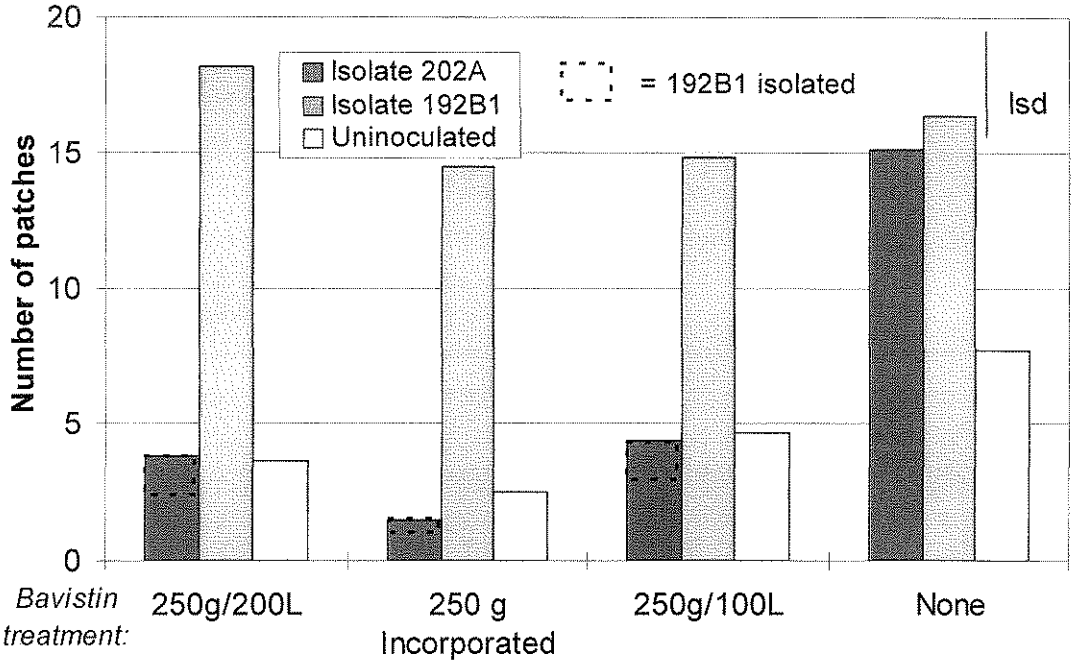
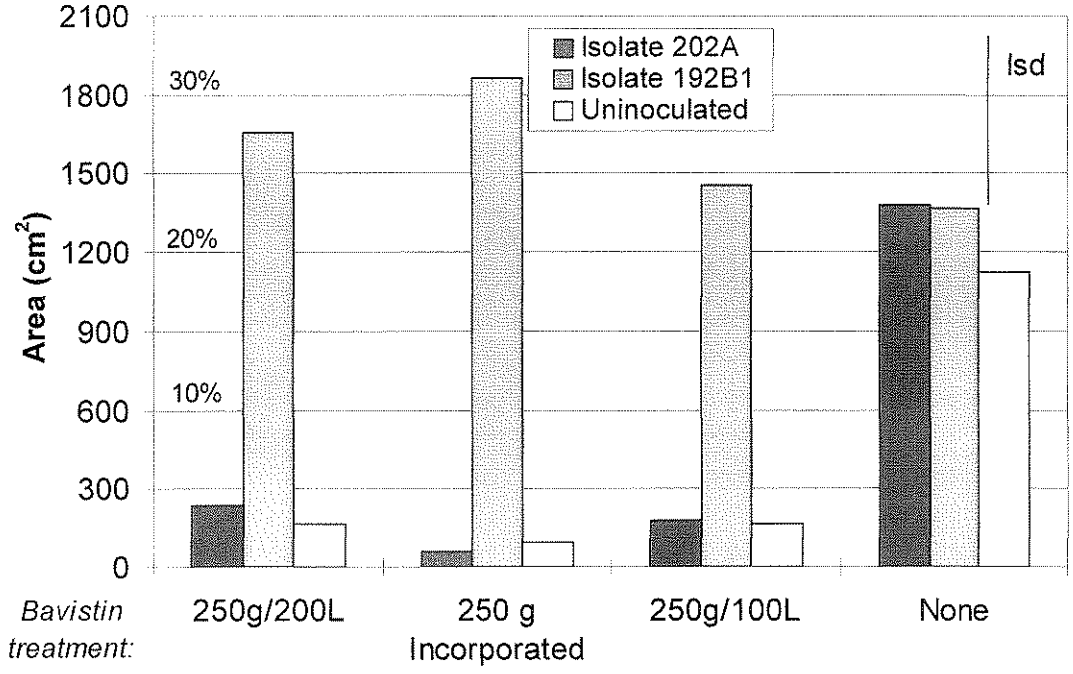


Figure 11. Area of cobweb (end of 2nd flush) following different inoculation and Bavistin treatments



5. The Efficacy of Hymush against two *Dactylium* isolates

5.1 Yield Results (Hymush)

Mushrooms were harvested over three flushes as disease levels were not severe enough to warrant cooking out after two flushes. However, for ease of comparison with Sporgon and Bavistin results, data for the first two flushes, rather than for three flushes, are presented. The average total yield (of spotted and unspotted mushrooms) for the uninoculated treatment with no fungicide was 221 kg/tonne. The yields from uninoculated Hymush-treated plots were similar at 217 to 226 kg/tonne (Figure 12).

Significant reductions in yield from 202A-inoculated treatments were only recorded when no Hymush had been applied, or when it had been applied as an interflush treatment only (Figure 12). Thus, Hymush prevented significant yield reductions due to cobweb when applied at casing.

Hymush did not prevent the development of spotted mushrooms, with all inoculated plots developing spotted mushrooms during the cropping period (Figure 13). However, in the first flush, fewer spotted mushrooms developed when Hymush was applied at casing whereas in the second flush, fewer spotted mushrooms developed when Hymush was applied as an interflush treatment (Figure 14).

Figure 12. Total yield of mushrooms (2 flushes) following different inoculation and hymush treatments

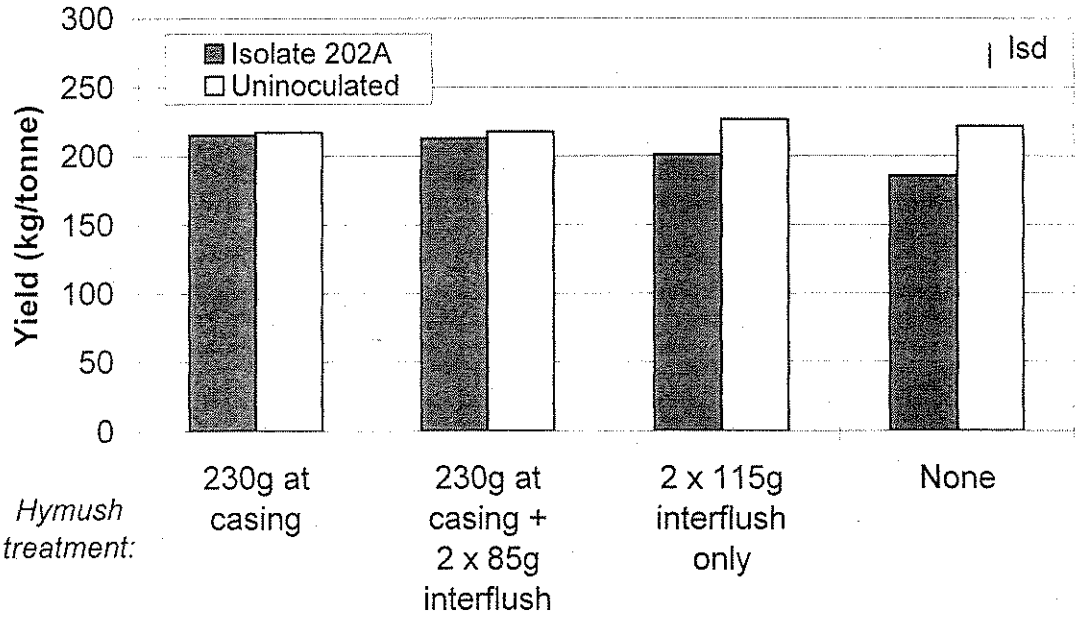


Figure 13. Yield of spotted mushrooms (2 flushes) following different inoculation and Hymush treatments

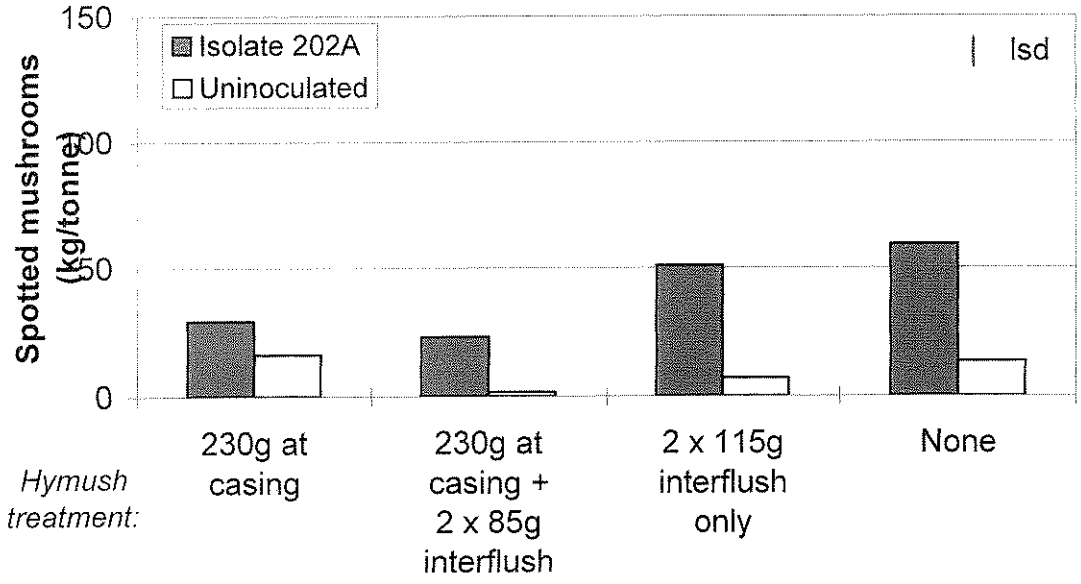
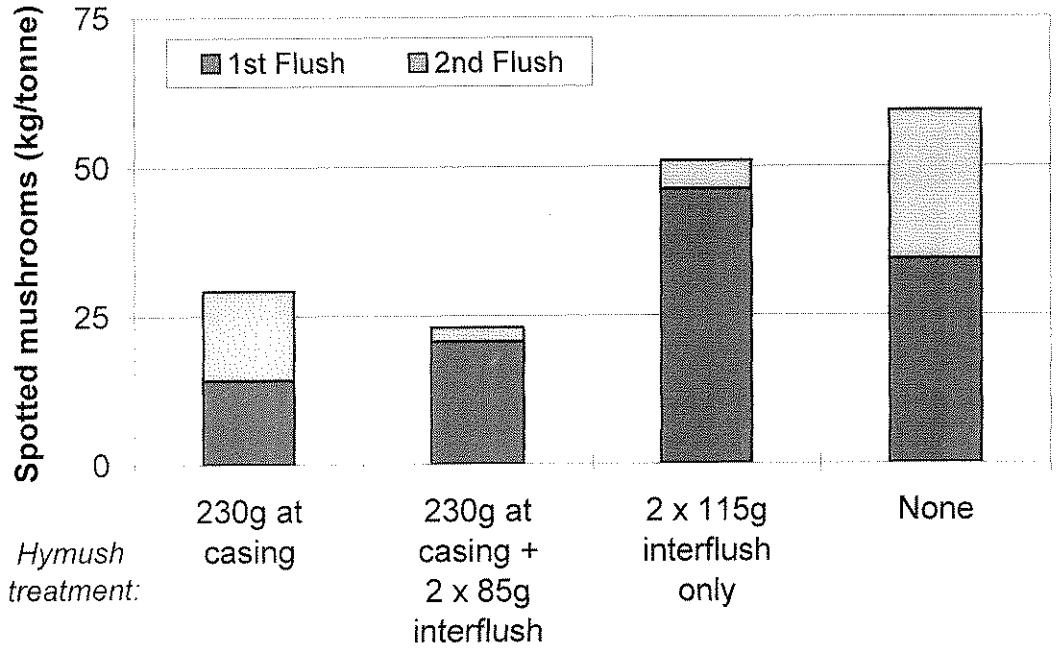


Figure 14. Yield of spotted mushrooms from 202A-inoculated plots receiving different Hymush treatments



5.2 Cobweb symptoms (Hymush)

Hymush did not totally prevent the development of cobweb on casing but it very significantly reduced both the number and area of patches. By the end of the second flush, less than 3 cobweb patches/plot had emerged when Hymush had been applied at casing, compared with an average of 20 patches/plot in the absence of Hymush (Figure 15). The application of Hymush as an interflush treatment only, (*i.e.* applied after cobweb has been observed in the first flush), succeeded in reducing the number of cobweb patches emerging in the second flush but numbers were still much higher than either the single casing treatment, or the casing plus interflush treatment (Figure 16). The casing plus interflush treatment was the best overall with very few patches emerging over three flushes.

A very similar picture emerged when the area of cobweb on the casing was calculated. At the end of the second flush, less than 0.6% of the surface area supported cobweb growth when Hymush had been applied at casing plus interflush. This compares with 14% cover in the absence of Hymush (Figure 17).

5.3 Conclusions

Hymush is very effective against partially resistant isolates of *Dactylium*, as represented by isolate 202A (see Figure 2, page 4). It does not prevent spotting symptoms but it can significantly reduce their number in the face of a high inoculum load. When applied at casing, it is very effective at reducing the development of cobweb patches, and, if followed by an interflush treatment after first and second flush, there should be very little further development. Therefore, Hymush is considered to be a very effective fungicide against *Dactylium* isolates which demonstrate a sensitive or partially-resistant profile when tested *in vitro*.

Figure 15. Number of cobweb patches (end of 2nd flush) following different inoculation and Hymush treatments

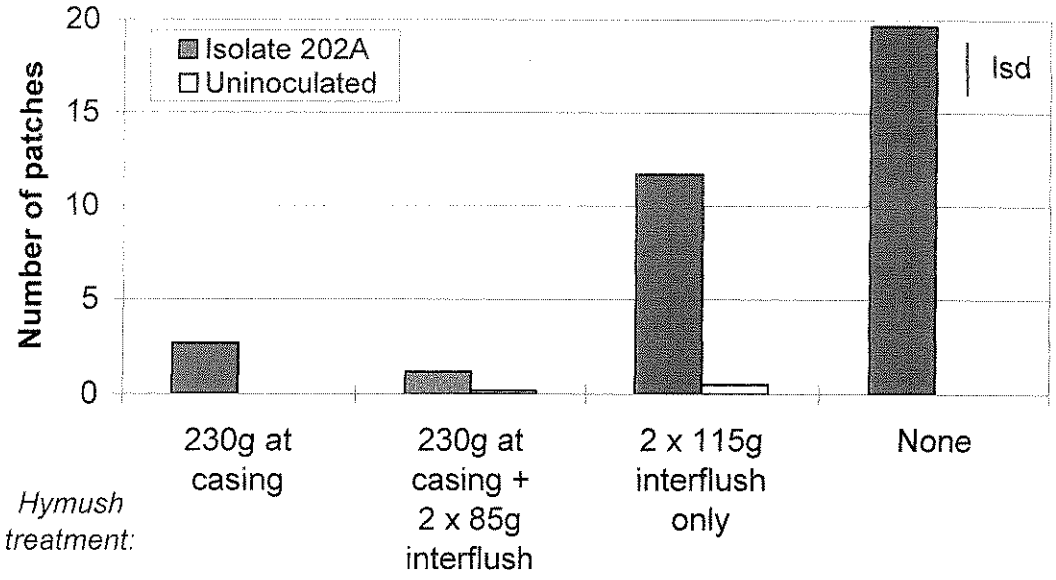


Figure 16. Number of cobweb patches on 202A inoculated plots receiving different Hymush treatments

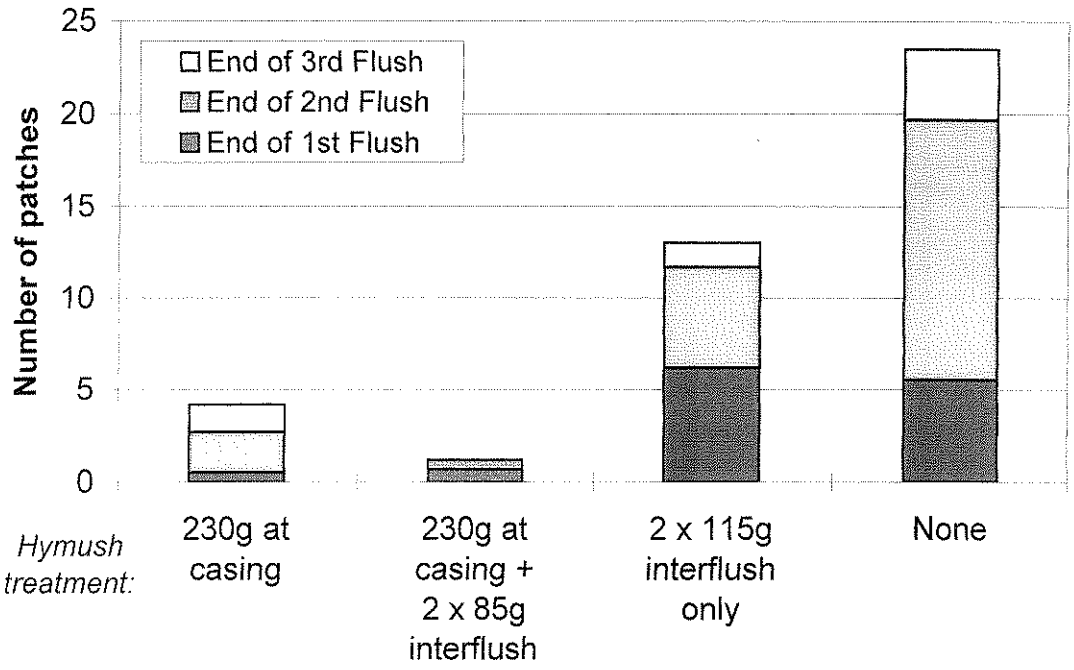
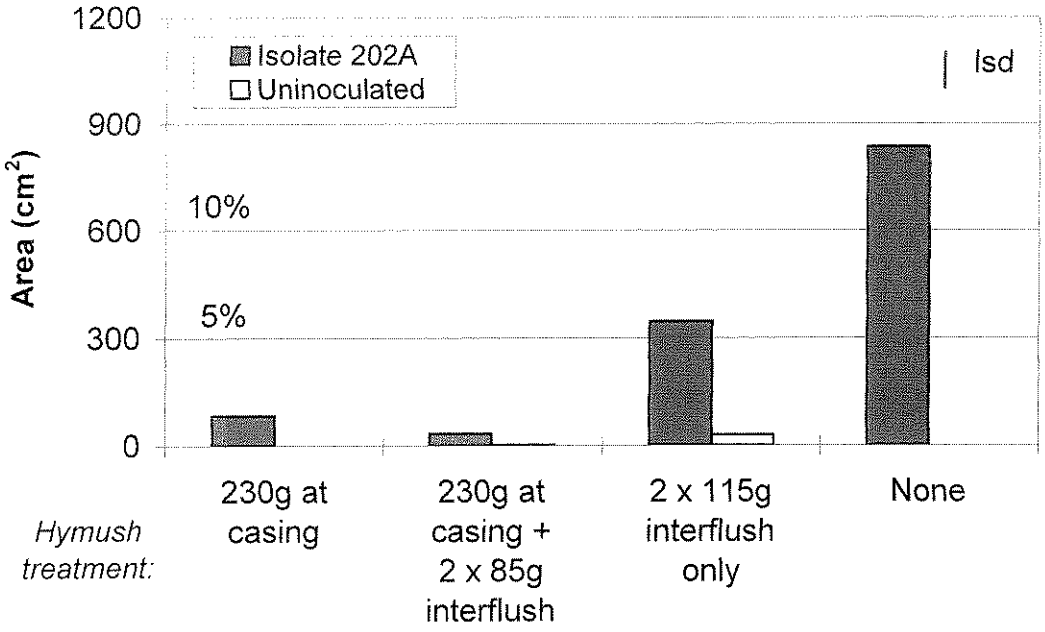


Figure 17. Area of cobweb (end of 2nd flush) following different inoculation and Hymush treatments



6. General Discussion

A previous HDC report (M 14a) found that about 20% of *Dactylium* isolates surveyed were sensitive to Bavistin and partially resistant to Hymush, while the remaining 80% of isolates were partially resistant to Bavistin and fully resistant to Hymush. All isolates tended to be partially resistant to Sporgon. Apart from highly resistant isolates, it is difficult to predict with certainty how fungicides will perform in a cropping situation, particularly against partially resistant isolates, as there are many other factors operating to affect efficacy. The current work was undertaken to provide some information on the relative efficacy of three fungicides in controlling deliberately infected crops using isolates which were either sensitive or partially resistant.

The fungicide Sporgon proved to be not fully effective against two "partially resistant" isolates of *Dactylium* which had an ability to tolerate moderate concentrations of the active ingredient. However, although inoculum loads in these experiments were high, some reduction in symptoms was achieved, namely 24-36% fewer colonies covering 48-61% less casing-area. This level of control may be of benefit under lower inoculum loads. Different application rates of the fungicide, in particular the 90 litres/100m^2 drench volume, had no significant effect on efficacy in this instance. Again, it may be of benefit under lower inoculum loads. These efficacy results are disappointing, as Sporgon has been considered to be a good crop protection chemical. The fact that some level of disease reduction occurred should be taken as encouraging, indicating that the chemical can provide a level of protection. The absence of total control however should be taken as a reminder of the need to ensure that inoculum loads do not get too high. Current work in progress (HDC project M 29) is examining the epidemiology of *Dactylium* and has demonstrated the enormous inoculum potential of a single patch of cobweb to infect a whole cropping chamber through the release of airborne spores. Future work in this area will try to identify ways to minimise spore release in order to prevent massive inoculum loads being released into the air.

The fungicide Bavistin proved to be very effective in controlling symptoms of *Dactylium* caused by a "sensitive" isolate, until well into the second flush. At this stage in the cropping cycle, it is known that the concentration of Bavistin is much reduced (see HDC report M 14a) so that efficacy will automatically be compromised. However, up until this point, it should give good protection against spotting and cobweb caused by sensitive isolates. For an isolate which was "partially resistant" to Bavistin, however, it was completely ineffective and such isolates should now be termed "Bavistin resistant". Different application rates had no significant effect on efficacy in this instance.

The fungicide Hymush was very effective in controlling cobweb development by a "partially-resistant" isolate up to, and including, the third flush. It did not prevent spotting but significantly reduced the number of spotted mushrooms which developed when applied either at casing or as an interflush treatment. The most effective application treatment consisted of 230g/100m2 applied in the first watering, followed by interflush applications of 85g/100m2 after the first and second flush. This treatment gave the least number of spotted mushrooms and the fewest number, and area, of cobweb patches. This information suggests that isolates which are currently known as "partially resistant" to Hymush should be called "Hymush-sensitive". Hymush was not tested against a "Hymush-resistant" isolate (192B1) as it was considered to be a foregone conclusion that such isolates would not be controlled by this product.

The manufacturers of Hymush have recently withdrawn this product from the market so that it is no longer available for use. The fact that the active ingredient, thiabendazole, is an effective fungicide against sensitive isolates of *Dactylium* means that it would be a great loss to the British mushroom industry not to be able to use it when needed. It is strongly recommended that an off-label be sought for another thiabendazole-containing product which could be used instead of Hymush.

Despite the fact that a significant proportion of *Dactylium* isolates are still sensitive to Bavistin and Hymush, it must be remembered that resistance to these chemicals can occur, and growers should not become over-reliant on them, or any other chemical.

7. Conclusions

Sporgon will not prevent spotting or cobweb symptoms from developing but it can significantly reduce the area of cobweb developing in infected crops. It may be more effective under lower inoculum loads.

Bavistin is very effective against sensitive isolates (following inoculation at pinning), preventing both spotting and cobweb symptoms from developing well into the second flush. Its efficacy is likely to be reduced in the latter stages of the crop as the concentration of the active ingredient falls during the cropping period. All partially-resistant isolates are now known to be totally Bavistin-resistant under cropping conditions. These isolates are also totally Hymush resistant.

Hymush is very effective against partially resistant isolates which should now be known as Hymush-sensitive isolates. It will not prevent spotting symptoms from developing but it will reduce their number significantly. Hymush applied at casing, followed by two interflush applications should result in very little spotting or cobweb developing in the presence of a very high inoculum load.

Off-label registration should be sought immediately for a replacement thiabendazole-containing product to replace Hymush which has been withdrawn from the market for commercial reasons.

8. References

Fletcher, J.T. and Yarham, D.T. (1976). The incidence of benomyl tolerance in *Verticillium fungicola, Mycogone perniciosa* and *Hypomyces rosellus* in mushroom crops. *Annals of Applied Biology* **84**, 343-353.

Fletcher, J.T., Connolloy, G., Mountfield, E.I. and Jacobs, L. (1980). The disappearance of benomyl from mushroom casing. *Annals of Applied Biology* **95**, 73-82.

Gaze, R.H. & Grogan, H.M. (1996). The persistence of carbendazim (Bavistin DF) in mushroom casing. *HDC Project News*, **40**, p5.

Grogan, H.M. (1996). Survey of fungicide resistance in the mushroom pathogens *Dactylium, Trichoderma* and *Aphanocladium* and assessment of carbendazim degradation in casing. HDC Report M 14a

Gragan, H.M (1997). Fate of sporgon in casing. HDC Report M 26

Grogan, H.M. & Gaze, R.H. (1996). Fungicide resistance in Mushroom pathogens. *HDC Project News*, **38**, 18-20.