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THE BIOLOGY AND CONTROL OF FUNGAL PATHOGENS OF ERICA AND CALLUNA

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REPORT 3

1 October 1989 to 30 September 1990

A project funded jointly by the Department of Agriculture for Scotland, the Highlands and Islands Development Board and the Horticultural Development Council (Contract No. HO/17a/87)

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INTRODUCTION

This report is the third and final one on Rhizoctonia infection on heathers and heaths. A comprehensive document (in the form of a PhD thesis) which records all the work conducted since 1987 together with a detailed literature review and several detailed discussions will be available early in 1991.

The investigation of soil-borne pathogens poses particular problems for the plant pathologist, requiring special techniques to introduce the pathogen, to induce controlled infections, to assess the effects of disease and to devise effective control programmes. Much of the first year of the project was spent devising techniques and becoming familiar with the particular requirements of Rhizoctonia. The patience and hard work during the initial period paid dividends in the second year with a wealth of important results on the sources of Rhizoctonia and the management conditions under which damaging levels of disease are liable to develop. In the third report we summarise the results from experiments on fungicides and our attempts to look at the interesting but difficult area of biological control. A 'blue-print' to minimise the risk of damaging infection by Rhizoctonia is proposed.

Over the past three years we have been much gratified by the interest shown by growers throughout the U.K. One major grower of heathers adopted our proposed 'blue-print' some time ago and it gives great satisfaction to be able to say that the scheme is practical, cheap and effective.

We are delighted that the HDC is to fund our work on heathers and heaths for a further three years. During this period we will apply the same approach to other important root pathogens, and in particular Pythium, Phytophthora and Fusarium.

SUMMARY

The main conclusions to be drawn from this year's work are as follows:-

1. Of the fungicides with activity against Rhizoctonia which were tested, Basilex and Captan 83 proved most effective in preventing infection of Calluna cuttings. Benlate, Rovral, Plantvax and Quintozene provided less satisfactory control.

2. Compost type had little influence on the efficacy of Basilex or Rovral.

3. The control of Rhizoctonia by Basilex and Captan 83 declined markedly as the rate of fungicide was reduced. There appears to be little scope for reducing fungicide rates below those recommended by the manufacturers.

4. The amount of water applied to pots following fungicide treatment had a marked influence on the efficacy of Basilex. This is likely to be of greater significance for potted-on plants which may receive considerable amounts of irrigation water. The frequency of watering should be taken into account when formulating fungicide programmes.

5. The persistency of Basilex and Captan 83 in compost differed markedly. Thus whilst Basilex incorporated into compost pre-striking will provide control through the initial rooting period repeat treatments with Captan 83 will be

necessary.

6. Earlier work has shown that fungicides can be phytotoxic to heather cuttings, in particular they may inhibit root initiation. Tests with older plants indicate that they are more tolerant and no phytotoxicity was recorded.

7. Rhizoctonia mycelium can grow over a wide range of temperatures (5-35°C) with most isolates growing optimally at 20-25°C. Plants may be most at risk at low or high temperatures where induced stress may predispose them to attack under conditions where they cannot respond by producing new roots and by growing vigorously.

8. A range of compost additives including bark, sewage sludge and oxygen-generating granules (Fertilox) had relatively little effect on the incidence of Rhizoctonia.

9. The commonly occurring soil-fungus Trichoderma which has been shown to have biological control properties (e.g. control of silver leaf disease of plums) did demonstrate some activity against Rhizoctonia on agar media, but this was not repeated in compost. The possible reasons for this are discussed.

EXPERIMENT 1

Objective: To determine the efficacy of several fungicides in controlling Rhizoctonia infection of cuttings.

Treatments: Forty-eight cuttings of Calluna cv. Alba Praecox were struck in each of four trays containing Bulrush propagation compost which had received one of the following treatments:-

1. No fungicide in compost, no Rhizoctonia
2. Basilex incorporated pre-striking, no Rhizoctonia
3. Rovral " " " "
4. Quintozene " " " "
5. Plantvax 75 " " " "
6. Benlate " " " "
7. Captan " " " "

Treatments 8-14, as for 1-7 but with incorporation into the compost of Rhizoctonia isolate D1 before the cuttings were struck.

Treatments 15-21, as for 1-7 but with incorporation into the compost of Rhizoctonia isolate 64 before the cuttings were struck.

Treatments 22-28, as for 1-7 but with incorporation into the compost of Rhizoctonia isolate 48 before the cuttings were struck.

METHODS

1. Fungicide rates

a. Basilex (50% tolclofos-methyl) at 80 g/m^3 compost in 30l water (i.e. 40 ppm).

b. Captan 83 (83% captan) at 80 g/m^3 compost in 30l water (i.e. 66 ppm).

c. Quintozene (50% PCNB) at 80 g/m^3 compost in 30l water (i.e. 40 ppm).

d. Plantvax 75 (75% oxycarboxin) at 54 g/m^3 compost in 30l water (i.e. 40 ppm).

e. Benlate (50% benomyl) at 80 g/m^3 compost in 30l water (i.e. 40 ppm).

f. Rovral (50% iprodione) at 80 g/m^3 compost in 30l water (i.e. 40 ppm).

2. Following striking, the cuttings were covered in white polythene and assessed at weekly intervals. At the end of the experiment 12 cuttings from each treatment were placed on agar media to determine infection by Rhizoctonia.

3. The foliage condition was assessed on the following scale:-

   0 = No foliar browning
   1 = Tips or bases of a few branches brown
   2 = Tips or bases of a few branches brown + 1 or 2 shoots totally brown
   3 = Extensive foliar browning, but some green tissue
   4 = Totally brown foliage

RESULTS

All three isolates of Rhizoctonia caused severe browning of the foliage where no fungicide was incorporated into the compost pre-striking (Table 1). Benlate, Rovral, Plantvax and Quintozene provided little control of the fungus. Captan 83 gave effective control of all the isolates and no foliar browning was recorded on any cuttings struck in compost which contained Basilex.

The results of the isolations onto agar media (Table 2) show that no infection occurred in any of the control trays which contained no Rhizoctonia. Benlate, Rovral, Plantvax and Quintozene provided no protection against Rhizoctonia at the rates used whereas complete protection was obtained with Basilex and Captan.

Table 1. The effect of fungicides on the development of Rhizoctonia disease on heather cuttings

Fungicide	Foliage scores*				
	No Rhizoctonia	I-D1	I-48	I-64	Mean
Control	0.00	3.35	3.21	3.56	3.57
Benlate	0.00	2.75	2.58	2.83	2.72
Rovral	0.00	1.75	2.04	2.75	2.18
Basilex	0.00	0.00	0.00	0.00	0.00
Captan	0.00	0.19	0.15	0.38	0.24
Plantvax	0.00	2.73	3.17	3.15	3.02
Quintozene	0.00	3.08	3.10	3.42	3.20
Mean	0.00	1.98	2.04	2.30	

* 0-4 scale where 0 = no browning and 4 = totally brown

Table 2. Number of cuttings (max. 12) from which Rhizoctonia was isolated

Treatment	Rhizoctonia isolate			
	None	I-DI	I-64	I-48
Control	0	12	12	12
Benlate	0	12	10	11
Rovral	0	10	11	10
Basilex	0	0	0	0
Captan	0	0	0	0
Plantvax	0	12	12	11
Quintozene	0	12	12	12

DISCUSSION AND CONCLUSIONS

This experiment provided a valuable comparison of the relative activity of a range of fungicides which might be expected to give some control of Rhizoctonia. Basilex proved outstanding, but at present has no manufacturer's recommendation for use on heathers. Captan 83 looks an effective and relatively cheap alternative. Rovral is widely used by growers for control of Rhizoctonia but provided only modest control of the three isolates used. Benlate, Plantvax and Quintozene were ineffective. Rovral, Plantvax and

Benlate do not have manufacturer's recommendations for incorporation into compost, and may be more effective if used as drenches. However, it was noted in Research Report 2 that Rovral used at rates up to 400 g/m^3 compost incorporated followed by a drench at 2 g/l 1 month after striking failed to control one of the isolates used in that experiment.

EXPERIMENT 2

Objective: Effect of compost type on the efficacy of fungicides against Rhizoctonia

Treatments: Three replicate trays each containing five cuttings of Calluna cvs. Bognie, Alba Major and Golden Hue were prepared as follows:-

1. 50:50 v/v peat and perlite

a. No Rhizoctonia, no fungicide (control)
b. " , Rovral (2 g/l water/m^2 compost) drench
c. " , Basilex (4 g/l water/m^2 compost) "
d. Rhizoctonia isolate D1, no fungicide
e. " " " , Rovral (2 g/l water/m^2 compost drench
f. " " " , Basilex (4 g/l water/m^2 compost) "

2. 70:30 v/v peat and grit

a-f as above

3. 50:50 v/v peat and cambark

a-f as above

METHODS

1. The Rhizoctonia was introduced on pieces of sterilized straw (16 pieces/tray) four days after the cuttings were struck. Each piece was pushed approximately 1 cm into the compost.

2. The condition of the foliage was assessed 6 weeks after striking.

3. All trays were watered 2 and 4 days after the fungicide drenches were applied (5l water/9 trays on each occasion) to examine the possibility of differential leaching from the three compost types.

Table 3. The effect of compost type on the foliage condition of cuttings growing in Rhizoctonia-infested, fungicide-treated compost

Treatment		Foliage score		
		Peat + grit	Peat + bark	Peat + perlite
Control	No fungicide	0.00	0.00	0.00
	Basilex	0.00	0.00	0.00
	Rovral	0.00	0.00	0.00
Isolate 64	No fungicide	0.62	0.56	0.62
	Basilex	0.00	0.00	0.00
	Rovral	0.00	0.00	0.00

* Foliage condition, 0-4 scale where 0 = no foliar browning and 4 = totally brown

The levels of foliar browning recorded in trays of cuttings growing in compost which contained Rhizoctonia but no fungicide were similar in all three compost types, and generally were lower than recorded in previous experiments (Table 3). Under these conditions, both Basilex and Rovral gave complete disease control.

There was no indication that the application of water to the trays before inoculation caused differential leaching from the three compost types.

DISCUSSION AND CONCLUSIONS

Heathers and other nursery stock species have been shown to grow and develop well in an open, well drained compost with an air-filled porosity of 12-17%. Such composts will allow for good aeration and rapid drainage. However this may also mean rapid leaching of fertilisers and crop protection chemicals. A careful manipulation of compost ingredients may allow free drainage and aeration while maintaining a high cation exchange capacity to minimise losses of fertilisers and crop protection chemicals.

Although no evidence of loss of fungicide efficacy was observed in this experiment, large volumes of water are not usually applied to cuttings, hence leaching would be less of a problem at that stage compared with potted, rooted cuttings.

A larger scale experiment would require to be carried out involving potted, rooted cuttings before definite statements could be made regarding possible loss of fungicide efficacy due to leaching.

EXPERIMENT 3

Objective: To determine the effect of fungicide rates on the control of Rhizoctonia on heather cuttings.

Treatments: Four replicate boxes (10 x 10 x 8 cm deep) each containing 10 cuttings of Calluna cv. Bognie were prepared for each of the following treatments:-

1. No Rhizoctonia, no fungicide (control)
2. " , Basilex incorporated into compost (0.02 g/l compost)
3. " , " " " " (0.04 g/l compost)
4. " , " " " " (0.08 g/l compost)
5. " , " " " " (0.16 g/l compost)
6. No Rhizoctonia, Captan 83 incorporated into compost (0.03 g/l compost)
7. " , " " " " (0.06 g/l compost)
8. " , " " " " (0.12 g/l compost)
9. " , " " " " (0.24 g/l compost)

Treatments 10-18, as for 1-9 but with Rhizoctonia isolate D1 on pieces of sterilized straw (2 g/l compost) incorporated before amendment with fungicide.

Treatments 19-27 as for 10-18 but with Rhizoctonia isolate 64.

Basilex incorporated at 0.08 g/l compost and Captan 83 incorporated at 0.12 g/l compost are manufacturers recommended rates for ornamentals.

The whole experiment was repeated using Calluna cvs. Silver Queen and K94.

METHODS

1. The growing medium used was Bulrush propagation compost

2. The cuttings were struck and then the boxes were placed on a glasshouse bench and covered in white polythene. The temperature range during the course of the experiment was 18-22^{o}C.

3. At the end of the experiment (3 weeks) the condition of the foliage was assessed using the scale described in Experiment 1. Also the development of the roots was measured and a root index calculated as follows:-

$$\text{Root index} = \frac{\text{Mean number of roots per treatment} \times \text{mean length of longest root}}{100}$$

4. Isolations onto agar media were made from cuttings to determine the presence of Rhizoctonia.

Table 4. The effect of fungicide rates on the foliage condition of Calluna cuttings growing in Rhizoctonia-amended compost

		Foliage score[a]								
			Captan 83				Basilex				
Isolate	CV.[b]	No fungicide	0.03g	0.06g	0.12g	0.24g	0.02g	0.04g	0.08g	0.16g	Mean
Control	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	SQ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	K94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D1	B	0.75	0.33	0.25	0.00	0.00	0.67	0.58	0.00	0.00	0.29
	SQ	0.83	0.67	0.42	0.08	0.00	0.83	0.25	0.00	0.00	0.34
	K94	0.67	0.17	0.42	0.00	0.00	0.75	0.17	0.00	0.00	0.24
Mean	D1	0.75	0.39	0.36	0.03	0.00	0.75	0.33	0.00	0.00	0.29
64	B	1.17	0.75	0.00	0.00	0.00	0.67	0.42	0.00	0.00	0.33
	SQ	1.17	0.75	0.17	0.00	0.00	0.42	0.33	0.00	0.00	0.32
	K94	0.66	0.66	0.00	0.00	0.00	0.33	0.25	0.00	0.00	0.21
Mean	64	1.00	0.72	0.06	0.00	0.00	0.47	0.33	0.00	0.00	0.29

a Foliage condition, 0-4 scale, where 0 = no foliage browning and 4 = foliage completely brown

b B = Bognie, SQ = Silver Queen, K94 = K94

Virtually no foliar browning occurred on any cultivar infected with either isolate when treated with Basilex or Captan 83 at the manufacturer's recommended rate or at double that rate (Table 4, see also Fig. 1). Foliar browning was recorded in all treatments which involved Rhizoctonia where the rate of either fungicide was reduced. However, the extent of the damage was less than where no fungicide was used at all.

Cuttings growing in uninfested compost with or without fungicide amendment showed no foliar browning.

Root production was greatest on cuttings growing in compost which did not contain Rhizoctonia and which had not been amended with fungicide (Table 5).

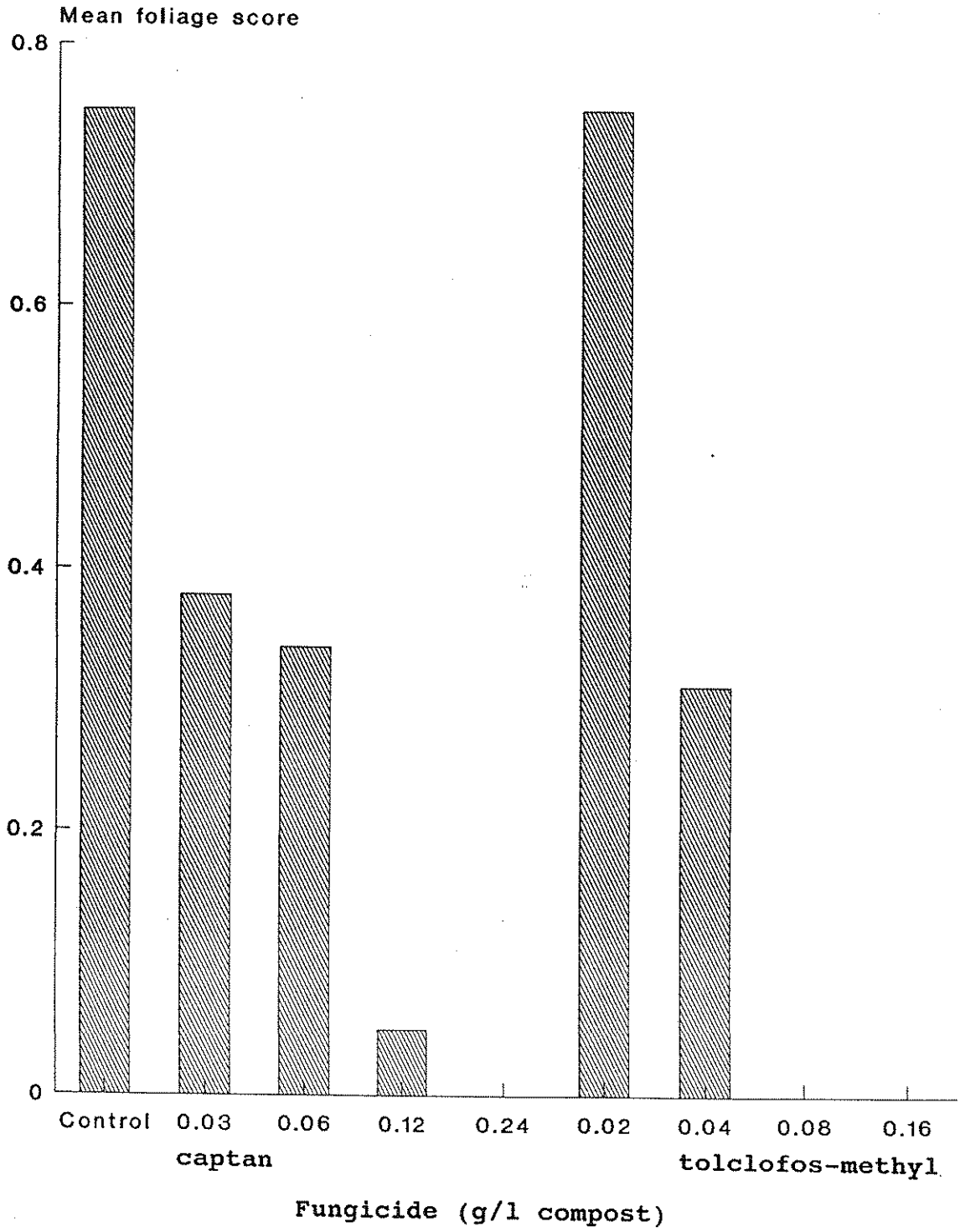

Fig. 1 . The effect of different compost incorporation rates of tolclofos-methyl and captan on the mean foliage score[a] of C. vulgaris cvs. Bognie, Silver Queen and K94 grown in Bulrush propagation compost amended with binucleate Rhizoctonia spp. isolate D1 assessed 3 weeks after striking.

[a]Foliage score (means taken from three cvs.) : 0 = no foliage browning;
4 = foliage totally brown.

Table 5. Mean root indices of Calluna cuttings growing in infested and uninfested fungicide-treated compost (mean of three cultivars)

Fungicide	Rate (g/l compost)	Isolate of Rhizoctonia			
		Control	D1	64	Mean
None		27.3	17.2	10.4	18.3
Captan 83	0.03	13.1	21.6	16.1	16.9
	0.06	18.1	17.7	13.9	16.6
	0.12	13.5	13.0	10.5	12.3
	0.24	2.0	6.2	4.8	4.3
Basilex	0.02	18.0	15.1	16.9	16.7
	0.04	15.0	17.6	18.2	16.9
	0.08	17.9	16.5	19.3	17.9
	0.16	18.2	14.4	17.7	16.8

The addition of either fungicide at any rate to uninfested compost reduced rooting. These reductions were most marked when Captan 83 was added to compost at the highest rate (0.24 g/l compost).

The addition of either strain of Rhizoctonia to the compost resulted in a reduction in root production. Although amendment of infested compost with fungicide reduced foliage browning (viz. Table 4) this was not necessarily associated with an improvement in root production. Both fungicides (except Captan 83 at the 0.24 g/l rate) increased root production of cuttings in compost amended with Rhizoctonia isolate 64 this was not the case with isolate D1.

As shown in Table 6, no infection was found in any cuttings growing in compost treated with Captan 83 at the highest rate, (0.24 g/l) or with Basilex at the two higher rates, (0.08 g/l and 0.16 g/l). The lower rates of Captan and Basilex did not prevent infection of cuttings growing in infested compost, although the percentage infection of cuttings growing in fungicide-treated, infested compost was lower than that of cuttings grown in untreated infested compost.

Table 6. Number of infected cuttings (max. 12) from which Rhizoctonia was isolated

Fungicide	Rate (g/l compost)	Isolate of Rhizoctonia: Control	D1	64
None		0	9	8
Captan 83	0.03	0	6	7
	0.06	0	5	4
	0.12	0	1	0
	0.24	0	0	0
Basilex	0.02	0	1	2
	0.04	0	0	1
	0.08	0	0	0
	0.16	0	0	0

DISCUSSION AND CONCLUSIONS

It was thought that it would be possible to reduce fungicide rates, and still achieve good control of Rhizoctonia. In this way costs could be saved and the risk of phytotoxicity would be minimised. However, the results of this experiment indicate that control of Rhizoctonia cannot be achieved with reduced rates of either Basilex or Captan 83, therefore this line of approach is not feasible.

EXPERIMENT 4

Objective: The effect of watering on the efficacy and persistence of fungicides used to control Rhizoctonia

Treatments: Bulrush propagating compost which was unamended, or into which had been incorporated 80 g/m^3 compost of Basilex was placed in half seed trays and treated as follows:-

1. 1.25l of water applied with a watering can fitted with a fine rose
2. 20l " " " " " " " " " "
3. 40l " " " " " " " " " "
4. 60l " " " " " " " " " "

The trays were allowed to drain for three hours and then to half of them was added Rhizoctonia isolate 64 (16 pieces of inoculated sterilized straw were mixed into the compost in each tray). Thus three replicate trays of each of

the 16 treatments were prepared. In each tray were struck 15 cuttings of Calluna cv. Cuprea.

METHODS

1. Following striking, the trays were placed in a glasshouse (12-15^{o}C) and covered in polythene.

2. Foliage condition was assessed 5 weeks after striking the cuttings.

RESULTS

Basilex gave complete control of Rhizoctonia when cuttings were watered with 1.25l of water shortly before the fungus was introduced into the compost (Fig. 2). However, the level of control was reduced significantly (X^2 = 57.424; p = < 0.001) when larger quantities of water were applied. Thus the foliage condition scores were 0.6, 1.2 and 1.5 where the compost was drenched with 20l, 40l and 60l of water respectively.

Rhizoctonia was isolated from 3/12, 11/12 and 10/12 cuttings from infested composts which had been treated with fungicide and watered with 20l, 40l and 60l of water respectively. No Rhizoctonia was isolated from cuttings grown in compost treated with Basilex which received 1.25l of water after incorporation of the fungicide.

The control cuttings grown in uninfested compost showed no foliar browning and rooted in two to three weeks.

DISCUSSION AND CONCLUSIONS

The application of water to propagation compost resulted in loss of efficiency of the fungicide, possibly as a consequence of leaching. This would not normally cause a problem during the propagation of C. vulgaris and Erica spp. as the application of large volumes of water is not necessary at this stage, since the cutting trays normally are covered in polythene whilst rooting. However, once potted, crops of C. vulgaris and Erica spp. often are irrigated daily, using overhead irrigation systems for up to one hour, particularly during spring and summer. Loss of fungicide through leaching in such situations may present a serious problem.

Avoidance of over-watering, or the placement of plants on capillary sand-beds, may help to conserve fungicide within the compost. The frequency of watering may also be taken into account when formulating fungicide programmes. Plants watered with overhead irrigation in summer may require more frequent fungicide applications than those grown in capillary beds.

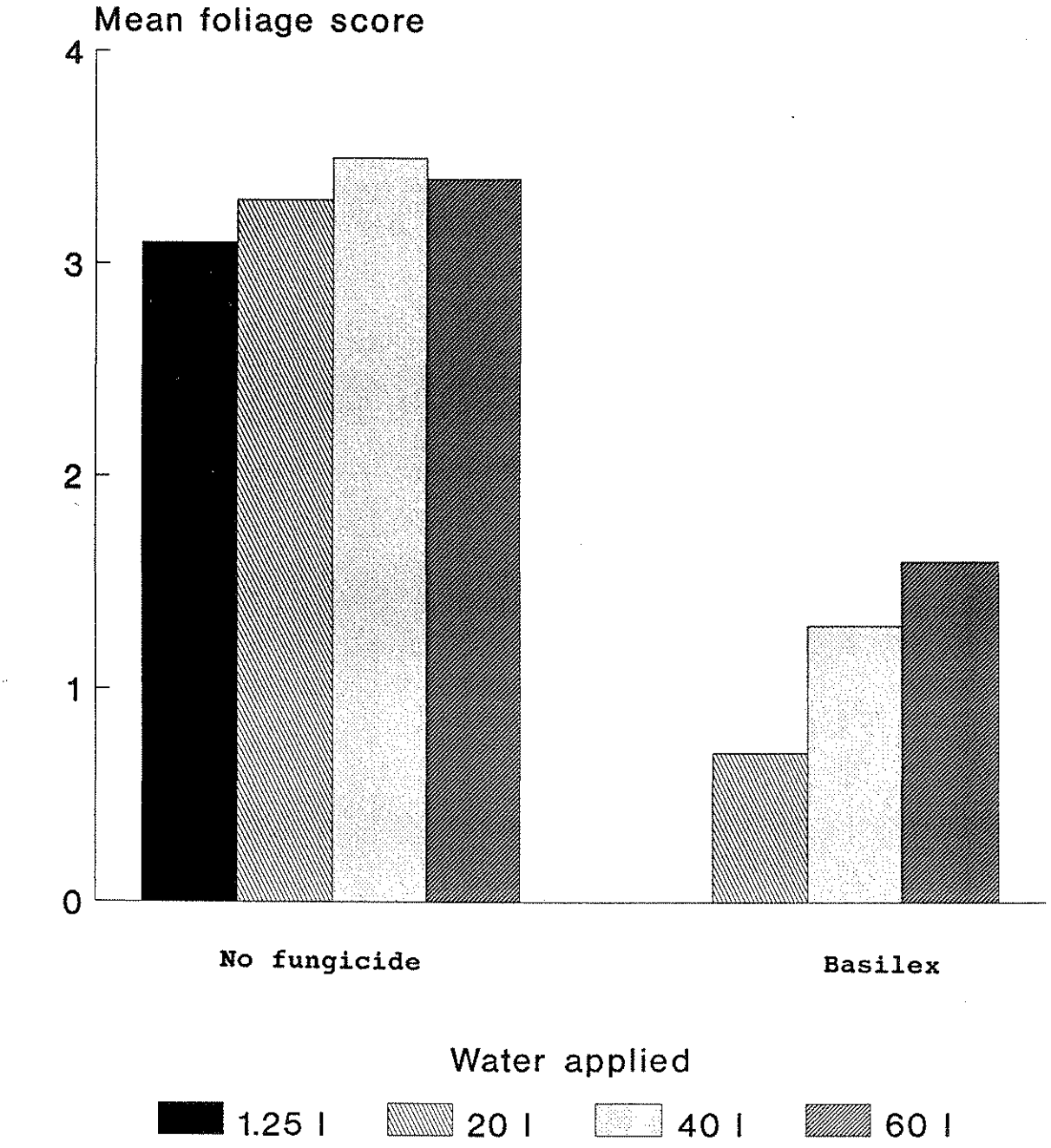

Fig. 2. The effect of irrigation and Basilex incorporated in compost on the foliage condition of C. vulgaris cv. Cuprea cuttings struck in Bulrush propagation compost amended with binucleate Rhizoctonia spp. isolate 64 and assessed 3 weeks after striking.

[a]Foliage score: 0 = no browning; 4 = totally brown foliage

EXPERIMENT 5

Objective: To determine the effect of fungicide timings on the control of Rhizoctonia

Treatments: Six replicate trays were filled with fungicide-amended compost at weekly intervals pre-striking as follows:-

1. Basilex (80g in 40l water/m^3 compost) 3, 2, 1 and 0 weeks before striking the cuttings.

2. Captan 83 (120g in 40l water/m^3 compost) 3, 2, 1 and 0 weeks before striking the cuttings.

3. Control (40l water/m^3 compost) 3, 2, 1 and 0 weeks before striking the cuttings

Immediately before striking the cuttings, Rhizoctonia isolate 48 (16 pieces of inoculated sterilized straw/tray) was incorporated into the compost of half of the trays of each of the three above treatments.

Fifteen cuttings of C. vulgaris cv. Cuprea were struck in each tray.

The trays were placed on a glasshouse bench and covered in polythene.

Assessments:

1. Foliage assessments were conducted after 3 weeks using the scale described in Experiment 1.

2. Stem base sections for 12 cuttings taken at random from each treatment were plated on P.D.E.S. following the final assessment to determine the presence of Rhizoctonia.

RESULTS

No foliar browning occurred on cuttings in untreated uninfested compost or uninfested compost treated with Basilex. A small but significant (chi-squared analysis, $p < 0.05$) amount of browning occurred on cuttings in uninfested compost treated with Captan 83 (Table 7).

Foliage browning occurred in infested composts which received no fungicide treatment and in compost treated with Captan 83 (0.12 g/l compost) 1, 2 and 3 weeks before striking. No foliage browning was recorded where Captan 83 was applied immediately before the cuttings were struck. Although a small amount of browning was seen on cuttings struck in infested compost which had been treated with Basilex (80 g/m^3 compost) 1 and 2 weeks before striking, control generally was excellent where Basilex had been used.

No infection of cuttings occurred in composts treated with either fungicide at striking (Table 8). Infection was reduced (compared to controls), in infested

composts treated with Basilex 1,2 or 3 weeks before striking. No such reduction was observed with Captan 83.

Table 7. The effect of Captan 83 and Basilex incorporated in compost 0, 1, 2 and 3 weeks before cuttings were taken, on the foliage condition of C. vulgaris cv. Cuprea cuttings grown in compost amended with Rhizoctonia isolate 48. Assessment conducted 3 weeks after striking.

		Foliage score *				
		Timing of fungicide incorporation (weeks before striking)				
Rhizoctonia isolate	Fungicide	3	2	1	0	Mean
None	None	0.00	0.00	0.00	0.00	0.00
None	Captan 83	0.04	0.02	0.02	0.00	0.02
None	Basilex	0.00	0.00	0.00	0.00	0.00
48	None	1.62	1.51	1.38	1.78	1.57
48	Captan 83	1.36	2.96	3.11	0.00	1.86
48	Basilex	0.00	0.04	0.04	0.00	0.02

* Foliage score: 0 = No browning; 4 = Foliage totally brown

Table 8. Infection of cuttings of C. vulgaris cv. Cuprea 3 weeks after striking in compost amended with Rhizoctonia and treated with Captan 83 or Basilex 0, 1, 2 or 3 weeks before the cuttings were struck.

		Number of cuttings (max. 12) infected with Rhizoctonia			
Rhizoctonia isolate	Fungicide	3 weeks	2 weeks	1 weeks	0 weeks
None	None	0	0	0	0
None	Captan 83	0	0	0	0
None	Basilex	0	0	0	0
48	None	7	6	5	7
48	Captan 83	5	8	9	0
48	Basilex	0	1	0	0

DISCUSSION AND CONCLUSIONS

Basilex gave good control of Rhizoctonia in all treatments although a small amount of infection was detected in cuttings growing in compost treated one or two weeks before striking. These results indicate that Basilex persists at an effective level long enough in compost to provide protection of cuttings through the rooting period. However, this is not the case with Captan 83. It has been shown to have a short persistence in soil. According to Burchfield, (1959) the half life of Captan is only 3-4 days in moist soil. It can be fully degraded within one week when applied at or below 250 ppm concentration (Agrihotri, 1971). Furthermore, the application of Captan 83 one or two weeks before striking actually increased disease development. This may be because Captan 83 is a broad spectrum fungicide and that it affected the compost microflora removing competitors and antagonists to Rhizoctonia.

The conclusion from this experiment is that whilst Captan 83 is active against Rhizoctonia, its short persistence means that incorporation pre-striking will not provide effective control during the rooting period. Repeat treatments would be necessary at approximately weekly intervals. In view of this, the more expensive, but more persistent action of Basilex would seem to be the best option.

EXPERIMENT 6

Objective: To determine the effect of fungicides on the health and growth of potted, rooted cuttings.

Treatments: Six replicates of five Calluna plants in 8 cm square pots were prepared for each of the following treatments:-

1. Untreated controls.

2. Plants potted into compost containing Rovral dust (1.25% iprodione) at 400 g/m^3 compost and drenched every 4 weeks with Rovral WP (50% iprodione) at 6 $g/l/m^2$. (Low rate Rovral).

3. Plants potted into compost containing Rovral dust (1.25% iprodione) at 800 g/m^3 compost and drenched every 4 weeks with Rovral WP (50% iprodione) at 6 $g/l/m^2$. (High rate Rovral).

4. Plants potted into compost containing Basilex (50% tolclofos-methyl) at 80 g/m^3 compost and drenched every 4 weeks with Basilex at 2 $g/l/m^2$. (Low rate Basilex).

5. Plants potted into compost containing Basilex (50% tolclofos-methyl) at 160 g/m^3 compost was drenched every 4 weeks with Basilex at 4 $g/l/m^2$. (High rate Basilex).

METHODS

1. Plants were potted into the following compost:-

25% Cambark
75% Bulrush peat
2 kg/m^3 Ficote 140
1.8 kg/m^3 Dolodust
0.3 kg/m^3 Fritted trace elements

After potting, the plants were maintained on polythene beside other plants at a similar stage on the nursery.

2. The plants were managed in the same way as the other heathers on the nursery, with the exception of the drenches which were applied as described above.

3. The foliage of each plant was assessed at each drenching date using the scale described in Experiment 1.

4. On the final assessment the dry weight of the shoots was determined and root and stem base sections from 10 plants per treatment were taken at random and plated on P.D.E.S. to check for the presence of the pathogen.

RESULTS

No foliage browning was observed on plants in any treatment. Although the foliage dry weights of Basilex-treated plants were in general lower than those of untreated plants (Table 9), analysis of variance revealed that these differences were not significant. No Rhizoctonia was isolated from plants in any treatment.

Table 9. The effect of fungicide treatment on the shoot dry weight (g) of Calluna plants 6 months after potting

Fungicide treatment	Rate	Shoot dry weight (g)
None		0.79
Rovral	Low	0.68
Rovral	High	0.81
Basilex	Low	0.73
Basilex	High	0.64
SED (29 d.f.)		0.05

DISCUSSION AND CONCLUSIONS

Earlier work (see Research Report 1) showed that the use of fungicides on cuttings often results in phytotoxicity, and in particular the inhibition of

rooting. This experiment was designed to determine whether older potted heathers were liable to fungicide damage. No foliar browning occurred on treated plants, and root and foliage development were not significantly affected. The indications are that heathers of this age and cultivar safely can be treated with Basilex or Rovral at the rates used. However, further evaluation with a range of cultivars is necessary before general recommendations can be made.

EXPERIMENT 7

Objective: To determine the effect of temperature on the growth of isolates of Rhizoctonia in culture.

Treatments: Three replicate petri dishes containing Rhizoctonia isolate 72 or 48 (both Rhizoctonia spp.) or E or A (both Rhizoctonia solani) growing on potato dextrose agar were placed in each of seven incubators at 5^{o}, 10^{o}, 15^{o}, 20^{o}, 25^{o}, 30^{o} and 35^{o}C.

METHODS

1. Discs (11 mm diameter) were cut from 2 week old cultures of two binucleate Rhizoctonia isolates 72 and 48 and each of the two R. solani isolates E and A and were placed in the centre of 9 cm diameter petri dishes containing potato dextrose agar.

2. The radial growth of the mycelium was measured 24, 48 and 72 h after the start of the incubation.

RESULTS

Temperature had a significant effect (SED 0.91, $p < 0.001$) on the growth of isolates of R. solani and binucleate Rhizoctonia spp. in vitro (Fig. 3). R. solani isolate A and binucleate Rhizoctonia isolate 48 did not grow at 5^{o}C. However, R. solani isolate E and binucleate isolate 72 grew slowly at 5^{o}C (approx. 0.01 mm/hour). Rhizoctonia isolates 48 and A grew optimally at 25^{o}C (approx. 0.67 mm/hour) and isolates E and 72 grew optimally at 20^{o}C (approx. 0.75 and 0.67 mm/hour respectively). There were significant differences (SED 0.43, $p < 0.001$) between the growth rates of isolates E and 72 and isolates A and 48 at 20^{o}C and 25^{o}C.

DISCUSSION AND CONCLUSIONS

The results clearly show that Rhizoctonia can grow over a wide temperature range with an optimum in the range of 20-25^{o}C. In vitro investigations give an indication of the influence of temperature on the growth of the fungus. As they give no indication of the effect on infection then careful interpretation of the practical significance is essential. Whilst Rhizoctonia is pathogenic on many host species, it may be regarded as an opportunistic fungus, causing most damage to plants which have been subject to a check. Generally it causes least damage to plants which are growing vigorously. Thus although the fungus may grow optimally at 20-25^{o}C, it may be more damaging at low or high

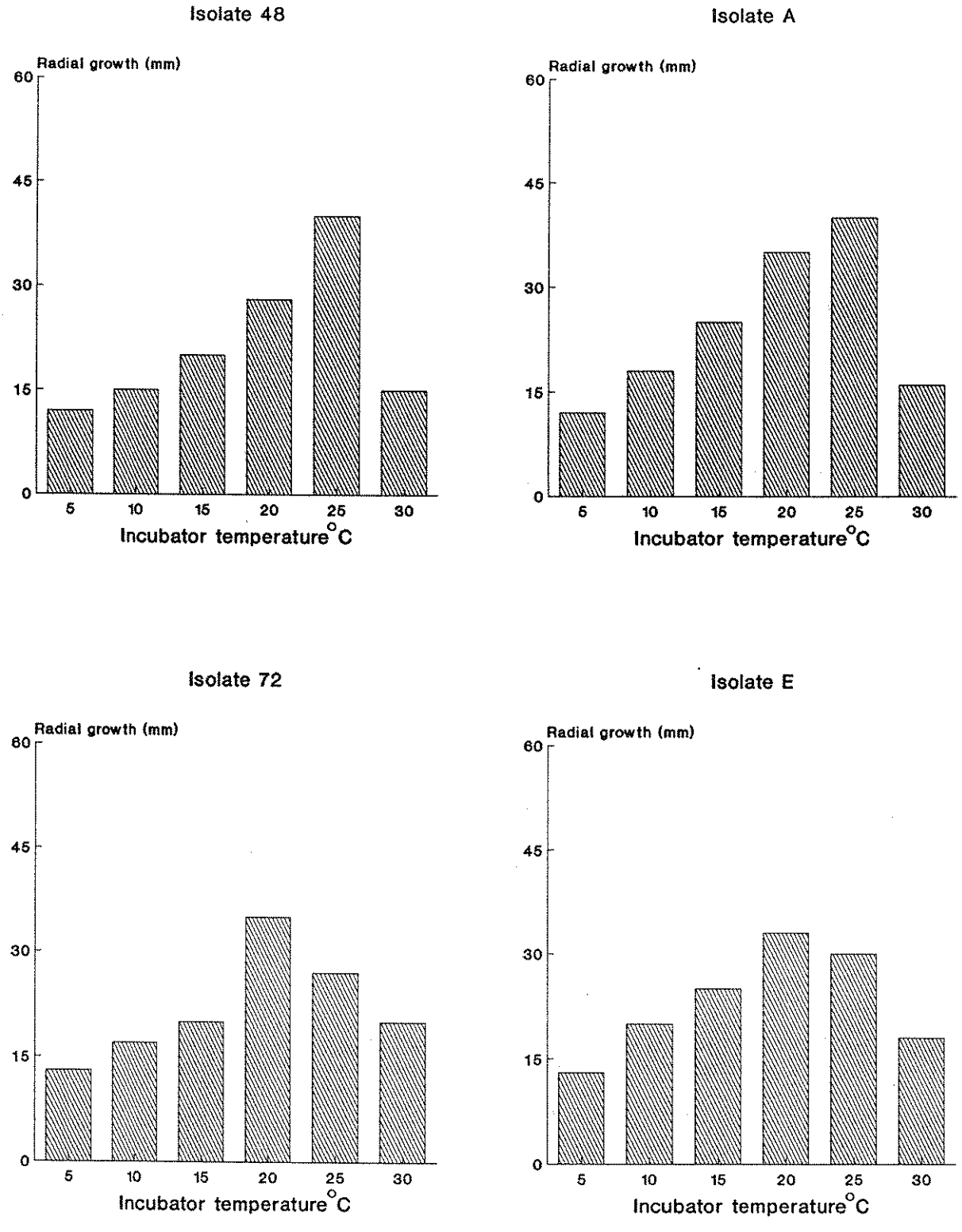

Fig. 3. Growth of R. solani isolates A and E and binucleate Rhizoctonia spp. isolates 72 and 48 at a range of temperatures on potato dextrose agar. (Means of three measurements of colony radius from original 5 mm culture disc to edge of colony in mm.

temperatures which cause stress to the plants rendering them more susceptible to infection.

EXPERIMENT 8

Objective: To determine the effect of temperature on the development of Rhizoctonia on Calluna plants.

Treatments: Four replicate trays each containing four cuttings each of Calluna vulgaris cvs. Darkness and Cuprea and Erica cinerea cv. Lilacina were prepared for each of the following treatments:-

1. 5-10°C Uninoculated compost
2. 5-10°C Rhizoctonia isolate 48
3. 5-10°C Rhizoctonia isolate 72

4. 10-17°C Uninoculated compost
5. 10-17°C Rhizoctonia isolate 48
6. 10-17°C Rhizoctonia isolate 72

7. 15-25°C Uninoculated compost
8. 15-25°C Rhizoctonia isolate 48
9. 15-25°C Rhizoctonia isolate 72

METHODS

1. The boxes were filled with compost (Bulrush proprietary propagation compost) which had been amended with 2g sterile chopped straw/l compost or with the same rate of sterilized straw on which had been grown Rhizoctonia isolate 48 or 72.

2. The cuttings were struck into the compost immediately after incorporation of the straw. The treatments then were arranged in a randomised block layout in growth cabinets and covered with white polythene to create a suitable environment for rooting. A lighting regime designed to simulate normal daylight was provided in each 24 h cycle at each temperature.

3. Assessments of the foliage conditions were made after 4 weeks using the foliage browning scale described in Experiment 1.

RESULTS

The foliage scores of cuttings grown in Rhizoctonia-amended compost differed significantly between temperatures ($p < 0.001$) and isolates ($p < 0.001$). Rhizoctonia isolate 72 caused most foliar browning at 10-17°C (Table 10), whereas isolate 48 caused most foliar browning in the highest temperature regime (15-25°C). Foliage scores of E. cinerea cv. Lilacina cuttings were significantly lower ($p < 0.001$) than those of the two Calluna cultivars.

There was no foliar browning on control cuttings grown in uninfested composts.

A similar experiment was carried out using Rhizoctonia isolates D1, 48 and 64.

Table 10. Mean foliage[a] scores of C. vulgaris and E. cinerea cuttings grown in composts amended with binucleate Rhizoctonia isolates 48 and 72 and kept in three different temperature regimes, assessed 4 weeks after cuttings were struck.

Temperature regime	Rhizoctonia isolate	Mean foliage score			
		C. vulgaris		E. cinerea	Mean
		Darkness	Cuprea	Lilacina	
5-10°C	Control	0.00	0.00	0.00	0.00
5-10°C	72	2.63	2.50	0.50	1.88
5-10°C	48	0.94	1.25	0.88	1.02
10-17°C	Control	0.00	0.00	0.00	0.00
10-17°C	72	3.63	3.63	0.81	2.69
10-17°C	48	2.94	2.75	1.19	2.29
15-25°C	Control	0.06	0.00	0.00	0.02
15-25°C	72	1.50	0.88	0.19	0.86
15-25°C	48	3.50	3.31	1.69	2.83
Mean		1.69	1.59	0.58	

[a]Foliage scores: 0 = no browning; 4 = totally brown foliage.

Cuttings grown in compost amended with isolates 48 and 64 showed the most severe browning in the highest temperature regime (15-25°C) where mean foliage scores of 3.48 and 3.12 were recorded on C. vulgaris cuttings grown in compost amended with Rhizoctonia isolates 48 and 64 respectively. Cuttings grown in compost amended with Rhizoctonia isolate D1 showed most foliar browning in the 10-17°C regime (mean score of 3.24 for C. vulgaris cuttings in amended compost).

DISCUSSION AND CONCLUSIONS

The wide temperature range over which Rhizoctonia is active, and the variation in response of isolates of the fungus to temperature make it difficult to manipulate temperature as a means of disease control.

EXPERIMENT 9

Objectives: To determine the influence of compost components/additives on the development of Rhizoctonia in cutting compost.

Treatments: Four cuttings each of C. vulgaris cvs. Beoley Gold, Mousehole and Cuprea were struck in seed trays containing one of the following composts and amended with Rhizoctonia isolate 48 (2g straw/l compost) as indicated. A similar number of trays contained 2g sterile straw/l compost.

1. Bulrush sphagnum moss peat (screened 22 mm)
2. 1:1 (v/v) peat + fine grade Cambark
3. 1:1 (v/v) peat + Horticultural bark (Milcourt Industries)
4. 10:1 (v/v) peat + liquid sewage sludge
5. 3:1 (v/v) peat + solid sewage sludge
6. Bulrush peat + 15g Fertilox granules (Interox Chemicals Ltd)/l

METHODS

1. The condition of the foliage used was assessed after 4 weeks on the scale described in Experiment 1.

2. Mean dry weight of roots was determined after assessment of foliage condition.

3. At the end of the experiment, two, 2-5 mm length pieces of stem base were removed from 12 cuttings taken at random from each treatment and placed on P.D.E.S. to check for the presence of Rhizoctonia.

RESULTS

The foliage scores of cuttings grown in peat and bark (Milcourt Industries) compost amended with Rhizoctonia isolate 48 were significantly lower than those of cuttings grown in other Rhizoctonia-amended composts (Table 11). For example, a mean score of 2.5 was recorded on C. vulgaris cv. Beoley Gold

Table 11. The effect of compost type on the foliage condition[a] of C. vulgaris cvs. Mousehole, Cuprea and Beoley Gold cuttings struck into Rhizoctonia amended compost, assessed 4 weeks after cuttings were struck.

Compost	Foliage score[a]			
	Mousehole	Cuprea	Beoley Gold	Mean
Bulrush peat	3.4	3.2	3.4	3.3
1:1 (v/v) Peat + Cambark	3.1	3.4	3.4	3.3
1:1 (v/v) Peat + M.I.[b] bark	2.6	3.0	2.5	2.7
1:1 (v/v) Peat + liquid sludge	3.5	3.4	3.6	3.5
1:1 (v/v) Peat + solid sludge	3.3	3.4	3.5	3.4
Peat + Fertilox granules (15 g/l)	3.4	3.7	3.5	3.5
(15) = 106.365; $p < 0.001$				

[a]Foliage score: 0 = no browning; 4 = foliage totally brown

[b]Bark produced by Melcourt Industries

cuttings grown in peat + bark compost whereas scores of 3.4 and 3.6 were recorded on cuttings of the same cultivar grown in peat + Cambark and peat + liquid sludge composts respectively. There were no significant differences between scores of cuttings grown in other composts amended with isolate 48.

Isolations from stem bases of cuttings revealed that all foliar browning was due to infection by Rhizoctonia. No Rhizoctonia was isolated from control cuttings grown in unamended composts which rooted in 2-4 weeks and showed no foliar browning.

The mean root dry weight of cuttings grown in 3:1 (v/v) peat + solid sewage sludge compost which had not been amended with Rhizoctonia was significantly lower ($p < 0.001$) than that recorded on cuttings grown in the other control composts. However, root dry weights recorded on cuttings grown in 1:1 (v/v) peat and bark, pure peat, 10:1 (v/v) peat + liquid sludge and peat + 15g Fertilox granules/l compost were not significantly different from those recorded on cuttings grown in standard propagation compost.

There was extensive growth of algae and moss on the surface of the compost which contained solid sewage sludge.

DISCUSSION AND CONCLUSIONS

Although there were indications that peat and bark (Milcourt Industries) compost ameliorated the disease effects, there was still a significant amount of foliage damage. The other composts used did not reduce damage. This lack of effect may be because no chemical inhibitors capable of restricting the growth of Rhizoctonia through composts were present, or that there were no micro-organisms (or sufficiently high populations of micro-organisms) which were antagonistic to the Rhizoctonia isolate used in these tests.

That compost ingredients can suppress diseases caused by soil-borne pathogens such as Rhizoctonia and Pythium has been demonstrated by various research workers. In 1982 Tahvonen found that half of the Finnish sphagnum peat samples which he tested significantly reduced or inhibited damping-off caused by R. solani on cauliflowers. Lumsden et al (1983) showed that the addition of 10% composted sewage sludge to soil significantly reduced the level of Rhizoctonia root rot on cotton, bean and radish and Nelson & Hortink (1983) demonstrated that the addition of composted hardwood bark to peat and perlite composts significantly reduced the damping-off of Celosia seedlings caused by R. solani.

No U.K. source of composted hardwood bark (as used by Nelson & Hortink, 1982) was found, hence two proprietary brands of composted pine bark were used. In view of the numerous reports of successful control of Rhizoctonia spp. in growing media amended with composted hardwood bark (Daft et al, 1979; Stephens et al, 1981; Hortink & Kuter, 1986) it is possible that composts amended with this type of bark may aid the control of disease of C. vulgaris and Erica spp. caused by Rhizoctonia.

Further testing of compost additives may well be worthwhile.

EXPERIMENT 10

Objective: To identify the location and nature of damage caused by Rhizoctonia spp. on C. vulgaris and E. cinerea.

Treatments and Methods:

Ninety rooted cuttings of each of C. vulgaris cvs. My Dream and Cuprea and of E. cinerea cv. Golden Hue were potted, 12 weeks after striking, in standard potting compost in which had been incorporated sterilized straw colonised by one of five isolates of Rhizoctonia (2g straw/l compost), or in which sterilized uninoculated straw had been incorporated (2g straw/l compost).

After 4 weeks, the roots, stem-bases and foliage were examined visually to determine the presence of browning. Five, 2-5 mm length pieces of surface sterilized root and stem-base from each plant were placed on P.D.E.S. agar. Ten, 10-15 mm length pieces of fine root were taken from each plant and placed in sterile distilled water in petri dishes. Foliage pieces (2-10 cm length branches) were incubated in high humidity. The development of Rhizoctonia on these plant tissues was recorded after 24-72 hours.

RESULTS

E. cinerea cv. Golden Hue was less severely infected and showed less foliar browning than the two Calluna cultivars (Tables 12, 13, 14). Rhizoctonia isolate 56 was the least pathogenic of the isolates tested. It did not infect E. cinerea Golden Hue plants and although it infected the roots and stem base of the Calluna cultivars, it caused no foliar browning.

Rhizoctonia isolates 72, D1, 64 and 48 caused varying levels of infection and browning of foliage and stem base depending on cultivar. The fungus was most frequently isolated from the lower foliage, stem base and woody roots. It was isolated only occasionally from the fine roots and upper foliage.

No foliar browning or root rot was observed on, and no Rhizoctonia was isolated from control plants grown in uninfested compost.

DISCUSSION AND CONCLUSIONS

The results of this experiment highlighted several important points. Firstly, isolates of Rhizoctonia differ markedly in the damage which they cause to heathers. Secondly, the two Calluna cultivars tested were more susceptible to infection and damage than was the cultivar of E. cinerea. Thirdly Rhizoctonia infects mainly at or around soil level and for this reason every effort must be made to reduce humidity in this region thereby making the environmental conditions less favourable for infection (e.g. wider plant spacing, plant trimming). Careful fungicide application to ensure good penetration to the plant base and the compost also is an important aspect of disease management.

Table 12. Isolation of binucleate Rhizoctonia spp. from, and health of E. cinerea cv. Golden Hue plants 4 weeks after potting.

Rhizoctonia isolate	Fine roots	Woody roots	Stem base	Lower foliage[a]	Upper foliage[b]	% Browning on foliage
None	H-	H-	H-	H-	H-	0
	H-	H-	H-	H-	H-	0
	H-	H-	H-	H-	H-	0
	H-	H-	H-	H-	H-	0
	H-	H-	H-	H-	H-	0
72	H-	H-	N+	B+	H-	0-20
	H-	H-	N+	B+M	H-	0-20
	H-	H-	H-	H-	H-	0
	H-	H-	H-	H-	H-	0
	H-	H-	H-	H-	H-	0
D1	H-	H-	H-	H-	H-	0
	H-	H-	H-	H-	H-	0
	H-	H-	H-	H-	H-	0
	H-	H-	H-	H-	H-	0
	H-	H+	H+	B+	H-	0-20
64	H-	H-	H-	B+M	H-	0-20
	H-	H-	H+	B+M	H-	0-20
	H-	H-	N+	B+M	H-	0-20
	H-	H-	H-	H-	H-	0
	H-	H-	H-	H-	H-	0
48	H-	H-	H-	B+M	H+	0-20
	H-	H-	H-	B+M	H-	0-20
	H-	H-	H-	H-	H-	0
	H-	H-	H-	H-	H-	0
	H-	H-	H-	H-	H-	0
56	H-	H-	H-	H-	H-	0
	H-	H-	H-	H-	H-	0
	H-	H-	H-	H-	H-	0
	H-	H-	H-	H-	H-	0
	H-	H-	H-	H-	H-	0

Key to assessment tables

N = Necrotic; H = Healthy; B = Browning visible

+ = Rhizoctonia isolated; - = No Rhizoctonia isolated

M = Mycelium visible using hand lens

Total browning on foliage measured in 20% increments:

0-20%, 20-40%, 40-60%, 60-80%, 80-100%

a - Lower foliage = foliage < 0-3 cm above soil level
b - Upper foliage = foliage > 3 cm above soil level

Table 13. Isolation of binucleate Rhizoctonia spp. from, and health of C. vulgaris cv. My Dream plants assessed 4 weeks after potting.

Rhizoctonia isolate	Fine roots	Woody roots	Stem base	Lower foliage	Upper foliage	% Browning of foliage
None	H-	H-	H-	H-	H-	0
	H-	H-	H-	H-	H-	0
	H-	H-	H-	H-	H-	0
	H-	H-	H-	H-	H-	0
	H-	H-	H-	H-	H-	0
72	H-	H-	N+	B+M	H-	0-20
	H-	H-	H+	B+M	H-	0-20
	H-	N+	H-	B+	H-	20-40
	H-	H-	H-	B+M	H-	0-20
	H-	N+	N+	B+M	H-	0-20
D1	H-	H-	N+	B+M	B+M	20-40
	H-	H-	N+	B+M	H-	0-20
	H-	H-	H-	B+M	H-	0-20
	H-	H+	H-	B+M	H-	0-20
	H-	H-	H-	B+	H-	0-20
64	H-	H+	H-	B+M	H-	0-20
	H-	H-	N+	B+M	H-	0-20
	H-	H-	N+	B+M	H-	0-20
	H-	H-	N+	B+M	H-	0-20
	H-	H-	H-	H-	H-	0-20
48	H-	H-	H+	H+	H-	0-20
	H-	H-	H+	B+M	H-	0-20
	H-	H-	H-	B+M	H-	0-20
	H-	H-	H+	B+M	H-	0-20
	H-	H-	H-	H-	H-	0
56	H-	H+	H+	H-	H-	0
	H-	H+	H+	H-	H-	0
	H-	H-	H-	H-	H-	0
	H-	H-	H-	H-	H-	0
	H-	H-	H-	H-	H-	0

Table 14. Isolation of binucleate *Rhizoctonia* spp. from, and health of *C. vulgaris* cv. Cuprea plants assessed 4 weeks after potting.

Rhizoctonia isolate	Fine roots	Woody roots	Stem base	Lower foliage	Upper foliage	% Browning of foliage
None	H-	H-	H-	H-	H-	0
	H-	H-	H-	H-	H-	0
	H-	H-	H-	H-	H-	0
	H-	H-	H-	H-	H-	0
	H-	H-	H-	H-	H-	0
72	H+	H+	N+	B+M	H-	20-40
	H-	H+	N+	B+M	H-	20-40
	H-	N+	N+	B+M	H-	10-20
	H-	N+	N+	B+M	H-	20-40
	H-	H-	H-	H-	H-	0
D1	H-	H+	N+	B+M	B+M	20-40
	H-	H-	H-	H-	H-	0-10
	H-	H-	N+	B+M	H-	20-40
	H-	H-	N+	B+	H-	10-20
	H-	H-	H-	H-	H-	0
64	H-	H-	H-	H-	H-	0
	H-	H+	H+	B+	H-	0-20
	H-	H+	N+	B+M	H-	0-20
	H-	H-	N+	B+	H-	0-20
	H-	H-	H+	B+	B+M	0
48	H-	H-	H+	H-	H-	0
	H-	H-	H-	B+M	H-	0-20
	H-	H-	H-	B+M	H+	0-20
	H+	H-	H-	B+M	H+	0-20
	H-	H-	H+	B+	H-	0
56	H-	H-	H+	H-	H-	0
	H-	H-	H-	H-	H-	0
	H-	H+	H+	H-	H-	0
	H-	H-	H+	H-	H-	0
	H-	H-	H-	H-	H-	0

EXPERIMENT 11a

Objective: To determine the effects of saprophytic compost fungi on the growth of Rhizoctonia spp. in vitro.

Treatments and Methods:

Eighteen isolates of saprophytic fungi including Trichoderma spp., Penicillium spp. and Mucor spp. were obtained from compost and from heather roots. Hyphal tip cultures were made from each of the isolates which were grown on P.D.E.S. agar. A 5 mm diameter agar disc bearing an isolate of one of the saprophytic fungi was placed at the edge of a 9 cm diameter petri dish containing P.D.E.S. A 5 mm diameter agar disc bearing Rhizoctonia isolate D1 or 64 was placed at the opposite edge. Growth of both isolates on each plate was examined under a microscope for evidence of parasitism or antibiosis by either isolate.

RESULTS

No isolate of Penicillium or Mucor spp. exhibited antagonism towards Rhizoctonia isolates D1 or 64, i.e. growth of Rhizoctonia was not stopped. In some cases the Rhizoctonia inhibited the growth of Mucor or Penicillium spp. (Table 15).

A variety of interactions were observed between Trichoderma spp. and Rhizoctonia. Trichoderma isolates 4, 7 and 9 prevented further growth of Rhizoctonia when their mycelium met. Trichoderma isolate 10 also stopped the growth of Rhizoctonia isolate 64.

Microscopic examination of the plates revealed that the hyphae of Trichoderma isolates 4, 7, 9 and 10 coiled around and penetrated the Rhizoctonia mycelium.

Table 15. Interactions between binucleate Rhizoctonia spp. isolates D1 and 64 and Trichoderma, Penicillium and Mucor spp., inoculated as 5mm diameter agar culture discs on extreme opposite sides of 9 cm potato dextrose agar plates, assessed 1 week after inoculation.

Saprophytic isolate		Interaction: Isolate D1	Interaction: Isolate 64
Penicillium	a	none	none
	b	none	none
	c	none	c
Mucor	a	none	none
	b	c	c
	c	none	none
Trichoderma	1	c	none
	2	c	c
	3	none	none
	4	b	b
	5	none	none
	6	none	none
	7	b	b
	8	none	none
	9	b	b
	10	d	b
	11	d	d
	12	none	none

none: i.e. both isolates grew across whole plate, no obvious damage or alteration to normal growth of either isolate.

b: growth of Rhizoctonia isolate stopped when contact made with saprophytic isolate. Saprophytic isolate grew over Rhizoctonia mycelium to colonise whole plate.

c: growth of saprophytic isolate stopped when contact made with Rhizoctonia. Rhizoctonia grew over whole plate.

d: growth of both isolates stopped when two isolates were 0-2 mm apart.

EXPERIMENT 11b

Objective: To evaluate the influence of Trichoderma spp. incorporated into compost on the infection of cuttings of C. vulgaris by Rhizoctonia spp.

Treatments and Methods:

1. Four isolates of Trichoderma spp. which were shown to inhibit the growth of

Rhizoctonia isolates D1 and 64 in vitro were grown on P.D.E.S. agar in 9 cm diameter petri dishes until the surface of the agar was colonised fully. Then they were grown on sterile 5-10 mm length pieces of chopped straw.

2. The inoculum of Trichoderma was mixed with moist Bulrush propagation compost at 2g straw/l compost. Polythene boxes were filled with this compost mixture, covered in polythene and left for 4 days in a polythene tunnel.

3. The compost was then removed from each box and mixed with either sterilized straw or straw colonised by Rhizoctonia isolate D1 or 48 at 2g straw/l compost. The boxes were left under polythene for a further 2 days when four cuttings each of C. vulgaris Mousehole, Cuprea and Silver Queen were struck in each box.

4. Foliar assessments were made at intervals for 4 weeks using the damage scale described in Experiment 1. After the final assessment, two, 2-5 mm length stem pieces were taken from each cutting and placed on P.D.E.S. agar to determine the presence of Rhizoctonia.

RESULTS

There were no significant differences between the levels of foliar browning on cuttings in composts amended with Rhizoctonia isolates alone and in those amended with both a Rhizoctonia isolate and a Trichoderma isolate (Table 16).

Rhizoctonia was isolated from all cuttings grown in infested compost. No Rhizoctonia was obtained from cuttings grown in unamended compost, or in compost containing the Trichoderma only. All cuttings grown in the absence of Rhizoctonia remained healthy, had foliage scores of 0 and rooted in 3-4 weeks.

Table 16. The effect of Trichoderma spp. incorporated into compost on the foliage condition of C. vulgaris[a] cuttings grown in compost amended with binucleate Rhizoctonia isolates, assessed 3 weeks after cuttings were struck.

Trichoderma isolate	Foliage condition score[b]		
	Control	Rhizoctonia isolate 64	Rhizoctonia isolate 48
Control	0.0	3.0	3.5
4	0.0	3.0	3.5
7	0.0	3.1	3.7
9	0.0	3.2	3.8
10	0.0	2.7	3.4
(4) (Rhizoctonia isolates) = 83.763; $p < 0.001$			

a : Scores are the mean from three C. vulgaris cvs. Mousehole, Cuprea and Silver Queen

b : Foliage score: 0 = no browning; 4 = totally brown foliage

DISCUSSION AND CONCLUSIONS

Four of the 12 isolates of Trichoderma spp. tested were antagonistic to one or both of Rhizoctonia spp. isolates D1 and 64 in vitro. Several other investigators have noted that many isolates of Trichoderma spp. show antagonism to isolates of R. solani in vitro.

Fungal biological control agents essentially have three modes of action, namely: mycoparasitism, antibiosis and competition. These three processes are not mutually exclusive, and in nature may occur simultaneously.

Microscopic observations of fungal interactions between Trichoderma spp. and Rhizoctonia spp. revealed that mycoparasitism occurred between several isolates of Trichoderma spp. with one or both of the Rhizoctonia spp. isolates used in the experiment.

A further two isolates of Trichoderma spp. stopped growing when the mycelium was between 0.5 and 2.0 mm from the mycelium of the advancing Rhizoctonia spp. Antibiotic production by one or both of the fungi may have been responsible for the cessation of growth. Several workers have reported that both Trichoderma spp. and R. solani are capable of producing antibiotics in vitro interactions (Henis, 1984; Swan et al, 1984). However, competition for nutrients may also have been involved in such interactions.

Unfortunately, successful biological control of Rhizoctonia spp. by Trichoderma spp. in vitro does not readily translate into the practical situation. Several investigations have demonstrated that isolates of Trichoderma which prevented growth of Rhizoctonia in vitro did not control the pathogen in soil (Lewis & Papavizas, 1985).

Failure of Trichoderma spp. to control Rhizoctonia infection of Calluna may have been due to several reasons. Firstly, the agar plate tests were carried out in the absence of other fungal species, whereas a wide range of micro-organisms normally found in peat and bark composts would have been present in the propagation trays in addition to the Rhizoctonia spp. Such micro-organisms may have affected the metabolism of the Trichoderma spp. either through competition for nutrients or antibiosis.

Secondly, the environment surrounding the cuttings may have been unsuitable for the growth of Trichoderma spp. Temperature, air relative humidity, compost moisture content, pH and nutrient levels would have differed considerably from those on agar media. Growth of Rhizoctonia spp. may have been favoured over that of the Trichoderma spp. isolates.

Thirdly, the form in which Trichoderma spp. were introduced into the compost may have been unsuitable to support the growth of mycelium capable of parasitising mycelium of Rhizoctonia spp. Lewis & Papavizas, 1985), demonstrated that the form in which Trichoderma spp. were applied to soil determined whether or not control of damping-off caused by R. solani was achieved. They found that mycelial preparations (grown on wheat bran), but not conidia of most isolates of Trichoderma tested prevented damping-off of sugar beet, cotton and radish seedlings by R. solani.

Although control of Rhizoctonia spp. isolates D1 and 64 was disappointing on this occasion, the screening of a large number of possible antagonistic fungi, and the examination of a range of application methods may lead to the development of a practical biological control strategy for use against Rhizoctonia spp. on C. vulgaris and Erica spp. in peat composts.

GENERAL DISCUSSION

The overall objective of this study, which began in 1987, was to devise an integrated programme for the control of Rhizoctonia based on a detailed knowledge of the epidemiology of the fungus. To a greater extent this has been achieved, although the host/pathogen interactions have proved more complex than anticipated. Also, the range of varieties grown on nurseries and the varying response to Rhizoctonia under different environmental conditions of those varieties used in these experiments has restricted the utilisation of varietal resistance in a 'blue-print' for disease control.

Taking into account all the data generated and considering the practical requirements of the grower, the following recommendations are made:-

1. The use of new or sterilized nursery material including trays, polythene, capillary matting etc. is of great importance in limiting the spread of Rhizoctonia.

2. Composts which consist only of fresh or sterilized components should be used and contact of plant pots with nursery soil should be minimised. Used nursery materials which cannot be sterilized either should be burnt or removed from the nursery together with old or diseased plants to reduce the quantity of inoculum of Rhizoctonia on the nursery.

3. Stock plant maintenance is central to the disease control programme. If Rhizoctonia is eliminated from stock plants then cutting material will be healthy. Observation of points 1 and 2 should minimise the risk of the cutting material becoming infected during the rooting phase.

   Stock plants should be potted and trimmed annually to maintain vigorous healthy growth. Spacing of the pots is necessary to minimise plant to plant contact and to reduce humidity levels around the base of the foliage.

4. Stock plants should receive a regular (14 day) high volume application of Rovral. It is particularly important to ensure that the chemical penetrates into the foliage canopy. This can be difficult with dense foliage varieties and in pots where the plants have been allowed to get too large and where as a consequence most of the spray runs over the outside of the pot.

5. Tip cuttings should be used rather than shoot-base cuttings. Experimental results indicate that Rhizoctonia does not readily grow more than a few centimetres above the compost. Reducing humidity and the application of Rovral should further reduce the risk of tip cuttings carrying mycelium of Rhizoctonia.

6. Early removal of polythene following rooting of cuttings (or removal of cuttings from mist) will reduce relative humidity. This has been shown to dramatically reduce the spread of Rhizoctonia between cuttings.

7. Unlimed propagation composts with a pH value of around 4.0 should be used. Growth of Rhizoctonia is much reduced at low pH values, and increases markedly once the pH rises above 5.0.

8. During the growth of C. vulgaris and Erica spp. prior to sale, every effort should be made to maintain plant vigour through the use of good cultural practices. Adequate irrigation, air circulation around the plants and a balanced nutrition in a well-drained compost with an AFP value of 15% to 20% combined with optimal levels of fertiliser will favour plant development over growth of the pathogen.

9. The use of fungicides to control Rhizoctonia (and other fungi too) at the propagation stage has been found to cause phytotoxicity (and in particular inhibition of root initiation) under certain conditions. Thus minimal fungicide usage at this critical stage is advised. Careful attention to hygiene and maintenance of stock plants as described above will provide effective control of Rhizoctonia in most situations.

   Further work is necessary to develop integrated programmes for diseases caused by such important pathogens as Pythium, Phytophthora, Fusarium and Cylindrocarpon. Although the management and hygiene recommended for the control of Rhizoctonia will also aid control of these other pathogens, cultural control measures may differ. For example, compost nutrients, temperature and air-filled porosity had little effect on Rhizoctonia, but

fungi such as Pythium may be sensitive to one or more of these factors. Knowledge of this would enable us to build a comprehensive, durable disease control programme for diseases of heathers and heaths.

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Acknowledgements

Financial support from the Department of Agriculture for Scotland, the Highlands and Islands Development Board and the Horticultural Development Council is gratefully acknowledged.

The continued support of growers also is acknowledged, and in particular Mr. Ian Willis, Inverliever Nursery, Ford, Argyll, Mr. John Hall Snr., Windlesham Court Nursery, Surrey, and Mr. John Hall Jnr., Winchfield Nursery, Hants.

The report was prepared by Jacqueline Miller Plant Sciences Department.