THE BIOLOGY AND CONTROL OF FUNGAL PATHOGENS OF ERICA AND CALLUNA

Audrey M. Litterick

Stephen J. Holmes

Report 2

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Contact : Dr. S.J. Holmes
The West of Scotland College
Plant Sciences Department
Auchincruive
Ayr KA6 5HW

Telephone 0292 520331
Fax 0292 521119
Telex 777400

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INTRODUCTION

During the second year of the project, the influence of a wide range of variable factors including humidity, pH, compost, nutrient content and air-filled porosity on the growth of *Rhizoctonia* and the infection of heathers have been investigated.

An evaluation of fungicides for the control of *Rhizoctonia* commenced. Whilst effective disease prevention is the primary objective, candidate chemicals will be assessed carefully for phytotoxic effects, as in earlier work some of the fungicides used caused serious damage to cuttings when applied in certain circumstances, and in certain combinations.

Several experiments investigating the sources of infection and possible reservoirs for *Rhizoctonia* on heather nurseries have been carried out. This area is of great importance as the elimination or reduction of such sources and reservoirs could do much to aid disease control all over the nursery.

Although each completed experiment helps to solve some part of the problems relating to *Rhizoctonia* on heathers, new questions are still arising. However it is hoped that by this time next year an integrated control programme will have been developed.

This Report begins with a summary of the main findings from the experiments conducted during the past year. This is followed by details of the methods used, and the results obtained from each experiment. Finally, a plan of the work to be conducted during the coming year is presented.

SUMMARY

The main conclusions to be drawn from this years work are as follows:-

1. The relative humidity of the air has an effect on the growth of *Rhizoctonia* over heather foliage. Growth of the fungus is fastest at humidity values of around 90 - 100%. *Rhizoctonia* growth decreases as relative humidity decreases from these values.

2. Although compost air-filled porosity does affect the rate of infection of heather cuttings to some extent, it is unlikely that manipulation of A.F.P. will provide a useful means of cultural control for *Rhizoctonia*, as heather cuttings do not tend to root well in uninfested compost of extreme A.F.P. values.

3. Compost pH affects the rate of disease development in cuttings growing in *Rhizoctonia*-infested compost. Disease development is considerably slowed in compost with a pH value below 4.0.

4. The addition of nutrients to cuttings compost does not significantly affect the development of disease on cuttings growing in infested compost. The addition of such nutrients to uninfested compost does however result in foliar browning.

5. Of the two fungicides tested so far, neither was shown to give full control of both of the isolates tested when used at the manufacturers recommended rate. One of the fungicides was totally ineffective against the concentration of inoculum used, and the other was fully effective against only one of the isolates. It is possible that some of the isolates of *Rhizoctonia* found on nurseries may be resistant, to some extent, to the only fungicide currently available for use by U.K. growers.

6. Although compost moisture content does affect the development of disease in cuttings growing in infested compost, it is unlikely that manipulation of moisture levels will prove to be a useful means of controlling the disease, as the extreme moisture levels which prevent growth of the fungus also inhibit good root development and plant growth.

7. In general, the higher the inoculum level of the fungus, the faster and more severe the disease development will be.

8. *Rhizoctonia* is capable of infecting heather cuttings from infected trays, cuttings, plastics including trays and polythene, gravel, sand and compost.

9. In general, the nearer the compost surface the inoculum is, the more quickly the disease development will progress.

10. The effects of the fungicides tested *in vitro* differ depending on the isolate.

11. *Rhizoctonia* was isolated from several sources on nurseries, including used composts, nursery soil, capillary matting, trays, pots and polythene. It was not isolated from new, unused compost components, or new materials such as trays pots or polythene on any occasion.

EXPERIMENT 1

The long term effects of *Rhizoctonia* on the growth and development of heather cuttings

Introduction

It is known that *Rhizoctonia* can produce extensive browning of foliage and root death on cuttings, also that it can attack plants of all ages. However past experiments have suggested that, in some cases, plants can survive the initial infection process. This experiment was designed to look at the reasons for the survival of such plants. Does the fungus remain in association with the plant during the survival and wait to attack when conditions for the plant deteriorate, or is it killed or rendered inactive permanently? Are other, perhaps saprophytic fungi, involved, or is it purely a plant/pathogen interaction? Are there different types of interaction? These are just some of the questions which this and a series of similar

experiments aim to investigate.

Treatments

1. Control - cuttings struck into 50:50 peat and bark into which chopped 5 - 10mm lengths of straw had been added and mixed at the rate of 2g straw/l compost.

2. *Rhizoctonia* Isolate D1 - cuttings struck into 50:50 peat and bark into which *Rhizoctonia* on straw, (chopped as above) had been added and mixed at the rate of 2g/l.

Each treatment was replicated three times. The experiment, which was located on a commercial nursery, commenced in October 1988 and terminated in August, 1989.

Methods

1. For each replicate of each treatment, 30 cuttings of 'Silver Knight' and 50 of 'Alba Major' and 'Robert Chapman' were struck into compost in cell trays. The trays then were set out on gravel in a polythene tunnel and covered with polythene.

2. *Rhizoctonia* inoculum on straw was produced as described in Research Report I.

3. The foliage was assessed every 3 months using the following scale:-

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

N.B. The outer rows of cuttings on every tray were treated as guard rows and

were not assessed.

4. The cuttings were liquid fed on the nursery along with other cuttings of a similar age in springtime. The cuttings were not potted on, but were left in the trays until they were destructively assessed in August, 9 months after being struck.

5. In August '89, the foliage of each plant was scored as before, and the dry weights were measured. The roots were microscopically examined, floats and platings were made from random samples of each cultivar/treatment combination and foliage pieces were incubated in damp chambers to check for disease. In addition, soil microbiology sampling tubes and the debris particle method were used to test for the presence of *Rhizoctonia* in the compost after the foliage had been removed.

Results

Table 1. Mean foliage scores and dry weights(g) of cuttings grown in uninoculated or *Rhizoctonia*-infested compost, August 1989.

	Treatment			
	Control		D1	
Cultivar	Foliage score	Dry weight (g)	Foliage score	Dry weight(g)
R. Chapman	0.07	0.46	0.72	0.54
A. Major	0.17	0.48	0.29	0.69
S. Knight	0.38	0.42	0.36	0.48
Mean	0.42	0.45	0.46	0.57

* 0-4 scale, 0 = no foliar browning, 4 = totally brown foliage

All plants in all treatments appeared healthy and no significant foliar browning was observed. The plants which were growing in compost which was originally infected with *Rhizoctonia* were slightly larger and more vigorous than those in the control treatments. The figures in Table 1 show that with each cultivar, the mean plant weight of heathers growing in infested compost was more than that of the same cultivar when grown in uninfested compost.

There was no clear relationship between treatment and level of foliar browning.

No *Rhizoctonia* was isolated from cuttings of either treatment using floats, platings or damp chamber incubations. In addition the use of soil microbiology sampling tubes or the debris particle method failed to yield *Rhizoctonia* from either treatment. Large numbers of the saprophytic fungus, *Trichoderma* were isolated from both treatments.

Discussion and Conclusions

The results obtained were unexpected. *Rhizoctonia* I-D1 is normally highly pathogenic to heather cuttings and although those cuttings which survive early infection have a good chance of survival, the appearance of such survivors is usually adversely affected.

In this experiment very few cuttings died and these were from both treatments. There are several possible explanations as to why the cuttings in treatment 2 survived and in most cases grew better than those in the control treatment.

Firstly, the cuttings were grown on a nursery alongside other cuttings in almost perfect growing conditions, thus reducing the chances for fungal attack and increasing the chances of successful root development. Secondly, the cuttings may have inadvertently been sprayed with fungicide (the grower concerned thinks this is unlikely). Thirdly, the fungus may have lost some or all of its pathogenicity through being cultured for too long on artificial media.

Fourthly, *Rhizoctonia* was no longer present in the compost or on the heather

roots. It may have died due to unfavourable conditions in the trays, or it may have been actively parasitised and/or killed by other fungi present in the compost. The phenomenon of fungal parasitism has been noted before in container media, (in experiments in the U.S.A.), the fungal parasites often being the saprophytic *Trichoderma* species. This seems possible since large amounts of *Trichoderma* species were isolated from the heather roots.

It is not clear why the plants in treatments 2 were slightly larger than those in treatment 1. It has been found in previous experiments that heathers growing in compost containing a weakly pathogenic strain of the fungus can be stimulated to produce more roots and often more foliage than control plants.

It may be the case that the *Rhizoctonia* , which was weakened for one of the reasons mentioned above, stimulated plant growth in treatment 2 before dying off at a later date.

Further experiments recently have been set up to investigate the reasons behind the results for this experiment. Experiment 2 has been set up as a larger scale repeat of experiment 1. In addition, several isolates of *Trichoderma* have been sub-cultured with a view to investigating their possible parasitism of *Rhizoctonia* strains.

EXPERIMENT 2

To examine the effects on a long term basis, of several *Rhizoctonia* strains on several commonly grown cultivars

Treatments

Three replicates of each of the following cultivars and treatments were set up on 12 July 1989:-

1 'Alba Elata' + sterile straw (control)
2 " " + *Rhizoctonia* isolate D1
3 " " + " " A

4	"	"	+	" " 64
5	'F. Wanderer'		+	sterile straw (control)
6	"		+	*Rhizoctonia* isolate D1
7	"		+	" " A
8	"		+	" " 64
9	'Braemar'		+	sterile straw (control)
10	"		+	*Rhizoctonia* isolate D1
11	"		+	" " A
12	"		+	" " 64
13	'T'folia'		+	sterile straw (control)
14	"		+	*Rhizoctonia* isolate D1
15	"		+	" " A
16	"		+	" " 64
17	'Janet'		+	sterile straw (control)
18	"		+	*Rhizoctonia* isolate D1
19	"		+	" " A
20	"		+	" " 64
21	'P. Beauty		+	sterile straw (control)
22	"		+	*Rhizoctonia* isolate D1
23	"		+	" " A
24	"		+	" " 64

Methods

1. Peat and bark compost (50:50, Vapo-peat : Scotbark) was mixed and put into polythene boxes (10cm x 10cm x 8cm deep).

2. Eight pieces of straw (sterile or colonised by *Rhizoctonia*) were mixed into the top 1cm of compost in each box. Twelve cuttings then were placed in each box.

3. The boxes were laid out in 5 groups, (one for each assessment date). Within each group, the replicates were arranged in a randomised block design.

4. The cuttings were placed on gravel on the tunnel floor and were covered with white polythene until rooting had taken place.

5. Following rooting, the polythene was removed and the cuttings allowed to grow until three months after striking. Those remaining will be potted on in October, and will be set out in the tunnel on Empot trays.

6. One fifth of the plants will be destructively assessed on each of five assessment dates. Assessments will take place 6 and 12 weeks after striking, and 2, 4 and 6 months after potting. At these times, foliage will be assessed and the dry weights determined, root dry weights will be measured where appropriate.

Platings and floats will be made from the roots, and foliage pieces incubated in a high humidity chamber (D.C.) to test for the presence of disease. In addition, the compost will be examined for the presence of live *Rhizoctonia* using soil microbiology sampling tubes and the debris particle method.

Results to date

Table 2. Mean root dry weights(g) of cuttings growing in *Rhizoctonia*-infested and non-infested compost.

	Isolate				
Cultivar	Control	I-D1	I-64	I-A	Mean
Tricolourifolia	0.041	0.047	0.053	0.039	0.04
Braemar	0.004	0.006	0.005	0.005	0.01
F. Wanderer	0.047	0.055	0.054	0.052	0.05
A. Elata	0.073	0.067	0.073	0.091	0.08
Mean	0.04	0.04	0.05	0.05	

N.B. Insufficient root was produced after 6 weeks on the Ericas to allow measurement of the root dry weights.

There were significant differences between the amount of root produced between cultivars, but there were no significant differences between the root produced by cultivars subjected to the different inoculation treatments.

No foliar browning was observed on any of the cuttings in the 6 weeks after striking, and no *Rhizoctonia* was isolated. *Rhizoctonia* was isolated from only 3 out of 8 pots originally containing I-D1, 0 out of 8 containing I-64 and 1 out of 8 containing I-A.

Discussion and Conclusions so far

Little or no infection had taken place in the heathers assessed. This was unexpected and the reasons for the lack of disease are unclear. The environmental conditions may have been poor for infection and/or ideal for plant growth thereby decreasing the chances for successful infection. The temperatures for rooting were low for the time of year, which may have reduced the pathogenicity of the fungus in this experiment.

Further assessments at later dates are necessary before more detailed conclusions regarding this experiment can be reached.

EXPERIMENT 3

The effect of relative humidity on the growth of *Rhizoctonia* over heather foliage

Treatments

Three replicates of five cuttings of *Calluna vulgaris* cv. Cuprea were set up for each of the following treatments on 27 February 1989:-

1. 0% relative humidity ($CaCl_2$)
2. 55% relative humidity (NaCl)
3. 75% relative humidity (KH_2PO_4)
4. 95% relative humidity (Cr_2O_7)

Methods

1. Constant relative humidity chambers were set-up as shown in Fig. 1.

2. Five healthy heather cuttings were placed on the net support in each jar.

3. One infected piece of heather foliage was placed at one end of the row of five healthy cuttings.

4. The healthy cuttings were examined visually 0, 3, 7, 14, and 18 days later for signs of colonisation by *Rhizoctonia*.

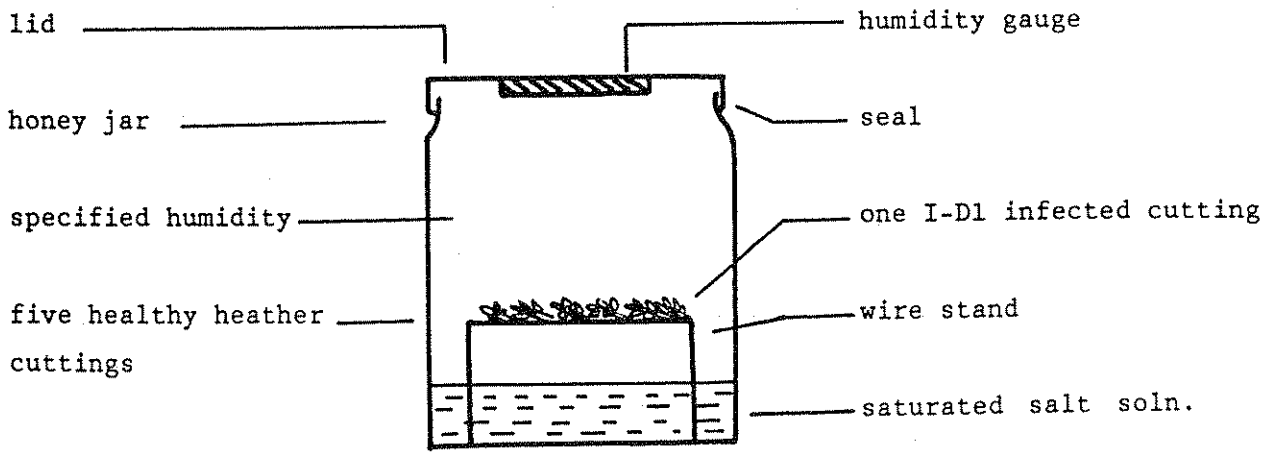

Fig. 1. Constant relative humidity chamber

Results

Table 3. Mean number of cuttings (max.5), colonised by *Rhizoctonia* under a range of relative humidities.

Days after inoculation	Relative humidity 0	55	75	95
0	0	0	0	0
3	0	1	2	3
7	0	2	3	4
14	0	2	4	5
18	0	2	5	5

Rhizoctonia growth was most rapid on cuttings kept in an atmosphere of 95% humidity. It grew more slowly in atmospheres of 75 and 50%. There was no growth in the dry atmosphere.

Discussion and Conclusions

The environmental conditions provided for newly-struck heather cuttings on nurseries obviously create a high risk of rapid spread of mycelium of *Rhizoctonia* over the foliar parts of the plants. The close packing of older plants in tunnels, and in particluar stock plants, also increases the risk of colonisation. This may be particularly important for stock plants, as *Rhizoctonia* mycelium on the foliage has been found to be an important source of the fungus on cuttings (see Research Report I).

EXPERIMENT 4

Further evaluation of the influence of humidity on the spread of *Rhizoctonia* over heather foliage

Treatments

Three replicates of each of the following treatments were set up on 5 July 1989. Twelve, 8cm pots each containing one potted-on cutting of *Calluna vulgaris* cv. Firefly constituted a replicate:-

1. Uninoculated control - relative humidity 90-100%
2. *Rhizoctonia* isolate D1 - " " "
3. " " 64 - " " "
4. Uninoculated control - relative humidity 70-80%
5. *Rhizoctonia* isolate D1 - " " "
6. " " 64 - " " "

Method

1. Well rooted cuttings were potted into 8cm pots containing 75% peat, 25% bark compost.

2. Inoculum in the form of infested straw was sprinkled on the surface of the relevant pots at the rate of 10 straw pieces per pot.

3. The growth of *Rhizoctonia* mycelium vertically up the heather foliage was measured using microscope, hand lens and ruler, three weeks after the start of the experiment.

Results

Table 4. Mean growth(mm) of *Rhizoctonia* on rooted heather plants grown in differing humidity regimes.

Treatment	Mean growth (mm) of *Rhizoctonia*	
	70-85% Relative Humidity	90-100% Relative Humidity
Control	0.00	0.00
D1	1.00	10.9
64	2.72	15.0

The results in Table 4 and Fig. 2 show that growth of *Rhizoctonia* was much slower in an atmosphere of 70-80% humidity than it was in the higher humidity range of 90-100%. This was true for both isolates used in the experiment. No growth of fungus was observed on the control plants.

Discussion and Conclusions

This experiment showed that humidity had a marked effect on the growth of *Rhizoctonia* on heather foliage. Clearly this has important practical implications. At certain times during the heather production cycle it is necessary to have high humidities around the plants, (in particular the early propagation stage), and at these times other cultural and chemical control measures must be applied. However if attempts are made at subsequent stages of plant growth to reduce atmospheric humidities around the plants, fungal growth may be substantially reduced.

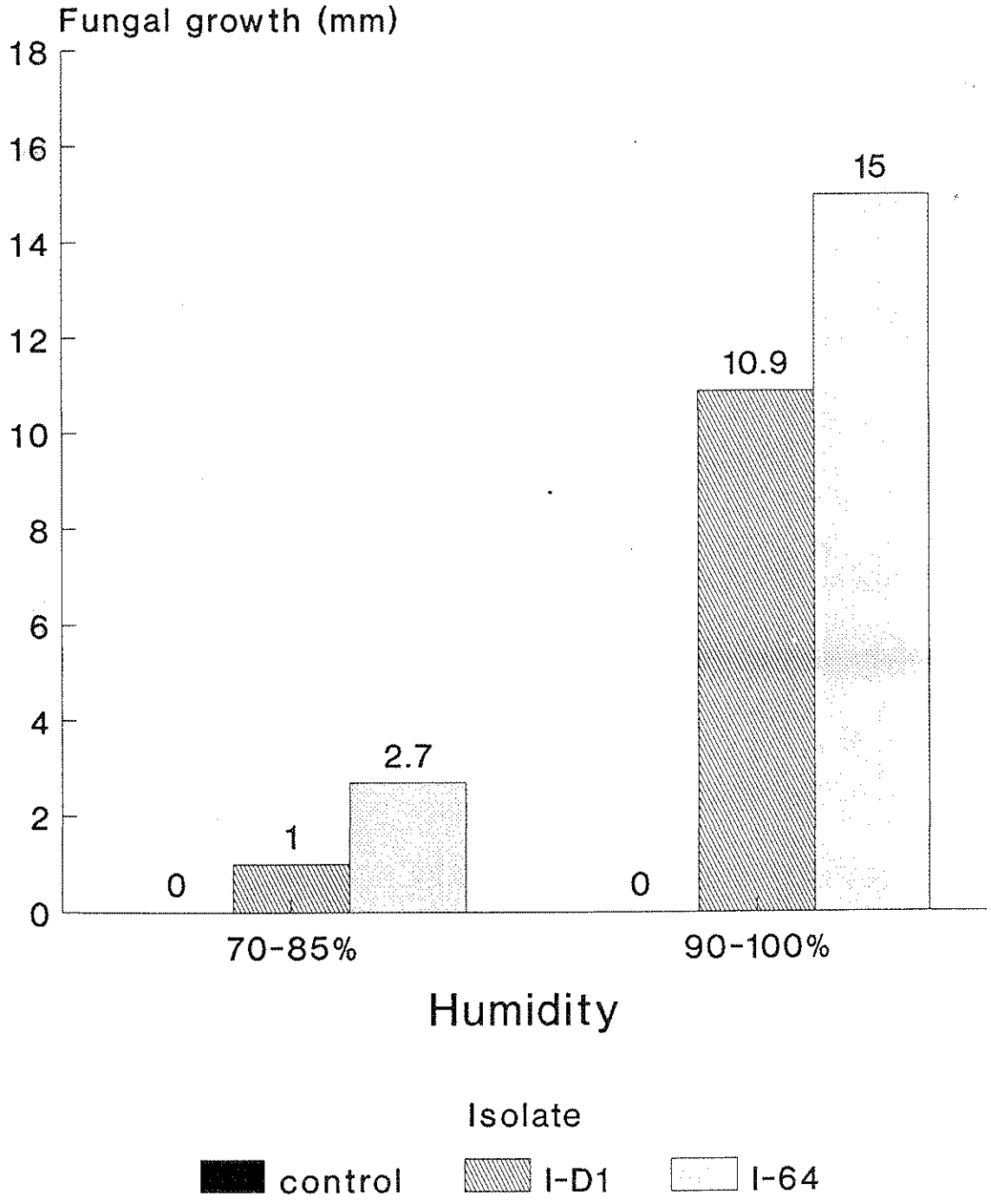

Fig. 2. The effect of relative humidity on the growth of *Rhizoctonia* on heathers.

Late removal of polythene coverings following rooting of cuttings, late potting of older plants and overcrowding of stock plants, particularly in tunnels are common situations which could frequently give rise to high humidities in and around the heather foliage. This could lead to a rapid spread of *Rhizoctonia* and other foliar pathogens causing large scale loss, especially when temperatures are high in summer.

Careful attention to plant production schedules in accordance with the weather conditions and maintenance of adequate air circulation around the plants should go a long way to preventing needless spread of the fungus in high humidities.

EXPERIMENT 5

The effect of compost Air-Filled Porosity (A.F.P.) on the development of infection in cuttings growing in *Rhizoctonia*-infested compost

Treatments

Three replicate trays each containing five cuttings of Calluna cvs. Beoley Gold, Lyonesse and Silver Queen (i.e. 15 cuttings per tray) were prepared for each of the following treatments:-

1. Control - compost A.F.P. 31 (1:1 peat and perlite)
2. Control - compost A.F.P. 16 (1:1 peat and scotbark)
3. Control - compost A.F.P. 9 (5:1 peat and fine sand)
4. Control - compost A.F.P. 4 (1:1 peat and fine sand)

5. *Rhizoctonia* isolate D1 - compost A.F.P. 31
6. " " - compost A.F.P. 16
7. " " - compost A.F.P. 9
8. " " - compost A.F.P. 4

Methods

1. Composts were mixed as shown above and the inoculum was mixed throughout the composts for treatments 5 - 8 at the rate of 2g chopped straw/1. The trays were then filled with the composts, a layer of uninfested compost being spread over the surface of the trays in treatments 5 - 8, (to prevent any rapid fungal surface growth which might mask any differences in disease development due to compost structure.)

2. Cuttings were then struck into the composts in the usual way.

3. The trays were set out on the tunnel floor, and were covered in white polythene until rooting had taken place.

4. The experiment was assessed 2,3,4 and 6 weeks after the cuttings were struck. Foliar assessments only were made on the first three assessments. However on the final assessment, floats and platings were made from the roots and foliage pieces were incubated in D.C's to check for infection.

A root index was calculated as follows:-

Root index value = (length of longest root + 5) x root score

Root scores were allocated per cutting as follows:-

1 = 1 to 10 roots
2 = 11 to 15 roots
3 = 16 to 20 roots
4 = 21 to 30 roots
5 = 31 to 40 roots
6 = > 40 roots

Foliage condition was assessed on the following scale:-

0 = No foliage browning
1 = Tips or bases of a few branches brown
2 = Tips or bases of a few branches brown + 1 or 2 branches totally brown

3 = Extensive browning, but some foliage still green

4 = Totally brown foliage

Results

Table 5. Mean values of root indices of cuttings growing in *Rhizoctonia*-infested and non-infested composts of different A.F.P. values.

Treatment	Air-filled porosity	Cultivar			Mean
		Silver Queen	Lyonesse	Beoley Gold	
Uninoculated	31	45	7	30	27
	16	61	41	51	34
	9	29	17	26	24
	4	38	22	31	30
Mean		43	22	45	
Inoculated	31	18	0	3	7
(isolate D1)	16	11	13	9	11
	9	7	5	6	6
	4	4	1	2	2
Mean		10	5	5	

Table 6. Mean foliage scores of cuttings grown in *Rhizoctonia*-infested and non-infested compost of different A.F.P.values.

	Air-filled porosity value			
Treatment	31	16	9	4
Uninoculated	0	0	0	0
Inoculated (isolate D1)	2.77	2.58	1.76	2.98

Rhizoctonia was not isolated from cuttings in treatments 1 to 4. It was isolated from 10/12 cuttings in treatment 5, 7/12 cuttings in treatment 6, 9/12 cuttings in treatment 7 and 9/12 cuttings in treatment 8.

The results in Tables 5 and 6 and in Fig. 3 show that there were differences in both the root development and the foliage appearance between cuttings growing in the different composts. The cuttings struck in infested compost grew best (i.e. produced most root) in the peat and bark compost, and did less well in the other three composts. No foliar browning was observed on any cuttings in treatments 1 to 4.

The cuttings growing in infested compost in general grew best in the peat and bark, although foliar browning was severe in all treatments including the peat and bark.

Discussion and Conclusions

Originally it was thought that since previous experiments have shown that *Rhizoctonia* growth is slower through media of low A.F.P., (e.g. peat and sand) than through, for example, peat and bark, the use of peat and sand as a

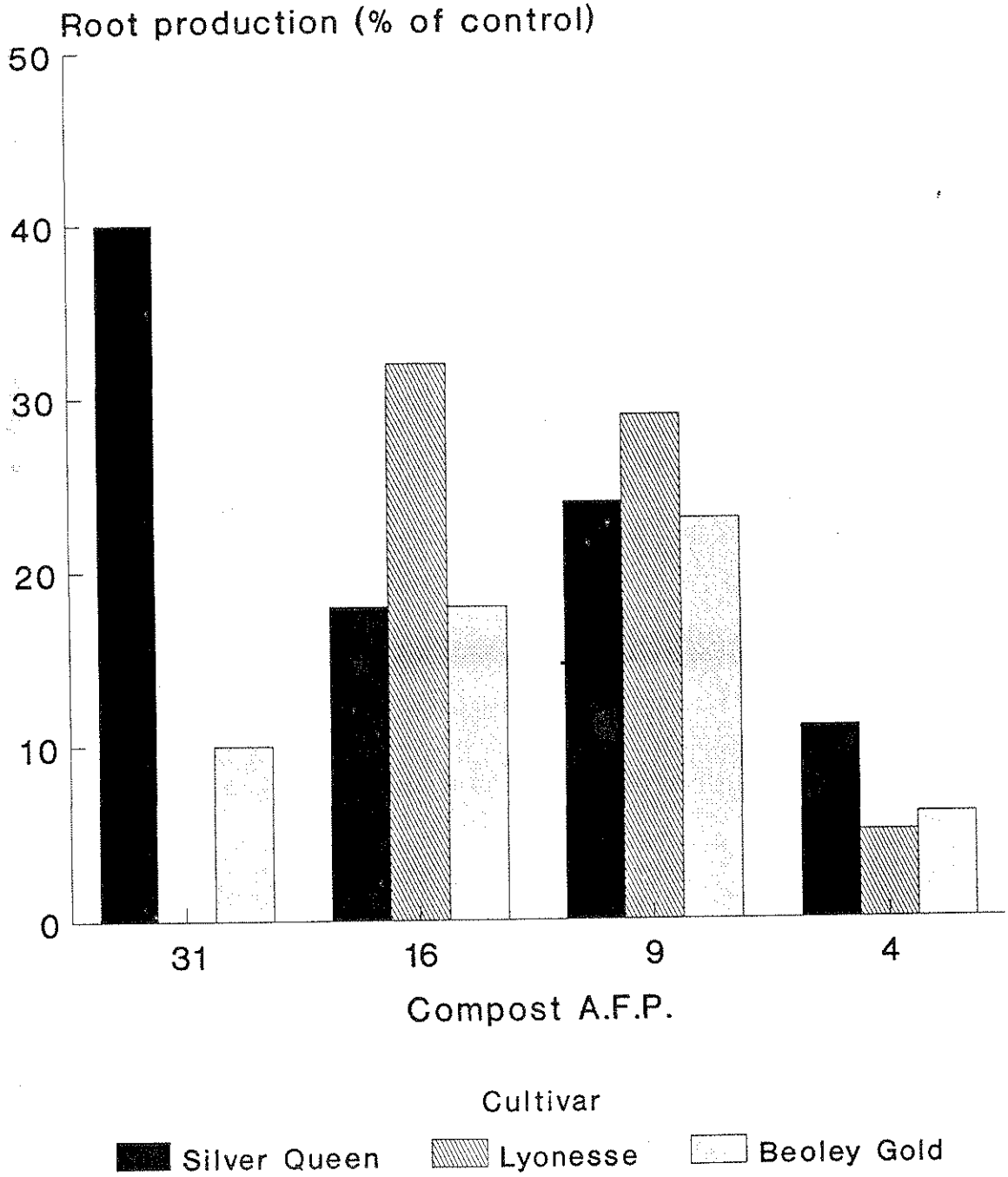

Fig. 3. The effect of compost A.F.P. on the development of *Rhizoctonia* disease.

propagating media may help to slow the spread of *Rhizoctonia* and thus reduce infection. This has not proved to be true.

In the absence of disease, the heather cuttings rooted most quickly in media with an A.F.P. value of 16. Rooting was slow and poor in media with A.F.P. values below 9, (due to a lack of air) and around 25, (due to a tendency for the new rootlets to dry out). Although *Rhizoctonia* growth may have been reduced in composts with a low A.F.P., infection still took place, perhaps aided as the cuttings were under stress due to a lack of air. Infection also took place in the peat and perlite composts, and in addition, the cuttings were difficult to keep moist.

It appears that since compost A.F.P. cannot be manipulated in such a way as to affect disease development without affecting cutting development, the ideal propagating medium to use will be one which encourages rapid and vigorous root production. Plants that are growing in this way will be least likely to succumb to infection. A medium with an A.F.P. value of between 12 and 20 is ideal, 50:50 peat and fine bark being a good example of such a medium.

Experiment 6

The effect of pH on the infection of cuttings by *Rhizoctonia*

Treatments

Three replicate trays each containing five cuttings of *Calluna* cvs. Cuprea, Flamingo and Silver Queen (i.e. 15 cuttings per tray) were prepared for each of the following treatments.

1. Control - compost unlimed (pH = 3.78)
2. Control - " limed @ 2g/l dolodust (pH = 4.88)
3. Control - " " @ 4g/l " (pH = 5.73)
4. Control - " " @ 6g/l " (pH = 6.00)

5. *Rhizoctonia* I-D1 - compost unlimed (pH = 3.78)
6. " " - " limed @ 2g/l dolodust (pH = 4.88)

7. *Rhizoctonia*	I-D1	-	compost limed @ 4g/l	"	(pH = 5.73)
8. "	"	-	" "	@ 6g/l	"	(pH = 6.00)

Methods

1. The compost used contained 50:50 Vapo-peat and Scotbark and was limed as shown above. The straw/inoculum was mixed throughout the compost at the rate of 2g/half tray.

2. The trays were covered with white polythene until rooting had taken place.

3. The foliage of cuttings was visually assessed 2, 4 and 6 weeks after striking, using the following scale:-

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

4. After 8 weeks, the entire experiment was destructively assessed. Root dry weights were measured and platings were made from cutting bases to test for the presence of infection. (4 cuttings/cv/treatment were taken at random.)

Results

The results in Tables 7 and 8 and Fig. 4 show that pH affected the development of disease on cuttings growing in infested compost (see Plate 1). Disease development was markedly more severe on cuttings growing in limed compost than in unlimed compost.

Cuttings growing in uninfested compost did equally well at all pH values. No reduction in root production or plant vigour was apparent in the unlimed compost.

Rhizoctonia was not isolated from any of the cuttings grown in uninfested compost (Table 9.)

Table 7. Mean foliage scores* of cuttings grown in *Rhizoctonia*-infested and non-infested composts of differing pH.

	Compost pH				
	3.78	4.88	5.73	6.00	mean
CONTROL					
Cuprea	0.00	0.00	0.00	0.00	0.00
Flamingo	0.00	0.00	0.00	0.00	0.00
Silver Queen	0.00	0.00	0.00	0.00	0.00
Rhizoctonia I-D1					
Cuprea	0.73	1.13	2.60	2.53	1.75
Flamingo	0.27	2.53	3.20	3.40	2.35
Silver Queen	0.20	2.73	3.33	3.07	2.33
I-D1 mean	0.40	2.13	3.04	3.00	

* 0 = No foliar browning, 4 = totally brown foliage

Table 8. Total root dry weights(g) of 5 cuttings grown in *Rhizoctonia*-infested and non-infested composts of different pH. Assessment 8 weeks after striking cuttings.

	Compost pH			
	3.78	4.88	5.77	6.00
CONTROL				
Cuprea	0.42	0.39	0.43	0.41
Flamingo	0.46	0.42	0.41	0.48
Silver Queen	0.33	0.37	0.33	0.31
Rhizoctonia I-D1				
Cuprea	0.16	0.02	0.03	0.02
Flamingo	0.14	0.04	0.02	0.01
Silver Queen	0.10	0.00	0.00	0.00

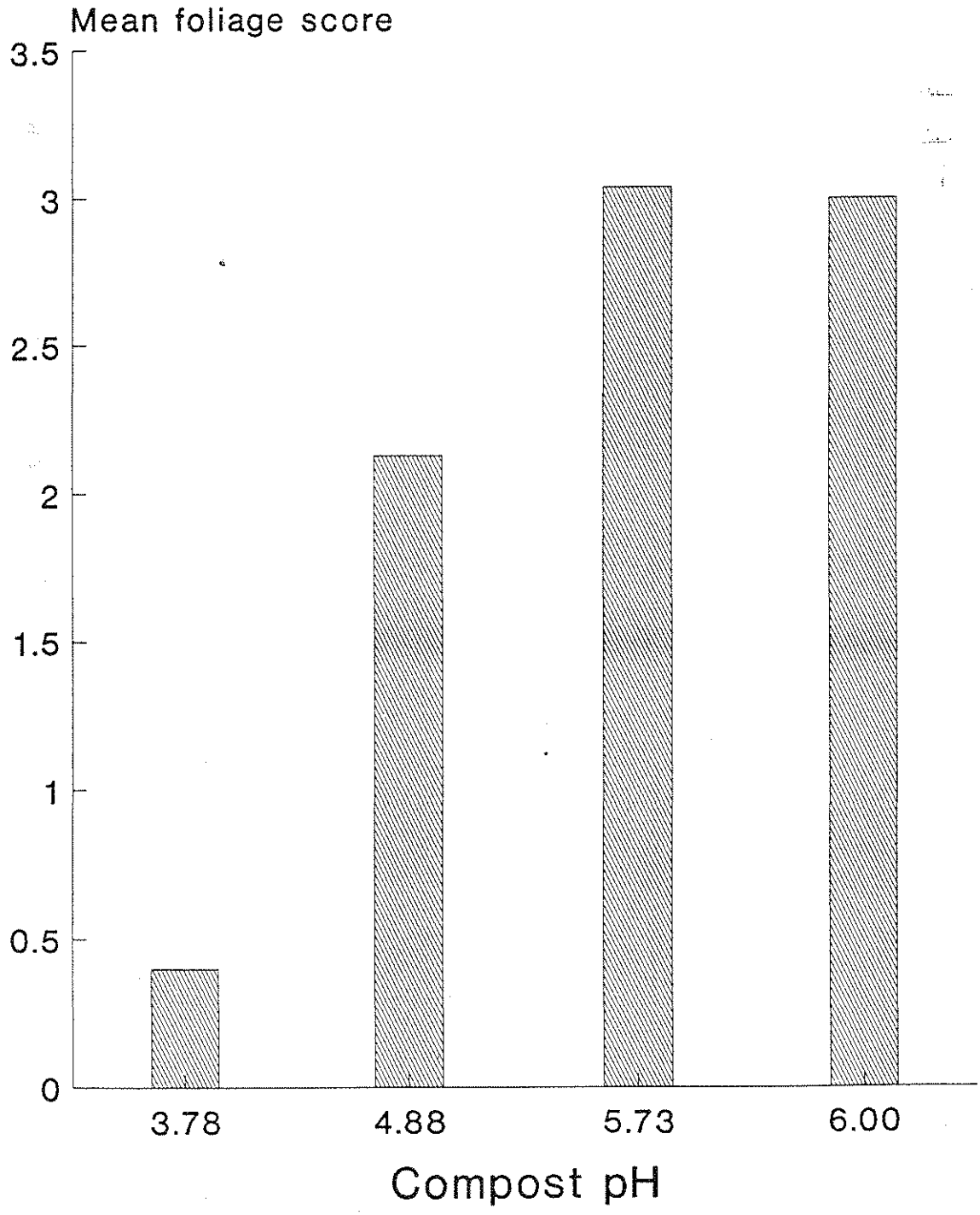

Fig. 4. The effect of pH on the development of *Rhizoctonia* on heather cuttings.

Foliage score : 0 = no foliar browning; 4 = foliage completely brown

Table 9. Infection of *Calluna* cuttings by *Rhizoctonia* 8 weeks after striking.

Treatment	Compost pH	Number of cuttings infected (max. 12)
Control	3.78	0
"	4.88	0
"	5.73	0
"	6.00	0
Rhizoctonia I-D1	3.78	7
"	4.88	9
"	5.73	7
"	6.00	10

Plate 1. A comparison of cuttings growing in *Rhizoctonia*-infested compost, (containing 0, 2, 4 or 6g/l dolodust) with uninfected, healthy cuttings growing in compost limed at 2g/l dolodust.

Discussion and Conclusions

The results from this experiment indicate that *Calluna* cuttings growing in uninfested compost root and develop well in composts of pH values between 3.8 and 6.0.

If *Rhizoctonia* is present in the compost, damage is reduced if the compost is left unlimed. This suggests that it may be wise to ensure that the pH of propagation composts lies below 4. If this is the case, *Calluna* cuttings should come to no harm, and damage due to *Rhizoctonia*, (if it is present) will be minimised.

These results may not apply to *Erica* cuttings. A repeat of this experiment is intended to find out whether *Erica* cuttings will or will not root

satisfactorily in composts of pH below 4.

EXPERIMENT 7

To determine whether the addition of nutrients to cutting compost has an effect on the development of *Rhizoctonia*

Treatments

Three replicate trays each containing five cuttings of *Calluna* cvs. Beoley Gold, Cuprea and Kinlochruel (i.e. 15 cuttings per tray) were prepared for each of the following treatments:-

1. Control 0g/l Ficote (N:P:K; 14:14:14; 9 month fertiliser)
2. I-D1 0g/l Ficote
3. I-64 0g/l Ficote
4. Control 1g/l Ficote
5. I-D1 1g/l Ficote
6. I-64 1g/l Ficote
7. Control 3g/l Ficote
8. I-D1 3g/l Ficote
9. I-64 3g/l Ficote

Methods

1. The compost consisted of 50:50 Vapo peat and Scotbark with Ficote added as shown above. The inoculum, (or plain chopped straw) was thoroughly incorporated at the rate of 2g/half tray.

2. Treatments were assessed 2,4,6 and 7 weeks after the start of the experiment. Foliar assessments only were made on the first three assessments, according to 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 browning but some green tissue
4 - Totally brown foliage

3. At the final assessment, 12 cuttings were taken at random from each treatment and were tested for *Rhizoctonia* infection. Pieces of cutting base were plated out on agar, and floats were made from the rootlets.

Results

Table 10. Mean foliage scores* of cuttings grown in *Rhizoctonia*-infested and non-infested composts of different nutrient levels.

	Level of nutrients (kg/m^3 Ficote 14:14:14)			
Treatment	0	1	3	Mean
Uninoculated Control	0.00	0.00	0.00	0.00
Rhizoctonia I-D1	2.64	2.42	2.09	2.38
Rhizoctonia I-64	2.87	2.71	2.35	2.64

* 0 = No foliar browning; 4 = Totally brown foliage

The results in Table 10 and Fig. 5 reveal that there were differences between the foliage scores of cuttings in different treatments. In all cases the controls had less foliar browning than did any of the treatments involving

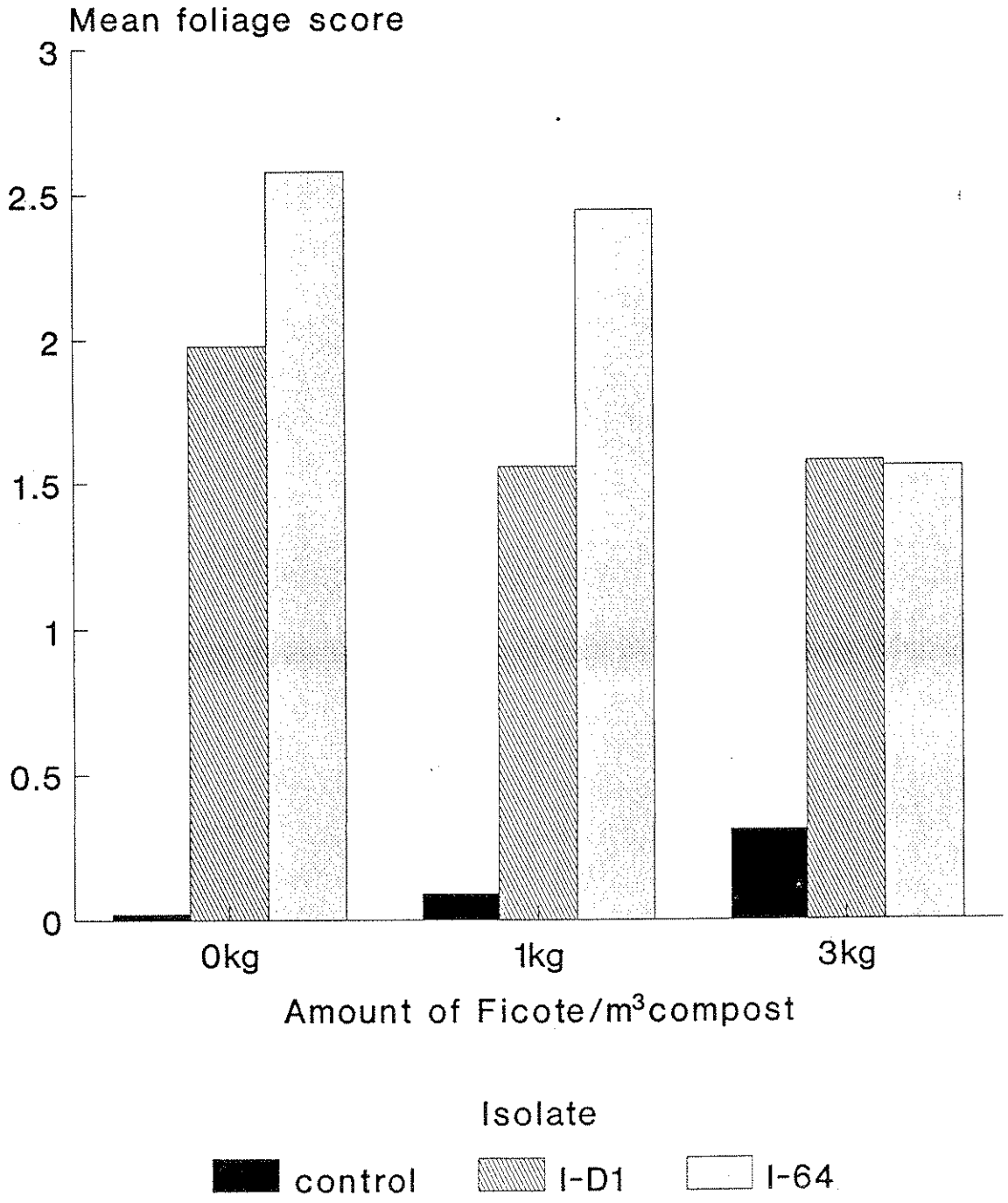

Fig. 5. The effect of nutrient levels on the development of *Rhizoctonia* on *Calluna* cuttings.

Rhizoctonia. Those cuttings growing in fertilised uninfested compost showed some degree of foliar browning in comparison with unfertilised controls.

Foliar browning was most severe in compost containing the equivalent of $3kg/m^3$ of fertiliser.

There was little difference between the degree of browning on the cuttings in infested compost at the three levels of fertilisation.

No *Rhizoctonia* was isolated from cuttings growing in uninoculated compost at any nutrient level. A high proportion of those cuttings from infested compost were infected with *Rhizoctonia*, and there was little effect of nutrient level.

Discussion and Conclusions

The level of fertilisation had little or no effect on the development of disease on cuttings growing in infested compost. Browning occured at a similar level in all treatments involving *Rhizoctonia*.

There was a significant degree of foliar browning observed on the cuttings in the fertilised uninfested controls. This was due to the higher levels of salts in the compost and was not caused by disease organisms.

There is no benefit to be gained by incorporating fertiliser into the cutting compost. Damage is likely to occur to the cutting foliage, rooting may be inhibited and no control of *Rhizoctonia* is given.

EXPERIMENT 8

The effect of the fungicides Basilex and Rovral on the infection of *Calluna* cuttings by *Rhizoctonia*

Introduction

For several years, growers have been using fungicides to control *Rhizoctonia* on heather crops, but little or no work has been done to examine the efficacy of such chemicals on these plants. This series of experiments is being set up to examine a range of fungicides which are available to control *Rhizoctonia*. It is hoped to investigate the responses of several isolates to these fungicides, as it is known that isolates may differ greatly in their sensitivity to chemicals.

Treatments

Four replicate boxes (10cm x 10cm x 8cm deep) each containing four cuttings each of *Calluna* cvs. Cuprea, Dart's Gold and Sister Anne were prepared for each of the following treatments on 29 August 1989:-

1. Uninoculated Control - No chemical treatment applied
2. " " - Rovral 0.2g/l(inc) + Rovral 1g/l(dr) after 1 month
3. " " - Rovral 0.4g/l(inc) + Rovral 2g/l(dr) after 1 month
4. " " - Basilex 0.08g/l(inc) + Basilex 2g/l(dr) after 1 month
5. " " - Basilex 0.16g/l(inc) + Basilex 4g/l(dr) after 1 month

6. *Rhizoctonia* I-D1 - No chemical treatment applied
7. " " - Rovral 0.2g/l(inc) + Rovral 1g/l(dr) after 1 month
8. " " - Rovral 0.4g/l(inc) + Rovral 2g/l(dr) after 1 month
9. " " - Basilex 0.08g/l(inc) + Basilex 2g/l(dr) after 1 month
10. " " - Basilex 0.16g/l(inc) + Bas. 4g/l(dr) after 1 month

11. *Rhizoctonia* I-64 - No chemical treatment
12. " " - Rovral 0.2g/l(inc) + Rovral 1g/l(dr) after 1 month

13. " " - Rovral 0.4g/l(inc) + Rovral 2g/l(dr) after 1 month

14. " " - Basilex 0.08g/l(inc) + Basilex 2g/l(dr) after 1 month

15. " " - Basilex 0.16g/l(inc) + Basilex 4g/l(dr) after 1 month

Note : inc = incorporated into compost immediately before striking cuttings.
dr = drench at indicated interval after striking cuttings.

Methods

1. Cuttings were struck into peat and bark compost (50:50 Vapo peat and Scotbark) and the inoculum was mixed through the compost at the rate of 2g/l. The boxes were then placed in a glasshouse (temps. 12-24^{o}C), and covered in white polythene.

2. Visual, non-destructive foliar assessments will be carried out at weekly intervals using the following scale.

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

3. The relevant sprays will be given at monthly intervals.

4. After 6-8 weeks, (depending on cutting development), the entire experiment will be destructively assessed. Foliage and roots will be microscopically examined and dry weights will be taken. Pieces of foliage will be incubated in D.C.'s and platings and floats made from the roots to test for infection.

Table 11. Mean foliage score* of fungicide-treated cuttings growing in infested compost. Assessed 2 weeks after striking.

Isolate	Fungicide rate	Cultivar			
		Cuprea	Sister A.	D'arts G.	Mean
Control	None	0.00	0.00	0.00	0.00
	Rovral - low	0.00	0.00	0.00	0.00
	Rovral - high	0.00	0.00	0.00	0.00
	Basilex - low	0.00	0.00	0.00	0.00
	Basilex - high	0.00	0.00	0.00	0.00
I-D1	None	0.31	0.44	0.56	0.44
	Rovral - low	0.38	0.50	0.19	0.36
	Rovral - high	0.13	0.38	0.31	0.27
	Basilex - low	0.00	0.00	0.00	0.00
	Basilex - high	0.00	0.00	0.00	0.00
I-64	None	3.19	3.38	3.13	3.23
	Rovral - low	3.19	3.56	3.25	3.33
	Rovral - high	3.38	3.38	3.19	3.32
	Basilex - low	0.69	0.38	0.00	0.36
	Basilex - high	0.00	0.00	0.00	0.00

* 0 = No foliage browning, 4 = Foliage completely brown

The results in Table 11, which are also shown in Fig. 6, indicate that both isolates of *Rhizoctonia* gave rise to foliar browning when grown in compost not

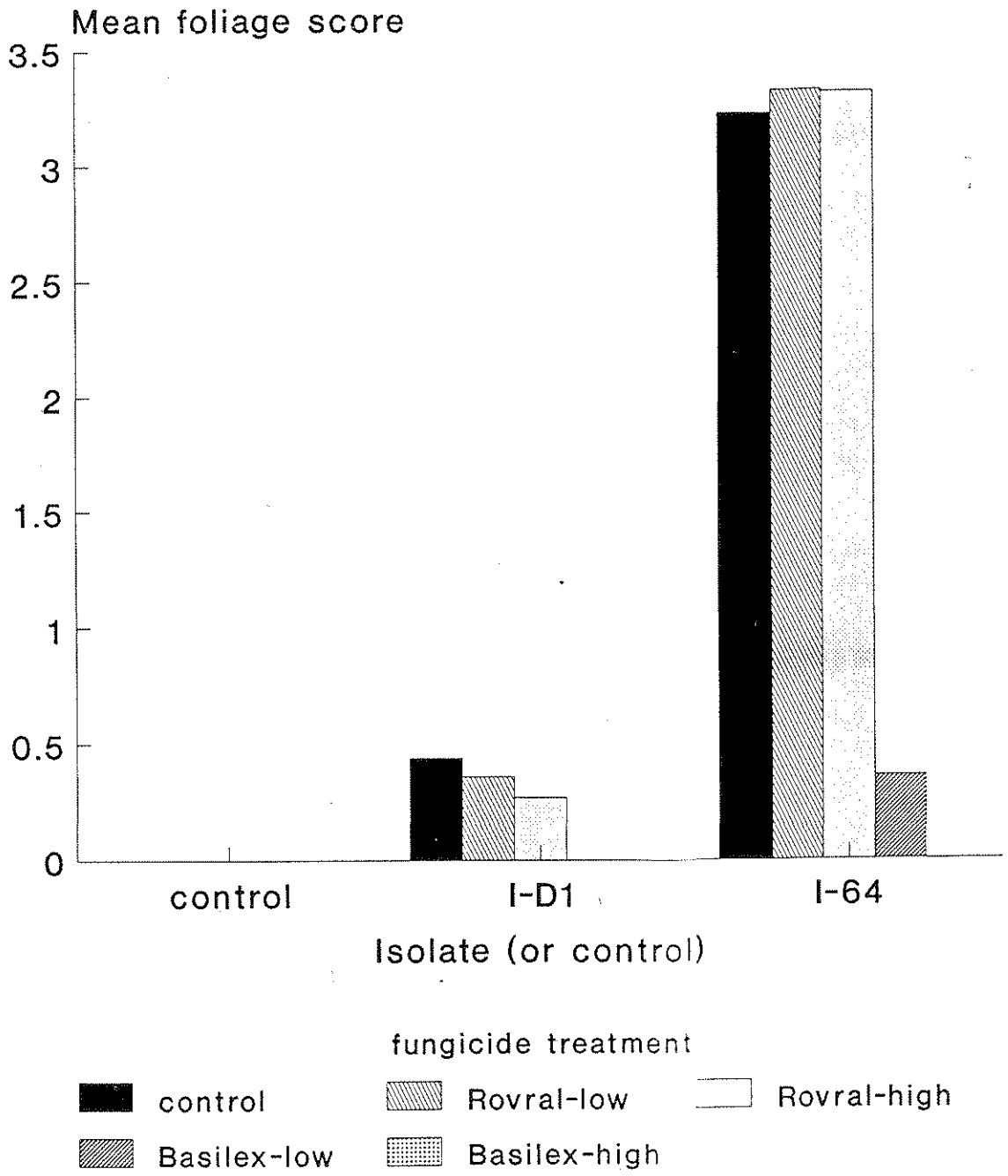

Fig. 6. The effects of fungicides on the development of *Rhizoctonia* disease.

Foliage score : 0 = no foliage browning; 4 = foliage completely brown

treated with fungicide. Isolate - 64 caused the most severe foliar browning. No foliar browning was observed in control cuttings grown in the uninfested composts at this stage.

Browning of the foliage in composts infested with I-64 was not significantly reduced by the addition of Rovral at either the high or low rate. It was reduced by the addition of Basilex at the low rate and eliminated entirely by the addition of Basilex at the high rate.

Foliage browning in I-D1-infested composts was not reduced by the addition of Rovral at the low rate. It was slightly reduced by the addition of Rovral at the high rate, and was eliminated by the incorporation of Basilex.

Plate 2 shows the effect of fungicide treatments on the development of disease caused by *Rhizoctonia*. Only the uninoculated cuttings and those treated with Basilex at the higher rate appear healthy.

Discussion and Conclusions

Neither of the fungicides tested proved completely effective in controlling both of the isolates of *Rhizoctonia* when used at the manufacturers' recommended rates. Rovral dust, which is recommended for use incorporated into compost at $200g/m^3$, was ineffective against both isolates used in this experiment. Even at twice this rate, it failed to control I-64. The manufacturer's approval for the use of Basilex on heathers recently was withdrawn because of possible phytotoxicity problems under certain conditions, thus Rovral is the only fungicide available for growers to use against *Rhizoctonia* at present. The fact that it is of little use against certain isolates of *Rhizoctonia* is of great concern. Basilex controlled I-D1 completely, but failed to control I-64 when used at the low rate.

Although all the results from this experiment are not yet available, it is not too early to begin drawing conclusions. Since the fungicides tested in this experiment appear less than effective at controlling at least some isolates of *Rhizoctonia* at the rates used, other means of control must be considered.

The rates used could be increased, however although this will be tried on an experimental basis, it is unlikely to prove practical on a large scale for several reasons. Firstly due to the cost, secondly it is environmentally undesirable to apply large quantities of fungicide to crops, and thirdly because root production and growth of heathers can be severely reduced when grown in compost containing high levels of fungicide.

There are a few chemicals which are not approved for use on heathers, but are known to control *Rhizoctonia* to some extent on other crops. These and a few experimental chemicals will be examined with a view to discovering their potential as fungicides for use on heathers. It may be possible for growers then to apply for off label approvals if such compounds prove useful.

It looks unlikely that fungicides will be able to provide the perfect solution to the problem of *Rhizoctonia* on heathers. Cultural measures and nursery hygiene so far remain of great importance in its control.

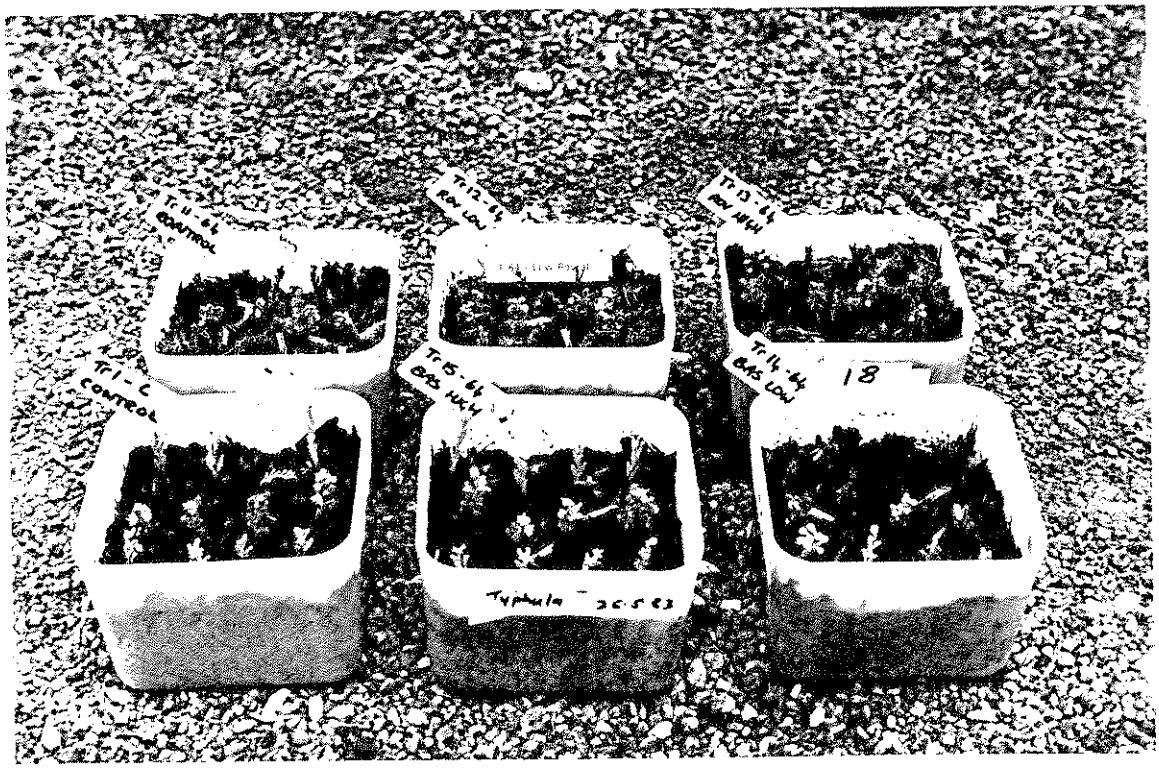

Plate 2. The effect of fungicide treatment on the development of *Rhizoctonia*. (Rear left, inoculated no fungicide; middle, inoculated low rate Rovral; right, inoculated high rate Rovral; Front left, uninoculated no fungicide; middle, inoculated high rate Basilex; inoculated low rate Basilex).

EXPERIMENT 9

The effect of compost moisture content on the development of *Rhizoctonia* on cuttings

Introduction

Earlier experiments have indicated that compost moisture content may have an effect on the development and severity of *Rhizoctonia* disease. This experiment was set up to determine whether or not moisture levels could be manipulated as a means of controlling the spread of the fungus in compost.

Treatments

Three replicate boxes (10cm x 10cm x 8cm deep) each containing four cuttings each of *Calluna* vars. Cuprea, Beoley Silver, and Robert Chapman were set up for each of the following treatments on 25 June 1989:-

1. Uninoculated Control - boxes set in cat trays in 0cm water
2. " " - " " " " " 2cm water
3. " " - " " " " " 4cm water
4. " " - " " " " " 6cm water

5. *Rhizoctonia* I-D1 - " " " " " 0cm water
6. " " - " " " " " 2cm water
7. " " - " " " " " 4cm water
8. " " - " " " " " 6cm water

9. *Rhizoctonia* I-48 - " " " " " 0cm water
10. " " - " " " " " 2cm water
11. " " - " " " " " 4cm water
12. " " - " " " " " 6cm water

Methods

1. The compost (25% Scotbark:75% Vapo-peat) was mixed and the relevant inoculum, (or sterile straw) was mixed through the compost at the rate of 16 pieces/box.

2. The boxes were placed on a single layer of gravel in the cat trays, which were then filled to the appropriate levels with water as detailed above. They were allowed to sit for 2 hours for the water levels to stabilise before the cuttings were struck into the composts.

3. Foliar assessments were made at 2 weekly intervals according to the following scale.

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

5. Six weeks after the start of the experiment, the final destructive assessment was carried out. This involved a foliage assessment as before. In addition, pieces of cutting base, taken at random from the treatments, were plated onto agar medium to test for the presence of *Rhizoctonia*.

Results

The results in Table 12 and Fig. 7, [which shows the effect of different moisture levels on the development of foliar browning in 'Robert Chapman' cuttings], demonstrate that there are differences in the levels of disease which developed in the different treatments.

Table 12. Mean foliage scores* of cuttings grown in *Rhizoctonia*-infested/non-infested compost of different moisture levels.

Treatment	Variety	Compost moisture level (cm water) 0	2	4	6
Uninoculated Control	Cuprea	0.00	0.00	0.00	0.17
	B. Silver	0.08	0.00	0.08	0.17
	R. Chapman	0.00	0.08	0.08	0.17
Mean		0.03	0.03	0.05	0.20
Rhizoctonia I-D1					
	Cuprea	3.42	3.33	1.75	0.58
	B. Silver	3.50	3.58	2.83	1.00
	R. Chapman	3.58	3.33	1.58	0.83
Mean		3.50	3.41	2.05	0.80
Rhizoctonia I-48					
	Cuprea	1.50	1.25	0.50	0.17
	B. Silver	2.08	1.50	0.75	0.58
	R. Chapman	1.92	1.33	0.66	0.50
Mean		1.83	1.36	0.64	0.42

* 0 = No foliage score, 4 = foliage totally brown

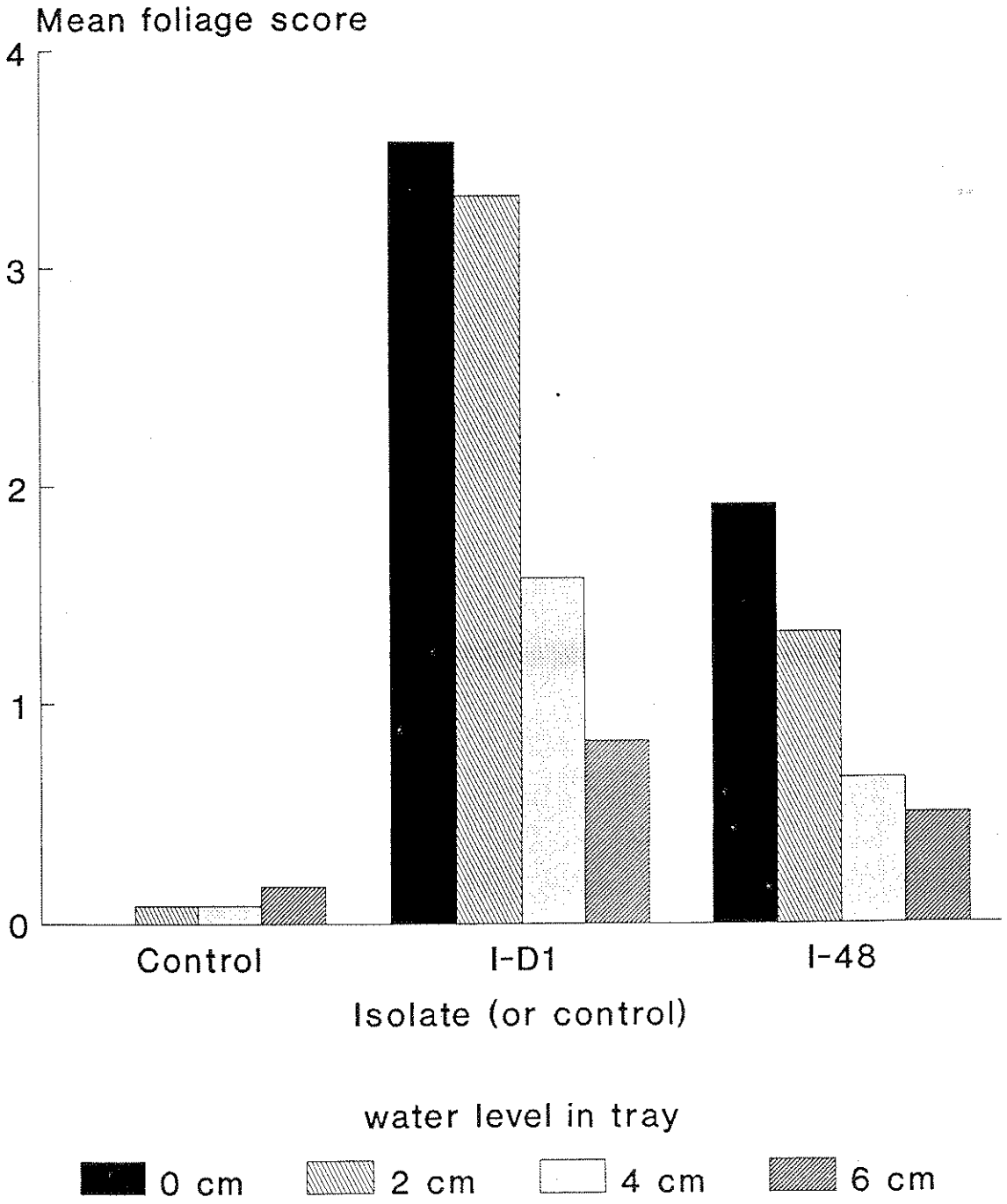

Fig. 7. The effect of compost moisture level on the development of *Rhizoctonia* on cuttings of *Calluna* cv. Robert Chapman.

Table 13. Isolation of *Rhizoctonia* from *Calluna* cuttings grown in compost of differing moisture content. Assessed 6 weeks after striking cuttings.

Treatment	Compost moisture content (cm water)	No. of cuttings from which Rhizoctonia isolated (max. 6)
Uninoculated	0	0
	2	0
	4	0
	6	0
Rhizoctonia I-D1	0	4
	2	5
	4	6
	6	3
Rhizoctonia I-48	0	4
	2	5
	4	6
	6	5

No infection was present in the controls, however infection took place in all treatments involving *Rhizoctonia* (Table 13). Foliar browning was most severe in treatments where the cuttings were growing in boxes set on gravel only. The browning was least severe where the boxes were set in 6cm of water.

Although root development was not fully assessed in this experiment, root development in the uninoculated controls was best in the boxes which were set on gravel alone, and was poorest when the boxes were set in 6cm of gravel.

Discussion and Conclusions

It is clear from this experiment that the level of moisture in the compost does affect the level of foliage browning in cuttings growing in infested compost. Although infection took place in cuttings in all treatments involving *Rhizoctonia*, the damage to cuttings was most severe in treatments where water levels were lowest. This may have been because the fungus grew more slowly in the wetter composts and the infection and therefore damage proceeded more rapidly in the drier media.

However it is unlikely that manipulation of moisture levels will provide a means of cultural control for fungi such as *Rhizoctonia*. The cuttings which were growing in uninfested compost grew best in the boxes sitting on gravel alone, and root production became poorer and slower, the deeper the water around the box. Although time did not permit detailed measurements of root development in the different treatments, it seems reasonable to conclude that the benefits gained by immersing the boxes in water are far outweighed by the disadvantages created by slower and poorer rooting.

EXPERIMENT 10

The effect of inoculum density on the development of *Rhizoctonia* disease

Introduction

Earlier work has suggested that the amount of *Rhizoctonia* inoculum and its location in relation to the heather cuttings/plants is of great importance in determining the severity of any disease which might result. This series of experiments was set up to examine the effects of inoculum density and inoculum placement (i.e. the location of the *Rhizoctonia* mycelium) on the development of the disease.

Treatments

Three replicate trays containing five cuttings each of the *Calluna* cvs. Loch Turret, Lyonesse and Silver Knight were prepared for each of the following

treatments:-

1. Control - no *Rhizoctonia*-infested straw
2. 1 piece of *Rhizoctonia*-infested straw/tray mixed into compost
3. 5 pieces of " " " " " " "
4. 20 " " " " " " " " "
5. 50 " " " " " " " " "

Methods

1. Twenty litres of peat and bark compost were mixed and 1 litre of compost was placed in each half seed tray.

2. The compost from each tray was then removed, one at a time and mixed with the correct level of inoculum before being replaced in the labelled trays. The cuttings were then struck, and the trays placed on gravel and covered with polythene in the glasshouse.

3. The foliage condition of cuttings was assessed after 1, 2, 4 and 6 weeks, using the following scale.

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

4. After 6 weeks, four cuttings per tray were taken at random and were examined for the presence of disease. Pieces of cutting base were plated out onto agar and root floats were made.

Table 14. Mean foliage scores* of cuttings growing in composts containing different concentrations of *Rhizoctonia* inoculum.

	No. of pieces inoculum/tray					
Cultivar	0	1	5	20	50	Mean
Loch Turret	0.00	0.46	0.27	2.20	3.73	1.33
Lyonesse	0.27	0.67	1.33	2.00	2.87	1.43
Silver Knight	0.00	0.07	0.20	1.87	3.40	1.11
Mean	0.09	0.40	0.57	1.98	3.33	

* 0 = No foliage browning, 4 = foliage totally brown

Table 15. Number of *Calluna* cuttings from which *Rhizoctonia* was isolated 6 weeks after striking.

Treatment	Inoculum level (pieces inoc/tray)	Number of cuttings from which *Rhizoctonia* isolated (max. 12)
Uninoculated	0	0
Rhizoctonia I-48	1	4
	5	6
	20	7
	50	11

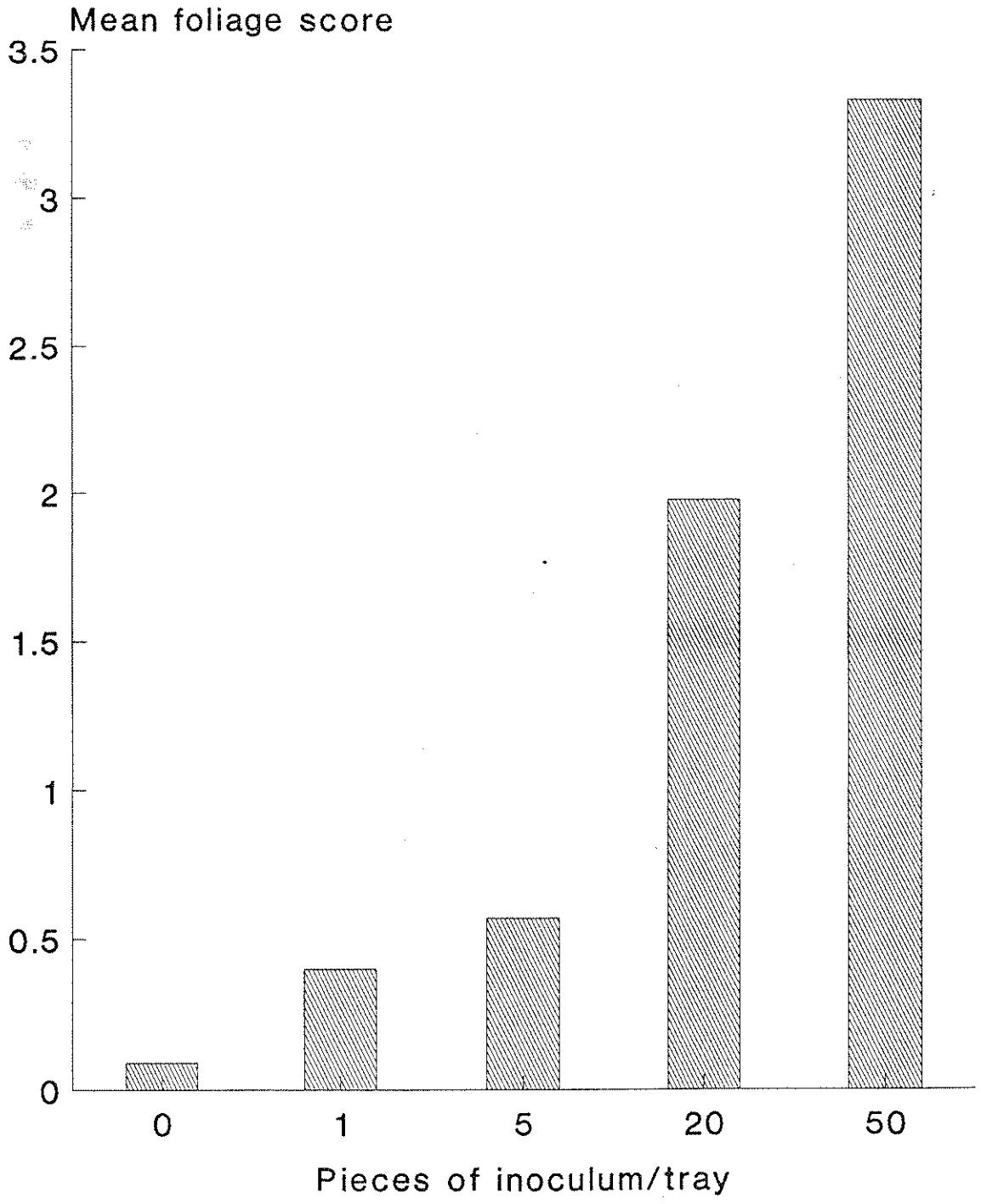

Fig. 8. The effect of inoculum concentration on development of *Rhizoctonia* on cuttings of three *Calluna* cultivars.

Foliage score : 1 = no foliage browning; 4 = foliage totally brown

The results in Table 14 and Fig. 8 show that the treatments involving the highest rate of *Rhizoctonia* inoculum displayed the greatest amount of infection and foliar browning. Isolation from cuttings showed that this was directly related to the number of cuttings which were infected in the different treatments (Table 15).

Discussion and Conclusions

The results from this experiment clearly show that the greater the amount of *Rhizoctonia* present in the compost, the greater the amount of damage caused to heather cuttings. Therefore it is important to reduce the quantity of the fungus on the nursery to as low levels as is possible. Even if it is not practical to remove *Rhizoctonia* altogether, its effects should be minimised if measures are taken to reduce its spread.

EXPERIMENT 11

Sources of *Rhizoctonia*

Treatments

Two replicate trays of 15 Erica vagans cv. Lyonesse were prepared for each of the following treatments on 21 April 1989 (*Rhizoctonia* isolate 48 was used throughout):-

1a. Cuttings in Optipot half trays set on top of *Rhizoctonia*-contaminated capillary matting set in cat trays.
1b. Uncontaminated control.
2a. Cuttings in Optipot trays growing on top of *Rhizoctonia*-contaminated sand set in cat trays.
2b. Uncontaminated control.
3a. Cuttings in Optipot trays growing on top of *Rhizoctonia*-contaminated gravel.
3b. Uncontaminated control.
4a. Cuttings in Optipot trays, set in cat trays and covered with *Rhizoctonia*-

contaminated polythene.

4b. Uncontaminated control.

5a. Cuttings grown in Optipot trays containing *Rhizoctonia*-contaminated compost fragments, and set in cat trays.

5b. Uncontamianted control.

6a. Cuttings grown in Optipot trays, (in cat trays) containing infected cuttings.

6b. Uncontaminated control.

7a. Cuttings grown in *Rhizoctonia*-contaminated Optipot trays, set in cat trays.

7b. Uncontaminated control.

Methods

1. Cuttings were struck into trays according to the treatments shown above, and were all watered and kept in a similar way.

2. All treatments were examined visually. Once suspected infection was noted on any treatment, cuttings were removed and tested for the presence of *Rhizoctonia*.

Results

The results show (Table 16) that all seven sources of *Rhizoctonia* tested succeeded in starting infection in the cuttings struck. Infection in the newly struck cuttings proceeded most rapidly from infected compost fragments and infected cuttings, and most slowly from contaminated capillary matting at the base of the tray.

Isolations from affected cuttings showed that all the brown foliage which developed in this experiment was due to infection by *Rhizoctonia*.

Table 16. *Rhizoctonia* **infection of cuttings grown in trays in contact with infected nursery materials (+ =** *Rhizoctonia* **present, - =** *Rhizoctonia* **absent).**

	No. of days from striking cuttings								
Treatment	3	6	9	11	18	25	32	39	46
1a	-	-	-	-	-	-	-	-	+
1b	-	-	-	-	-	-	-	-	-
2a	-	-	-	-	-	-	+	+	+
2b	-	-	-	-	-	-	-	-	-
3a	-	-	-	-	-	-	+	+	+
3b	-	-	-	-	-	-	-	-	-
4a	-	-	-	+	+	+	+	+	+
4b	-	-	-	-	-	-	-	-	-
5a	-	+	+	+	+	+	+	+	+
5b	-	-	-	-	-	-	-	-	-
6a	-	+	+	+	+	+	+	+	+
6b	-	-	-	-	-	-	-	-	-
7a	-	-	-	+	+	+	+	+	+
7b	-	-	-	-	-	-	-	-	-

Discussion and Conclusions

This experiment demonstrated that *Rhizoctonia* is capable of infecting cuttings from several sources, including inert nursery materials, decomposing organic matter and living materials. This suggests that nursery hygiene is of the utmost importance if the incidence of *Rhizoctonia* infection is to be kept at a minimum.

Nursery materials such as pots, trays, capillary matting and polythene should be new or at least rigorously sterilised prior to re-use. Care should be

taken to ensure that used compost or nursery soil does not come into contact with materials to be used for propagation of new cuttings.

The importance of infected cutting material as a source of *Rhizoctonia* clearly has been demonstrated. The maintenance of clean stock plants is essential to reduce the risk of serious disease.

EXPERIMENT 12

The effect of inoculum depth on the development of *Rhizoctonia* disease

Treatments

Three replicate trays each containing 5 cuttings of each of the *Calluna* cvs. Mousehole, Loch Turret and Lyonesse were prepared for each of the following treatments on 11 April 1989.

1. Control - Twenty-five pieces of sterile chopped straw spread on compost surface.
2. *Rhizoctonia* I-D1 - as above with 25 pieces of inoculated straw.
3. Control - Twenty-five pieces of sterile chopped straw spread in a horizontal layer midway between the top and the base of the tray.
4. *Rhizoctonia* I-D1 - as above with inoculated straw.
5. Control - Twenty-five pieces of sterile chopped straw spread in a layer on the base of the tray.
6. *Rhizoctonia* I-D1 - as above with inoculated straw.

Methods

1. The compost (50:50 Vapo-peat and Scotbark) was mixed and the trays were filled as shown above.

2. The cuttings were examined after 2,4 and 6 weeks and the foliage was scored according to the following scale:-

Foliar browning scale:-

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

3. After the foliage assessment on the 6th week, the cuttings were removed from the trays. Two cuttings per cultivar per tray were taken at random and tests were carried out to determine whether *Rhizoctonia* infection had taken place. Pieces of cutting base were plated out onto agar and floats were made from roots, where they had been produced.

Results

Table 17. Mean foliage scores of cuttings grown in composts with *Rhizoctonia*-infested and non-infested straw placed at different depths in the compost (6 weeks after striking cuttings).

	Depth of straw placement (from surface in cm)						
	Controls			*Rhizoctonia* I-D1			
Cultivar	0.0	2.5	5.0	0.0	2.5	5.0	Mean
Mousehole	0.00	0.00	0.00	2.87	2.27	0.00	0.86
Lyonesse	0.33	0.20	0.20	2.80	2.33	0.67	1.09
Loch Turret	0.00	0.00	0.00	3.47	2.67	0.13	1.01
Mean	0.11	0.07	0.07	3.05	2.42	0.27	

The results on the previous page, which are illustrated in Fig. 9, show that inoculum depth had an effect on the development of *Rhizoctonia* disease. The cuttings grown in compost with infested straw spread on the compost surface showed severe foliar browning due to *Rhizoctonia*, whereas those grown in the compost with the infested straw on the base of the tray showed the least foliar browning.

Table 18. Number of *Calluna* cuttings from which *Rhizoctonia* was isolated 6 weeks after striking.

Treatment	Position of inoculum (depth in cm)	Number of cuttings from which Rhizoctonia isolated (max. 18)
Uninoculated	0 (surface)	0
	2.5 (middle)	0
	5.0 (bottom)	0
Rhizoctonia I-D1	0	15
	2.5	12
	5.0	5

None of the control treatments showed significant foliar browning, and none were infected with *Rhizoctonia* (Table 18).

Discussion and Conclusions

The strain of *Rhizoctonia* used in this experiment grew best when located at or near the surface of the compost. It grew only slowly when placed at the base of the trays beneath 5cm of compost, and few cuttings became infected during the course of the experiment. It is known that some strains of *Rhizoctonia* are

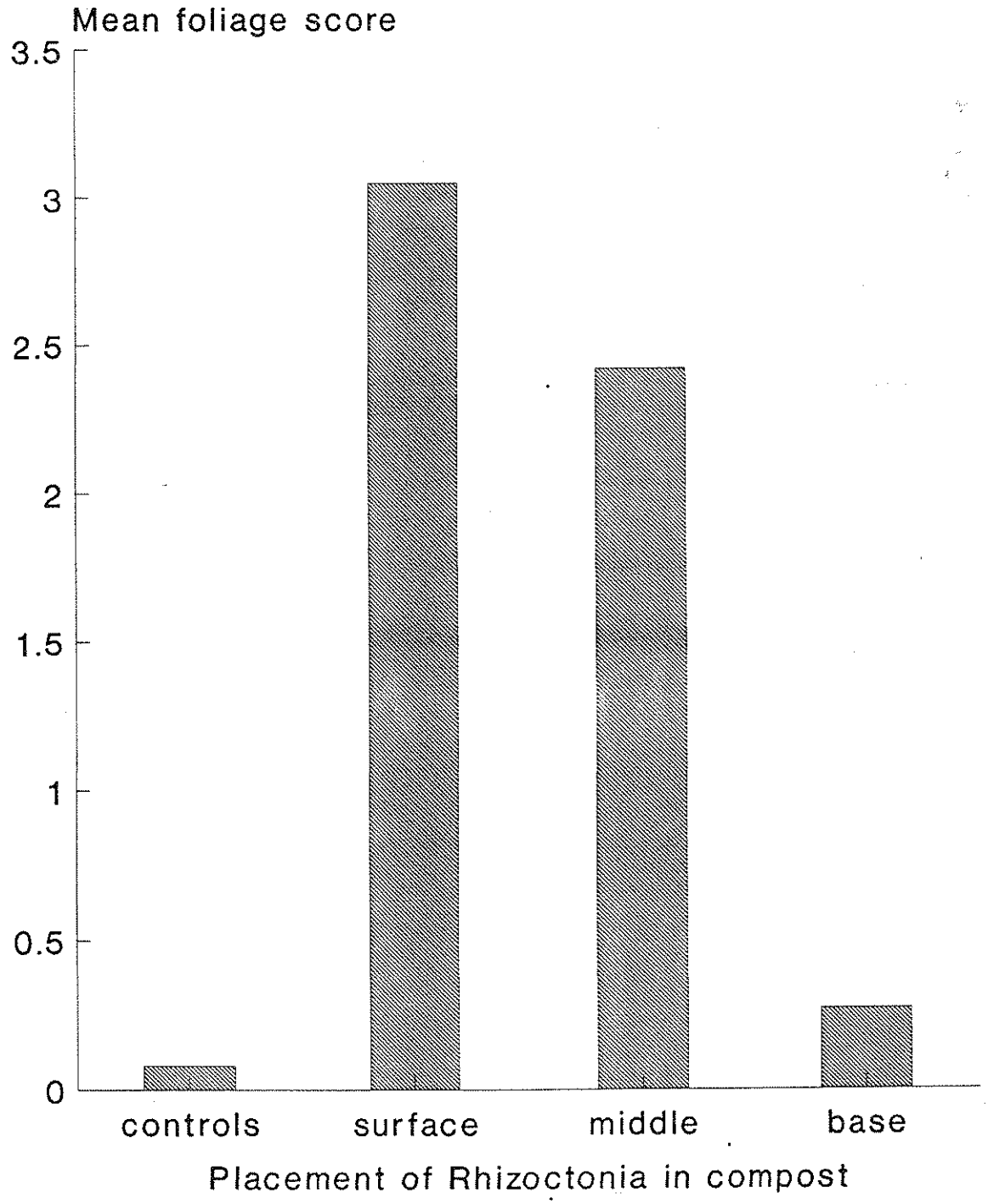

Fig. 9. The effect of inoculum depth on the infection of heather cuttings by *Rhizoctonia*.

Foliage score : 1 = no foliage brown; 4 = foliage totally brown

sensitive to carbon dioxide, hence they do not grow well when buried in soil, where carbon dioxide concentrations can be high. The strain of *Rhizoctonia* used in this experiment (D1) would appear to be a carbon dioxide sensitive type. It was originally isolated from the foliage, stem base and upper root zone of severely diseased *Calluna* plants and perhaps is not a true root pathogen. Other strains of *Rhizoctonia* which have been isolated from heathers from various parts of Britain are being examined to determine their requirements for growth and infection.

EXPERIMENT 13

An *in vitro* examination of the effect of fungicides on the growth of *Rhizoctonia*

Introduction

This is one of a series of laboratory tests to determine the activity of a range of fungicides against *Rhizoctonia*. The data obtained will be used to select rates, etc. for further evaluation in composts.

Treatments

Three replicate petri dishes of each of the following treatments were prepared for each of eight *Rhizoctonia* isolates in February 1989.

1. Control - unamended agar
2. Agar amended with 0.5ppm tolclofos-methyl (in Basilex)
3. " " " 5ppm " " "
4. " " " 50ppm " " "
5. " " " 500ppm " " "
6. Agar amended with 0.5ppm iprodione (in Rovral WP)
7. " " " 5ppm " "
8. " " " 50ppm " "
9. " " " 500ppm " "

Methods

1. Sterile, molten potato dextrose agar was mixed with Basilex on a laminar flow bench to give agar with a concentration of 500ppm tolclofos-methyl (in Basilex 50% WP).

2. Media from the above batch was then serially diluted to give agar containing 50, 5 and 0.5ppm tolclofos-methyl.

3. The agar lots were then poured and cooled under sterile conditions on the flowbench to give 28 plates of each concentration.

4. The same procedure was carried out for iprodione (in Rovral 50% WP).

5. Single 5mm discs cut from each isolate plate were then put into the centre of the freshly poured plates of control and fungicide media.

6. The plates were then sealed in polythene bags and were incubated at 23°C until the control plates of each isolate were fully colonised.

7. The growth of isolates on each plate was measured every 2 days until the control plates were colonised. Growth was measured using a ruler, and the mean of four measurements of growth from the original agar disc was taken for each plate.

Results

The data in Table 19 and Fig. 10 show that all isolates were controlled *in vitro* by concentrations of 5ppm of either iprodione or tolclofos-methyl. The effect of 0.5ppm of the active ingredients was variable depending on isolate. None of the 8 isolates tested were completely inhibited by 0.5ppm of either fungicide.

Table 19. Mean growth of *Rhizoctonia* (mm), in fungicide amended media, from original inoculum.

		Fungicide treatment							
		iprodione (ppm)				tolclofos-methyl (ppm)			
Isolate	Unamended Control	0.5	5	50	500	0.5	5	50	500
A	27	7	0	0	0	11	0	0	0
B1	17	5	0	0	0	8	0	0	0
24A	30	10	0	0	0	18	0	0	0
D1	19	6	0	0	0	9	0	0	0
72	27	9	0	0	0	10	0	0	0
55	40	5	0	0	0	13	0	0	0
56	40	13	0	0	0	21	0	0	0
48	40	12	0	0	0	21	0	0	0
Mean	30	8	0	0	0	14	0	0	0

Discussion and Conclusions

In this *in vitro* test, tolclofos-methyl, the active ingredient of Basilex, controlled *Rhizoctonia* at concentrations as low as 5ppm, which is well below the 40ppm recommended by the manufacturer for compost incorporation. Iprodione (in Rovral) was equally effective *in vitro*, but is not generally regarded to be as effective as Basilex *in vivo*. This is probably due to the fact that Rovral Dust is often used as a compost incorporant, although there is no manufacturer's recommendation for this. Rovral Dust contains 1.25% iprodione which means that at a rate of 400g/m^3 only 6ppm of active ingredient are

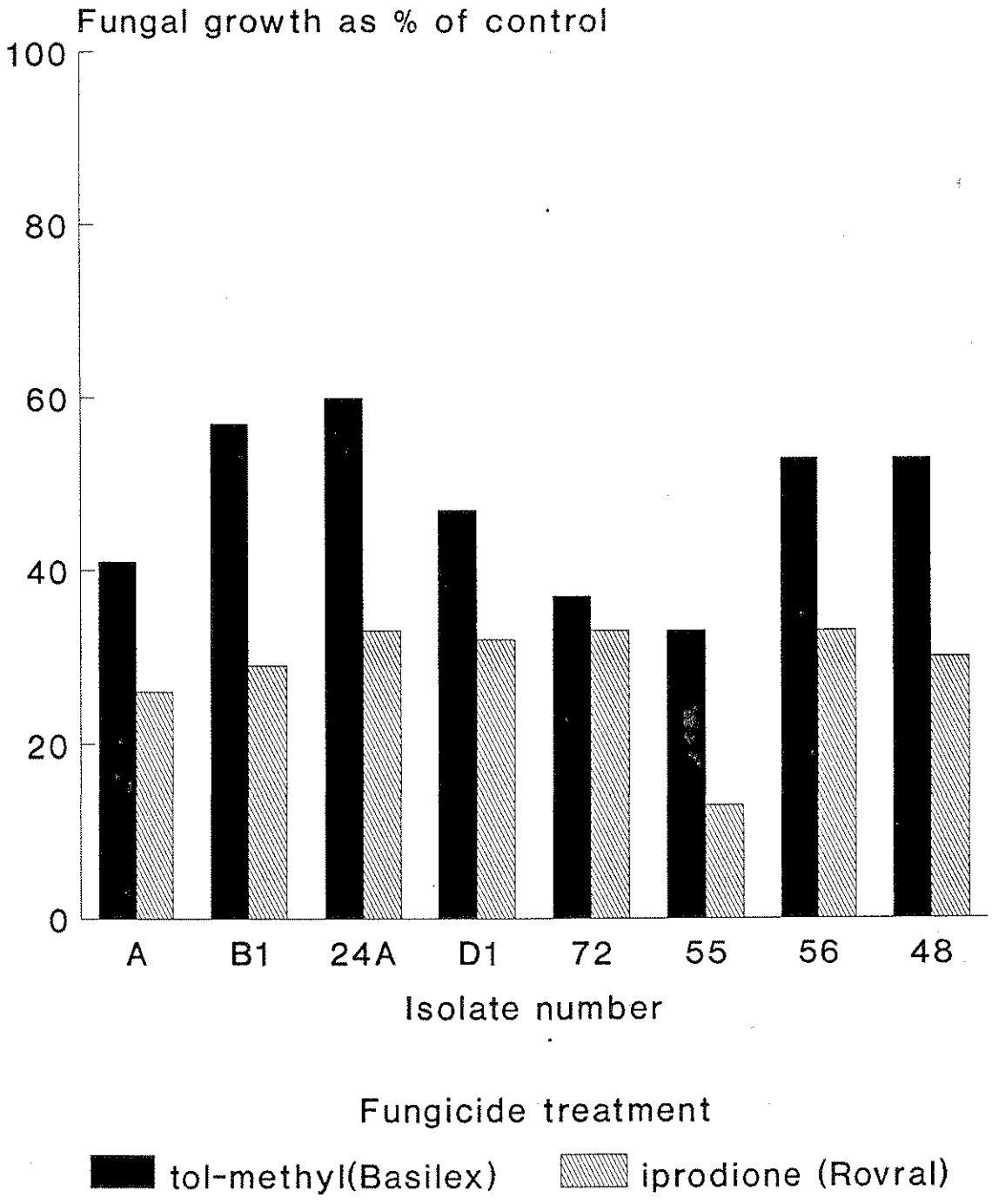

Fig. 10. The effect of fungicides on the growth of *Rhizoctonia in vitro*

applied. Rovral drenches at the recommended rate of 1g/l water (i.e. 1000ppm) may provide more active ingredient, although exactly how much gets into the compost depends on the amount of water applied and the amount retained.

Further experiments are planned to evaluate a wider range of fungicides *in vitro*, and to look at the efficacy of these materials in the nursery situation.

EXPERIMENT 14

The direct effect of fungicides on the development of potted, rooted cuttings

Introduction

This experiment was set up to examine the effects of some fungicides on older rooted heathers. Fungicides could prove very useful in helping to maintain the health of stock plants if they could keep the spread of pathogens such as *Rhizoctonia* at a low level.

Treatments

Three replicates of 5 *Calluna* plants each were prepared for each of the following treatments on 19 September 1989.

1. Untreated controls

2. Plants potted into compost containing Rovral dust at 200g/m^3. In addition, plants will be drenched once monthly with Rovral (1g/l).

3. Plants potted into compost containing Rovral dust at 400g/m^3. In addition, plants will be drenched once monthly with Rovral (1g/l).

4. Plants potted into compost containing Basilex at 80g/m^3. In addition,plants will be drenched once monthly with Basilex (2g/l).

5. Plants potted into compost containing Basilex at 160g/m^3. In addition, plants will be drenched once monthly with Basilex (2g/l).

Methods

1. Plants were potted into the following compost:-

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

Once potted the plants were stored on polythene beside other plants at a similar stage on the nursery.

2. The plants were looked after as the other heathers on the nursery, with the exception of the drenches which were carried out as noted above.

3. The foliage of each plant was assesed at each drenching date, using the scale shown below:-

Foliage browning scale

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

4. On the final assessment, which will take place in June 1990, the plants will be destructively assessed. The foliage will be examined, and foliage dry weights will be measured. One sample plant/treatment per replicate will be

tested for the presence of disease. Pieces of root and stem base will be plated onto agar and root floats will be made.

EXPERIMENT 15

To determine the presence of *Rhizoctonia* in nursery soils and composts

Introduction

It is of great importance when developing a control programme for any pathogen, that the sources and reservoirs for the pathogen are known and fully understood. It is known that *Rhizoctonia* is a competent saprophyte as well as being capable of existing as a parasite and pathogen, but up until now, it was unclear to what extent the fungus exists on nursery composts and inert materials such as trays and mattings. This experiment was set up to examine some of the potential reservoirs of the disease on nurseries, as an aid to developing control measures.

Methods

1. All soil/compost samples were examined and any stones or large lumps removed. Each sample (of approx 1 litre) was then further sampled, as follows. The 1 litre batch was spread out in a cat litter tray and several 'pinches' of soil/compost were taken at random from the batch and placed in an 8cm pot until it was filled to 1cm below the top. All samples were moistened if necessary, to a degree which would allow germination and growth of *Rhizoctonia* 'bait' plants (radish seedlings) .

2. Two nylon mesh packets containing radish seeds were then buried in each pot, one glass slide was pushed down the side of the pot, and one polythene vial containing Richard's medium (selective for *Rhizoctonia*) was pushed downwards from the surface.

3. The pots were then placed in a glasshouse at temperatures of 12 - 24^{o}C for

5 days. They were then removed for examination.

4. The glass slides were removed from the pots and were gently washed and examined under a microscope (x 100 and x 400) for the presence of *Rhizoctonia*. The bait packets were cut open, and the radish seeds examined under both a dissection microscope at x 40 and on slides at x 100. The polythene vials were also examined, using a hand lens and microscope.

5. The presence or absence of *Rhizoctonia* (as determined using the above methods), from each sample was recorded.

Results

Table 20. Detection of *Rhizoctonia* in various nursery composts and soils.

Substrate	Number of samples in which *Rhizoctonia* detected
Fresh Vapo peat	0
" Bulrush peat	0
" Cambark	0
" Scotbark	0
Potato field soil	25
Nursery soil	2
Used nursery compost	6

The results in Table 20 show that no *Rhizoctonia* was isolated from any unused nursery compost component. It was isolated most frequently from potato field soil. It was also isolated from 4% of samples of nursery soil tested, and from 12% of samples of used nursery compost.

Discussion and Conclusions

Rhizoctonia was not isolated from any of the samples of unused compost components. This was as expected, as the products tested were sold by companies who intend them for use as plant growing media. They should therefore be free of pathogens such as *Rhizoctonia*.

The potato field soil was included in this experiment mainly as a comparison. It is known that *Rhizoctonia* is a very common pathogen of potato and hence is frequently found in soils which are used to grow potatoes. A very large number, (50%) of the samples tested contained *Rhizoctonia*.

The fact that 2 out of 50 samples of nursery soil tested yielded *Rhizoctonia* is sufficient to suggest that such soils may be important reservoirs for the fungus. It can exist happily in soils, living on dead and decaying organic matter as well as on the roots of living plants such as heathers and many weed hosts. Hygiene is therefore very important if contact with contaminated soils is to be avoided. This may mean growing plants on gravel, sand or woven polypropylene and avoiding root penetration through such media. If any loam is used in the compost, it must be sterilised before use.

It can be concluded that since *Rhizoctonia* was isolated from 12% of used nursery composts, but was not isolated fron any batches of unused components, that infestation must come from either contaminated cutting material, soil or nursery equipment. The next experiment examined nursery equipment for the presence of *Rhizoctonia*.

EXPERIMENT 16

To determine the presence of *Rhizoctonia* on new and used nursery materials

Method

1. Thirty capillary matting samples (5cm x 5cm) were cut into 1cm squares and 5 of these were selected at random. The squares were then washed thoroughly

in sterile distilled water. They were then placed in flasks of sterile distilled water and shaken for 3 x 30 minutes, with the water being changed each time. The capillary matting pieces were then dried in a warm (20°C) oven for 24 hours.

The pieces were plated (5/plate) onto P.D.E.S. and were incubated at 23°C until growth of the fungi in the matting had taken place. - usually 24 - 48 hours. They were then examined under x 40 to x 100 magnification and *Rhizoctonia* was identified where present.

2. The trays were cut into manageable pieces (ie those which could be viewed easily under the dissecting microscope) and were gently washed and left to air dry. They were then examined under the dissecting microscope. *Rhizoctonia* mycelium was tentatively identified in this way, and pieces of tray containing the suspected *Rhizoctonia* were cut out. The fungus was scraped from the trays and plated out onto P.D.E.S. agar media where it was allowed to grow until it could be confirmed as being *Rhizoctonia* or not.

3. The polythene samples were treated in a similar way to the trays above.

4. The presence or absence of *Rhizoctonia* (as determined using the methods noted above), on each sample was recorded.

Results

Rhizoctonia was isolated from 10% of used cutting trays, 13% of samples of used capillary matting and 3% of samples of used polythene (Table 21). It was not isolated from any samples of new, unused materials.

Table 21. Detection of *Rhizoctonia* on nursery materials.

Material	Number of samples on which *Rhizoctonia* was detected (max. 30)	
	New	Used
Capillary matting	0	4
Cutting trays	0	3
Polythene	0	1

Discussion and Conclusions

The isolation of *Rhizoctonia* from used nursery materials demonstrated that it can survive and grow on inert substances. It has also been shown that *Rhizoctonia* can infect heathers from such materials, [see experiment 11]. This leads again to the conclusion that hygiene is of the utmost importance i *Rhizoctonia* is to be effectively controlled on the nursery.

If materials such as trays and pots are to be used more than once, it is good idea to sterilise them to kill any harmful pathogens that may be prese in or on them. It is not enough merely to wash them - *Rhizoctonia* adher very firmly to inert materials such as plastic and does not wash off easil Capillary matting should be changed regularly as it can provide an ide habitat for pathogens. Polythene and other disposable materials are be disposed of once finished with and not left lying around the nursery.

Attention to these and other similar matters of nursery hygiene may do a gr deal to limit the spread of *Rhizoctonia* and perhaps other pathogens around nursery, thus reducing the need for chemical control measures.

EXPERIMENT 17

Investigation of infection processes of *Rhizoctonia*

Introduction

In a project such as this, where the aim is to find practical solutions to a disease problem it is important to find out where and how infection occurs so that the correct control measures can be directed to the appropriate area of the plant. Experiments carried out in the first year of the project indicated that *Rhizoctonia* was most often isolated from the stem base/lower foliage area. Work which is now beginning, aims to look at a wide range of isolates and their effects on a range of cultivars. It is hoped in this way to discover whether all isolates infect heathers in a similar way, or whether there are a range of different infection patterns. Simple inoculation techniques using infested straw are used to infect plants, and standard isolation procedures such as those described in earlier experiments are being used to isolate the fungus from plant parts. Photographic records are being made of the plant/pathogen interactions where possible.

Results

So far, the effects of *Rhizoctonia* I-D1 on the cultivars 'Mousehole' and 'Springwood White' have been examined. In both cases the fungus tended to infect the stem base and lower foliage rather than the roots. Infection was seen to proceed fairly rapidly in the warm moist environment of a polythene tunnel.

Plate 3 (x 10) shows the fungus growing across a healthy *Erica carnea* 'Springwood White' shoot. It is interesting to note that although the fungus is obvious under a magnification of x 10, (as seen under a dissecting microscope), with the naked eye the foliage looks perfectly healthy and it is difficult to see any trace of the fungus.

Plate 4 shows a close up (x 40) of the same isolate infecting a single leaf of *Erica carnea* 'Springwood White'. There was no infection cushion present. The

fungus penetrated the plant cuticle directly. it may have entered through a stoma, (natural opening in the leaf), or it may have used enzymes to soften the tissue prior to penetration. It is hoped to develop techniques to cut very thin sections of heather leaves and stem so that the actual infection process can be looked at more thoroughly.

Plate 3. *Rhizoctonia* growing on 'Springwood white' shoots.

Plate 4. ***Rhizoctonia*** **I-D1 infecting** ***Erica*** **leaf.**

The fungus was seen to behave similarly on the *Calluna* cultivar 'Mousehole'. It spread rapidly over the foliage at the base of the plant, then after the fungus had been present for a day or two, the foliage was seen to turn brown, but only in the places where the fungus was in direct contact with the foliage. Plate 5 shows healthy 'Mousehole' foliage before the fungus infected. Plate 6 shows partially infected foliage with signs of browning appearing and Plate 7 shows foliage on a young plant which was totally killed by the fungus.

Plate 5. (x 10) Healthy uninfected 'Mousehole' foliage.

Plate 6. Partially infected 'Mousehole' foliage, showing browning on areas in contact with *Rhizoctonia*.

Plate 7. *Rhizoctonia* growing on dead 'Mousehole' foliage.

Project objectives for 1989/90

1. Continue long term experiments to determine whether inoculation of compost with *Rhizoctonia* will affect the long term growth and development of heather cuttings.

2. Continue work to examine the range of effects which *Rhizoctonia* isolates can have on heather cultivars.

3. Examine the reasons for failure to infect and loss of pathogenicity by isolates which are normally known to be pathogenic to heather cuttings.

4. Complete further experiments on the effect of pH on the development of disease in cuttings, this time using *Erica* cuttings.

5. Carry out experiment to determine the effects of temperature on the

development of *Rhizoctonia* disease in cuttings.

6. Carry on investigations into the infection processes of *Rhizoctonia* on heathers using embedding and sectioning techniques, microscopy and photomicrograpy.

7. Investigate the potential of a number of natural substances such as composted hardwood and softwood bark and sewage sludge as biological control agents for *Rhizoctonia*.

8. Carry out further experiments to determine the effects of fungicides on the development of *Rhizoctonia* disease on infected cuttings. Use a range of isolates and test several chemicals, (depending on availability), for efficacy and possible phytotoxicity.

9. Complete experiments to determine the effects of a range of fungicides on uninfected, healthy rooted heathers.

10. Carry out experiments to determine optimum rates and timings for one or more key fungicides.

11. Examine whether fungicide efficacy is affected by compost type and management regime.

12. Using the results gained from the past 3 years work, devise a set of integrated control measures for the disease.

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The report was prepared by Jacqueline Miller, Plant Sciences Department.