THE BIOLOGY AND CONTROL OF FUNGAL PATHOGENS OF ERICA AND CALLUNA

Report by A M Litterick

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CONTENTS

APPLICATION

This project concerned four fungi which cause root diseases of heaths and heathers, namely Cylindrocarpon, Cylindrocladium, Pestalotiopsis and Fusarium. These fungi can cause root-rot, foliar browning and death of cuttings. They also cause disease on older plants. They may cause disease singly, or in association with other fungi. The fungi which cause root-rots cannot be distinguished through simple examination with the naked eye. Laboratory diagnosis is necessary. The fungi live on dead and decaying plant material and in soil. They don't need a living host plant in order to survive. They spread through the production of air and water-borne spores and as mycelium (fungal threads) on unsterile nursery equipment and materials.

Results obtained from this work have shown that all of these fungi can attack healthy cuttings grown under good conditions. However, heather cuttings are much more likely to succumb to diseases caused by Cylindrocarpon, Cylindrocladium, Pestalotiopsis and Fusarium if they are stressed in some way, for example through inadequate irrigation, poor drainage, adverse temperatures, draughts etc.

Prevention and control measures for diseases caused by Cylindrocarpon, Cylindrocladium, Pestalotiopsis and Fusarium.

1. Use only new or sterilised nursery materials and equipment. Use a good proprietary sterilant which is safe for both plants and the user (e.g. Jet 5) to sterilise pots, trays, benches, pathways, trolleys etc. regularly.

2. Minimise or eliminate contact between plants and nursery soil.

3. Optimise conditions for vigorous, healthy plant growth. Pay attention to irrigation, drainage, fertiliser (if necessary, depending on growth stage), temperature and humidity. Stressed plants are much more susceptible to disease.

4. Have root-rot diseases correctly diagnosed. Do not guess. Application of the wrong fungicide is costly, ineffective and may cause plant damage.

5. Use prochloraz-manganese (Octave, Fisons) and carbendazim (Bavistin, BASF) to prevent and control diseases caused by Cylindrocarpon, Cylindrocladium, Pestalotiopsis and Fusarium on stock plants. If stock plants are kept healthy in this way, and nursery materials and equipment are sterile, the chances of disease on cuttings are minimal. There should, under normal circumstances, be no need to use fungicides to control the above diseases on cuttings.

6. Maintain strict quarantine procedures for plants coming on to the nursery from outside. Keep new arrivals at least 1 m away from existing plants for at least 6 months. Keep them in a separate tunnel or standing area if possible.

7. Consider the need for preventative fungicide treatments on plants other than stock if the disease risk is high, for example if:

   a. There have been disease outbreaks on the nursery
   b. Plants have been bought in from elsewhere
   c. Plants are known to have been subjected to a period of severe stress, e.g. cold, flooding etc.

8. Heaths and heathers are particularly susceptible to damage by crop protection chemicals, so always test fungicides out on a few plants if you have not used them on a particular cultivar before.

SUMMARY

The main conclusions to be drawn from all three years of this project are as follows :-

1. The fungal isolates used in experiments have been identified as *Fusarium sporotrichioides* Sherbak., *Fusarium tricinctum* (Corda) Sacc. *Fusarium avenaceum* Fr.) Sacc., *Cylindrocarpon destructans* (Zinssm.) Sholten., *Cylindrocladium ilicicola* (Hawley) Boed. & Reitsma., *Cylindrocladium scoparium* Morgan. and *Pestalotiopsis sydowiana* (Bresad.) B.Sutton.

2. Cylindrocarpon, Cylindrocladium, Pestalotiopsis and Fusarium were often isolated both singly and in combination from the roots of dead and dying ericaceous plants.

3. It was not possible to distinguish between root-rots caused by the above fungal pathogens simply by examining plants with the naked eye. Detailed lab diagnostic tests were necessary.

4. Cylindrocladium isolates have been shown to cause foliar browning and root-rot on heather cuttings. In general they caused more browning on cuttings than Cylindrocarpon isolates.

5. The level of foliar browning caused by Cylindrocarpon isolates varied a great deal depending on isolate. Some isolates caused severe foliar browning and cutting death. Others caused no damage.

6. Isolates of Fusarium tested generally caused lower levels of foliar browning than isolates of Cylindrocarpon, Cylindrocladium or *P. sydowiana.* The level of foliar browning caused by Fusarium isolates varied depending on isolate.

7. The level of foliar browning on cuttings differed depending on the environment in which cuttings were kept. In general, disease development was greater if cuttings were placed under stress (e.g. adverse temperatures or irrigation regimes).

8. The level of foliar damage associated with some isolates was not consistent. In some experiments, severe foliar browning occurred, whereas in others, no foliar browning occurred.

9. Prochloraz-manganese (Octave, Fisons) and carbendazim (Bavistin, BASF) gave good control of disease on heather cuttings grown in compost containing isolates of Cylindrocarpon, Cylindrocladium, *P. sydowiana* or Fusarium.

INTRODUCTION

This project followed a three year investigation at SAC Auchincruive into the biology and control of Rhizoctonia on heaths and heathers. The aim was to apply a similar approach to that used with Rhizoctonia, looking first at the pathogens in detail, then at the effect of cultural and environmental factors on the development of disease. Control measures were to be developed for the main root diseases of heaths and heathers.

In the final year of this project, we completed our investigation into the pathogenicity of isolates of Cylindrocarpon, Cylindrocladium, and Fusarium on heaths and heathers. A range of isolates taken from plants throughout the UK were examined. We also looked at the effect of *Pestalotiopsis sydowiana* on the roots and stem-base of heaths and heathers. This fungus is often isolated from the roots and stem-base of dead and dying nursery stock (Crop Health Centre case records). Work was already being carried out at SAC Auchincruive on the biology and control of Pestalotiopsis as an air-borne (foliar) pathogen (HDC Project HNS 33).

Work was continued to determine the effect of environmental and cultural conditions on diseases caused by Cylindrocarpon, Cylindrocladium, and Fusarium. This years' work also included isolates of *P. sydowiana.*

In the first two years of the project, the effects of fungicides on Cylindrocarpon, Cylindrocladium, and Fusarium isolates *in vitro* were examined. This work was continued in the final year of the project to look at the effects of fungicides on heather cuttings grown in compost containing Cylindrocarpon, Cylindrocladium, Fusarium and *P. sydowiana.*

GENERAL MATERIALS AND METHODS

All treatments within experiments were replicated three times and all experiments were set out in randomised block designs. Uninoculated control treatments were kept under separate polythene covers to avoid contamination from neighbouring treatments. Inoculated treatments were separated from each other by 1 cm on all sides. Trials involving cuttings were maintained in a glasshouse on a gravel-covered bench (temperature range 12 - 24°C). All un-rooted cuttings were struck into Bulrush Propagation Compost. All rooted cuttings were potted into the following mix:

Standard potting compost

Bulrush sphagnum peat, screened 22 mm
1.8 kg Dolodust/m^3 peat
3 kg Ficote 140 14:14:14 9 month controlled release fertiliser/m^3 peat
0.3 kg fritted trace elements/m^3 peat

Production of standard wheat seed inoculum

Wheat seeds were sterilised by autoclaving twice at 15 psi at 24 hour intervals. The seeds were inoculated with a single fungal isolate of Cylindrocarpon, Fusarium, Cylindrocladium or *P. sydowiana.* They were incubated at 23°C for 8 days, by which time fungal mycelium was visible on the seeds.

Isolates used in experiments

Isolates used in this work were obtained from ornamental plants in the UK between Autumn 1990 and Summer 1993. Some of these isolates have been identified to species level by IMI Biosystematics Services. Remaining isolates have been identified to genus level, have been sent to IMI and await further identification. Isolates used in this years' work are shown overleaf.

Isolates used in experimental work

Isolate number	Species	Original host plant	IMI identification number
C13	*Cylindrocarpon destructans*	Juniper	355123
C15	*Cylindrocarpon destructans*	Silver fir	355124
C18	*Cylindrocarpon destructans*	Erica	355122
C36a	*Cylindrocarpon destructans*	Erica	355127
C40a	*Cylindrocarpon destructans*	Calluna	355125
C34b	*Cylindrocarpon* species	Calluna	355125
C20	*Cylindrocarpon* species	Calluna	-
C21	*Cylindrocarpon* species	Calluna	-
C22	*Cylindrocarpon* species	Erica	-
C23	*Cylindrocarpon* species	Erica	-
C25	*Cylindrocarpon* species	Erica	-
C30	*Cylindrocarpon* species	Calluna	-
Cm26	*Cylindrocladium scoparium*	Calluna	355126
Cm28	*Cylindrocladium ilicicola*	Calluna	357151
Cm55	*Cylindrocladium* species	Bay laurel	357153
Cm56	*Cylindrocladium* species	Bay laurel	357152
F3	*Fusarium tricinctum*	Calluna	355128
F7	*Fusarium avenaceum*	Ivy	355130
F10a	*Fusarium sporotrichioides*	Erica	355129
F12	*Fusarium sporotrichioides*	Calluna	355131
P11	*P. sydowiana*	Erica	356306
P16	*P. sydowiana*	Rhododendron	356309
P22	*P. sydowiana*	Rhododendron	356312

EXPERIMENT 1. The effect of Cylindrocarpon, Cylindrocladium and Fusarium on heather cuttings

Aim: To determine the effect of different isolates of Cylindrocarpon, Cylindrocladium and Fusarium on the foliage of rooted heather cuttings.

Treatments (isolate number)

1. Uninoculated control
2. C13
3. C18
4. C36a
5. C40a
6. C34b
7. C22
8. C23
9. C25
10. C30
11. Cm26
12. Cm28
13. Cm55
14. Cm56
15. F10a
16. F7

Methods

Forty eight plastic seed trays (23 x 17.5 x 5.5 cm deep) were filled with standard potting compost. The compost in each tray was mixed with 20 inoculated wheat seeds (one isolate or control per tray). Four rooted cuttings of each of *C. vulgaris* 'Silver Queen', *E. carnea* 'Ruby Glow' and *E. cinerea* 'Violetta' were potted into each tray. Foliage of cuttings was assessed after 8 weeks using the following scale:

Foliar browning scale

0 - No foliar browning
1 - Tips or bases of a few branches brown
2 - As above, plus one or two branches totally brown
3 - Foliage almost totally brown, but some remaining green areas
4 - Foliage totally brown

Pieces of stem base were taken from two cuttings removed at random from each tray. These were surface sterilised, placed on potato dextrose agar and incubated at 24°C for 7 days to check for the presence of disease on the roots.

Results

There were great differences between the amount of foliar browning caused by the isolates tested (Fig. 1). The four Cylindrocladium isolates caused the most foliar browning (mean level of foliar browning was 3.5). Some Cylindrocarpon isolates were associated with very low levels of browning (e.g. heathers grown in compost containing isolates C22 and C25 had mean foliage scores of 0.2 and 0.1 respectively). Others caused high levels of browning (e.g. heathers grown in compost containing isolates C36a and C40a had mean foliage scores of 2.5 and 2.2 respectively).

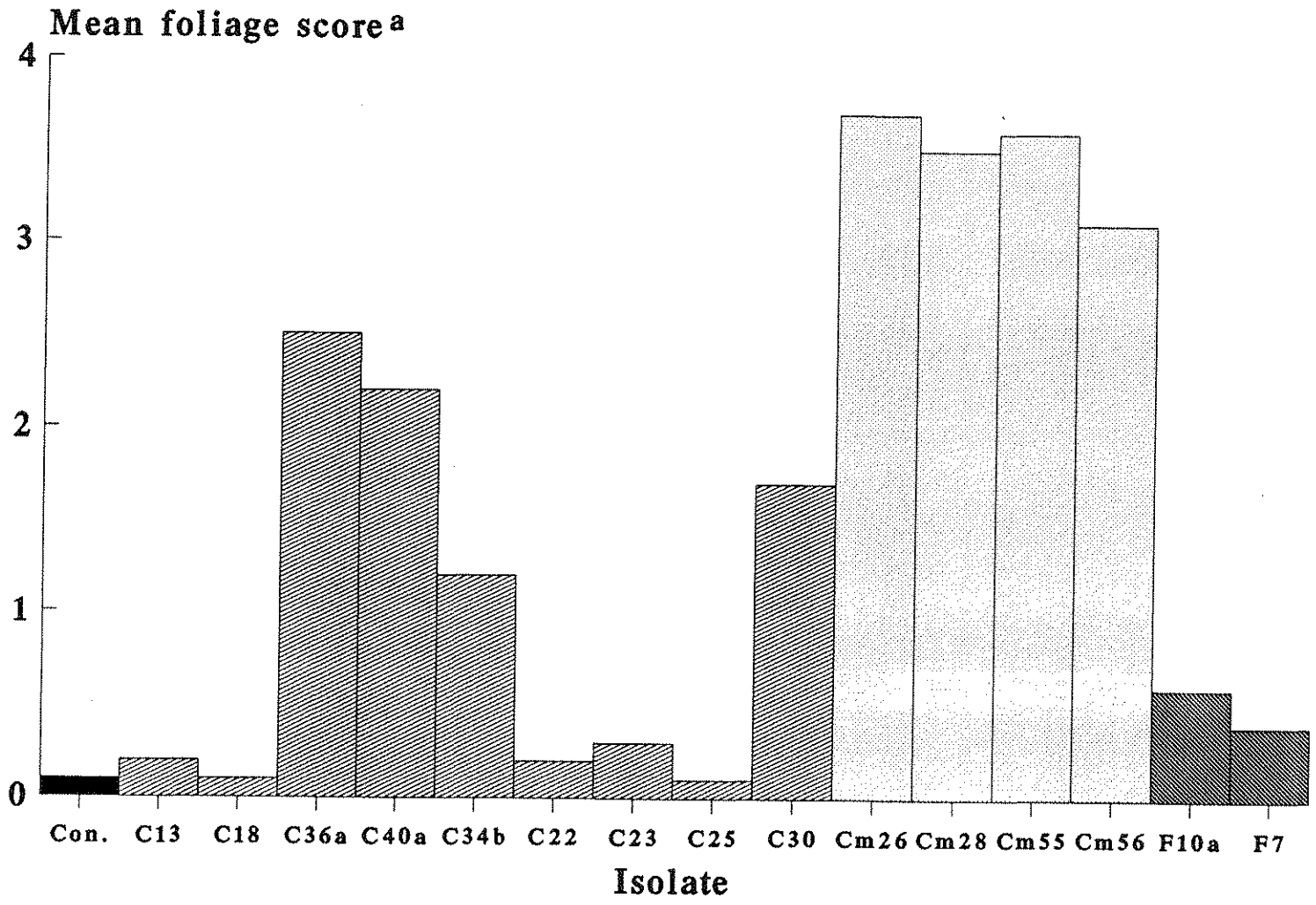

Fig 1. The effect of Cylindrocarpon, Fusarium and Cylindrocladium isolates on the foliage condition[a] of rooted heather cuttings (mean scores taken from three cultivars) assessed 8 weeks after potting. (Experiment 1)

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

There were differences between foliage scores recorded on the three heather cultivars. The *E. cinerea* cultivar 'Violetta' was least affected by disease (mean foliage score of 0.4). *C. vulgaris* 'Silver Queen' cuttings had a mean score of 2.2 and *E. carnea* 'Ruby Glow' cuttings had a mean score of 1.8.

The inoculated pathogen was re-isolated from cuttings in all treatments except those involving Cylindrocarpon isolates C22 and C25. No pathogens were isolated from uninoculated controls.

Discussion

It is generally thought that Cylindrocarpon and Cylindrocladium species act mainly as secondary pathogens (see overall discussion and conclusions). The results from Experiment 1 indicate clearly that some of the isolates tested were acting as primary pathogens on healthy cuttings maintained under good growing conditions (e.g. the four Cylindrocladium isolates and Cylindrocarpon isolates C36a and C40a). The control cuttings which were uninoculated showed very low levels of foliar browning. Difficulty was experienced, in previous years, in keeping control cuttings free from infection. However cross-infection between treatments has now been successfully prevented by keeping control treatments under separate polythene covers and by separating boxes or trays by 1 cm on all sides.

EXPERIMENT 2. The effect of *Pestalotiopsis sydowiana* on unrooted heather cuttings

Aim: To determine the effect of three different isolates of *P. sydowiana* on three cultivars of unrooted heather cuttings.

Treatments (isolate number)

1. Uninoculated control
2. P11
3. P16
4. P22

Methods

Twelve plastic boxes (10 x 10 x 8 cm deep with drainage holes) were filled with Bulrush propagation compost. The compost in each tray was mixed with 12 inoculated wheat seeds (one isolate or control per tray). Four un-rooted cuttings of each of *C. vulgaris* 'Silver Queen', *E. carnea* 'Ruby Glow' and *E. cinerea* 'Violetta' were struck into each tray. Foliage of cuttings was assessed after 8 weeks using the foliage browning scale. Pieces of stem base were taken from two cuttings removed at random from each tray. These were surface sterilised, placed on potato dextrose agar and incubated at 24°C for 7 days to check for the presence of disease on the roots.

Results

P. sydowiana isolate P22 in general caused most foliar browning of the three isolates tested on heather cuttings and isolate P11 the least (Fig. 2). Foliar browning was very low on *E. cinerea* 'Violetta' cuttings (mean score on inoculated cuttings was 0.1). Foliar browning on *E. carnea* and *C. vulgaris* cuttings was greater (mean scores on inoculated cuttings were 0.8 and 0.7 respectively).

Pestalotiopsis was isolated from all inoculated *C. vulgaris* and *E. carnea* treatments except *E. carnea* cuttings grown with isolate P11. No Pestalotiopsis was isolated from *E. cinerea* 'Violetta' cuttings.

Discussion

P. sydowiana is acknowledged as a foliar pathogen on several ornamental species (MacDonald, 1985). It has also frequently been isolated from the roots and stem-base of dying ericaceous plants (Crop Health Centre case records). This experiment was set up to determine whether isolates taken from the stem-base of ericaceous plants would cause foliar damage on heather cuttings. Results recorded in Experiment 2 show that some isolates can act as primary pathogens on healthy cuttings maintained under good growing conditions

EXPERIMENT 3. The effect of environment on heather cuttings grown in compost containing *P. sydowiana*.

Aim: To determine the effect of three isolates of *P. sydowiana* on three cultivars of rooted heather cuttings grown in three different environments.

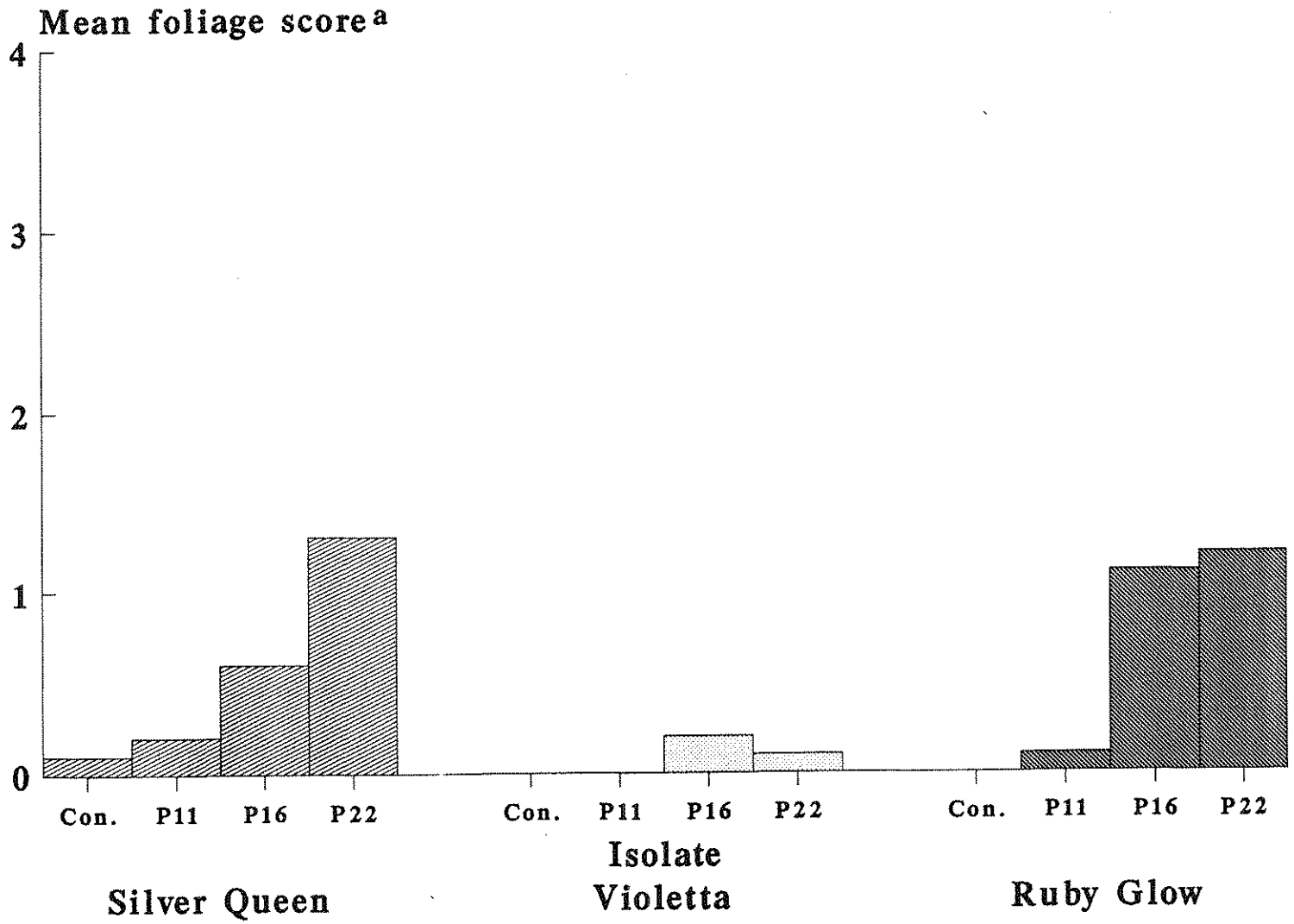

Fig 2. The effect of *P. sydowiana* isolates on the foliage condition[a] of un-rooted heather cuttings assessed 8 weeks after potting. (Experiment 2)

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

Treatments

Environment A. Unheated tunnel, net sides
Environment B. Cool glasshouse 6 to 18°C
Environment C. Heated glasshouse 12 to 24°C

1. Uninoculated control - Environment A
2. Uninoculated control - Environment B
3. Uninoculated control - Environment C
4. P11 - Environment A
5. P11 - Environment B
6. P11 - Environment C
7. P16 - Environment A
8. P16 - Environment B
9. P16 - Environment C
10. P22 - Environment A
11. P22 - Environment B
12. P22 - Environment C

Methods

Thirty six plastic seed trays (23 x 17.5 x 5.5 cm deep) were filled with standard potting compost. The compost in each tray was mixed with 20 inoculated wheat seeds (one isolate or control per tray). Four rooted cuttings of each of *C. vulgaris* 'Silver Queen', *E. carnea* 'Ruby Glow' and *E. cinerea* 'Violetta' were potted into each tray. The trays were placed in different environments as shown above. All trays were covered in polythene and were watered as required. Foliage of cuttings was assessed after 8 weeks using the foliage scale.

Results

P. sydowiana isolate P22 caused most foliar browning of the three isolates tested, and isolate P11 the least (Fig. 3). The level of browning recorded on cutting foliage differed depending on the environment in which cuttings were kept. Those kept in environment C (heated glasshouse) generally showed the highest level of browning and those in environment A (unheated tunnel) the lowest level.

There were differences between foliage scores recorded on the three heather cultivars. The *E. cinerea* cultivar 'Violetta' was least affected by disease (mean foliage score of 0.3. *C. vulgaris* 'Silver Queen' cuttings had a mean score of 1.1 and *E. carnea* 'Ruby Glow' cuttings had a mean score of 1.5.

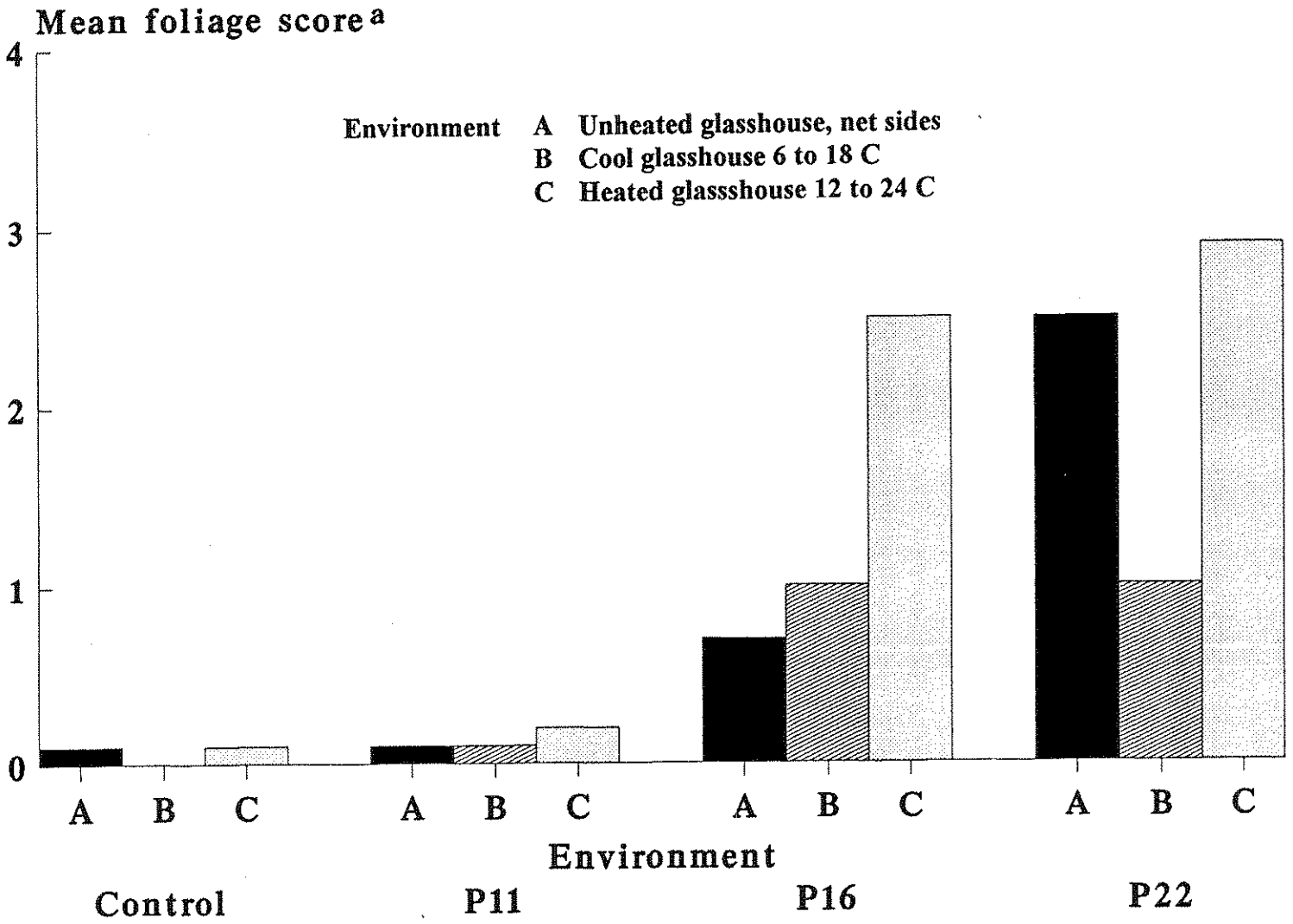

Fig 3. The effect of environment on the foliage condition[a] of heather cuttings (mean scores taken from three cultivars) potted into compost containing *P. sydowiana* isolates assessed, 8 weeks after potting. (Experiment 3)

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

Discussion

See discussion for Experiment 4

EXPERIMENT 4. The effect of environment on heather cuttings grown in compost containing Cylindrocarpon and Cylindrocladium.

Aim: To determine the effect of isolates of Cylindrocarpon and Cylindrocladium on three cultivars of rooted heather cuttings grown in three different environments.

Treatments

Environment A. Unheated tunnel, net sides
Environment B. Cool glasshouse 6 to 18oC
Environment C. Heated glasshouse 12 to 24oC

1. Uninoculated control - Environment A
2. Uninoculated control - Environment B
3. Uninoculated control - Environment C
4. Cm26 - Environment A
5. Cm26 - Environment B
6. Cm26 - Environment C
7. Cm28 - Environment A
8. Cm28 - Environment B
9. Cm28 - Environment C
10. C20 - Environment A
11. C20 - Environment B
12. C20 - Environment C
13. C36a - Environment A
14. C36a - Environment B
15. C36a - Environment C

Methods

Forty five plastic seed trays (23 x 17.5 x 5.5 cm deep) were filled with standard potting compost. The compost in each tray was mixed with 20 inoculated wheat seeds (one isolate or control per tray). Four rooted cuttings of each of *C. vulgaris* 'Silver Queen', *E. carnea* 'Ruby Glow' and *E. cinerea* 'Violetta' were potted into each tray. The trays

were placed in different environments as shown above. All trays were covered in polythene and were watered as required. Foliage of cuttings was assessed after 8 weeks using the foliage scale. Pieces of stem base were taken from one cutting of each species removed at random from each tray. These were surface sterilised, placed on potato dextrose agar and incubated at 24°C for 7 days to check for the presence of disease on the roots.

Results

The level of foliar browning caused by the two Cylindrocladium isolates was higher than that caused by the two Cylindrocarpon isolates (Table 1). Foliar browning recorded on cuttings was greatest in environment C (heated glasshouse, mean score on cuttings was 2.1). Browning was least in environment B (cool glasshouse, mean score on cuttings was 1.6).

The *E. cinerea* cultivar 'Violetta' was least affected by disease (mean foliage score of 0.9. *C. vulgaris* 'Silver Queen' cuttings had a mean score of 2.4 and *E. carnea* 'Ruby Glow' cuttings had a mean score of 2.3. The inoculated pathogen was re-isolated from *E. carnea* and *C. vulgaris* cuttings in all treatments. Pathogens were re-isolated only from *E. cinerea* cuttings infected with Cylindrocladium isolates grown in environments A and C, and Cylindrocarpon isolate 36a in Environment C

Discussion

Results obtained in the first 2 years work on this project showed that levels of disease and damage caused by Cylindrocarpon and Fusarium isolates differed depending on environmental conditions (Litterick & Holmes, 1991 and 1992). Results frequently also differed between experiments. Disease levels were generally higher where conditions for cutting development were unsuitable, for example, where cuttings were kept outside in autumn/winter, or where they were over or under-watered. Experiments 3 and 4 were set up to further investigate the effect of environmental/cultural conditions on disease development. It was found that diseases caused by *P. sydowiana,* Cylindrocladium and Cylindrocarpon were most severe in the heated house. In none of the three environments used in this experiment were conditions considered unsuitable for propagation of heathers. Conditions similar to all three environments are found on commercial nurseries. The fact that *P. sydowiana,* Cylindrocladium and Cylindrocarpon can all act as primary pathogens on healthy cuttings was further demonstrated.

Table 1 The effect of environment on the foliage condition[a] of heather cuttings (mean scores taken from three cultivars) potted into compost containing Cylindrocarpon or Cylindrocladium isolates, assessed 8 weeks after potting. (Experiment 4)

	Isolate					
Environment	Control	Cm26	Cm28	C20	C36a	Mean
A	0.0	3.2	3.1	1.5	1.8	1.9
B	0.0	2.8	2.6	1.0	1.6	1.6
C	0.1	3.6	3.4	1.4	1.9	2.1
Mean	0.0	3.2	3.0	1.3	1.8	

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

EXPERIMENT 5. The effect of fungicides on heather cuttings grown in compost containing Cylindrocarpon, Fusarium, *P. sydowiana* and Cylindrocladium,

Aim: To determine the effect of carbendazim (Bavistin, BASF) and prochloraz-manganese (Octave, Fisons) on the foliage and root development of three cultivars of rooted heather cuttings grown in compost containing *P. sydowiana,* Cylindrocladium, Cylindrocarpon and Fusarium.

Treatments

1. Uninoculated control, no fungicide
2. Uninoculated control, carbendazim
3. Uninoculated control, prochloraz-manganese
4. P16, no fungicide
5. P16, carbendazim
6. P16, prochloraz-manganese
7. P22, no fungicide
8. P22, carbendazim
9. P22, prochloraz-manganese
10. Cm26, no fungicide
11. Cm26, carbendazim
12. Cm26, prochloraz-manganese
13. Cm28, no fungicide
14. Cm28, carbendazim
15. Cm28, prochloraz-manganese
16. C20, no fungicide
17. C20, carbendazim
18. C20, prochloraz-manganese
19. C36a, no fungicide
20. C36a, carbendazim
21. C36a, prochloraz-manganese
16. F7, no fungicide
17. F7, carbendazim
18. F7, prochloraz-manganese
19. F10a, no fungicide
20. F10a, carbendazim
21. F10a, prochloraz-manganese

Methods

Sixty three plastic seed trays (23 x 17.5 x 5.5 cm deep) were filled with standard potting compost. The compost in each tray was mixed with 20 inoculated wheat seeds (one isolate or control per tray). Four rooted cuttings of each of *C. vulgaris* 'Silver Queen', *E. carnea* 'Ruby Glow' and *E. cinerea* 'Violetta' were potted into each tray. Both fungicides were applied as drenches (1 g product in 1 l water drenched to run-off) before the cuttings were covered in polythene. All cuttings were watered as required. Foliage of cuttings was assessed after 8 weeks using the foliage scale. Pieces of stem base were taken from one cutting of each species removed at random from each tray. These were surface sterilised, placed on potato dextrose agar and incubated at 24°C for 7 days to check for the presence of disease on the roots.

Results

Foliar browning was recorded on all treatments inoculated with *P. sydowiana,* Cylindrocladium, Cylindrocarpon or Fusarium isolates which were not treated with fungicide (Table 2 and Figs. 4 and 5). Foliar browning was reduced or in some cases eliminated when either carbendazim or prochloraz manganese was used on inoculated treatments. For example a mean foliage score of 3.0 was recorded on cuttings grown in compost containing Cylindrocladium isolate Cm26 which were not treated with fungicide. Cuttings grown in compost containing the same isolate and treated with carbendazim or prochloraz-manganese had scores of 0.0 and 1.1 respectively.

The *E. cinerea* cultivar 'Violetta' was least affected by disease (mean foliage score of 0.1). *C. vulgaris* 'Silver Queen' cuttings had a mean score of 1.0 and *E. carnea* 'Ruby Glow' cuttings had a mean score of 0.8.

The inoculated pathogen was re-isolated from cuttings in all trays which were untreated with fungicide (Table 3). The inoculated pathogens was isolated from few trays which had been treated with fungicide. No pathogens were isolated from uninoculated controls.

Discussion

Results of work carried out in the first and second years of this project showed that fungicides containing the active ingredients prochloraz-manganese and carbendazim inhibited the growth of isolates of Fusarium and Cylindrocarpon *in vitro.* (HN/17c Report Nos. 1 and 2). It has been shown that the development of foliar diseases caused by fungi closely related to Pestalotiopsis can be controlled through the application of prochloraz-manganese (Scott, 1983). Control of stem-girdling disease of eucalyptus

Table 2. The effect of fungicides on the foliage condition[a] of heather cuttings (mean scores taken from three cultivars) grown in fungicide-treated compost containing *P. sydowiana*, Fusarium, Cylindrocladium or Cylindrocarpon isolates assessed 8 weeks after potting. (Experiment 5)

	Isolate									
Fungicide	Control	P16	P22	Cm26	Cm28	C20	C36a	F7	F10a	Mean
None	0.1	1.7	0.9	3.0	3.4	1.8	1.4	0.8	0.3	1.5
Carbendazim	0.0	0.6	0.0	0.0	0.8	0.0	0.0	0.0	0.1	0.2
Prochloraz-manganese	0.2	0.0	0.0	1.1	0.4	0.0	0.0	0.0	0.2	0.2
Mean	0.1	0.8	0.3	1.4	1.5	0.6	0.5	0.3	0.2	

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

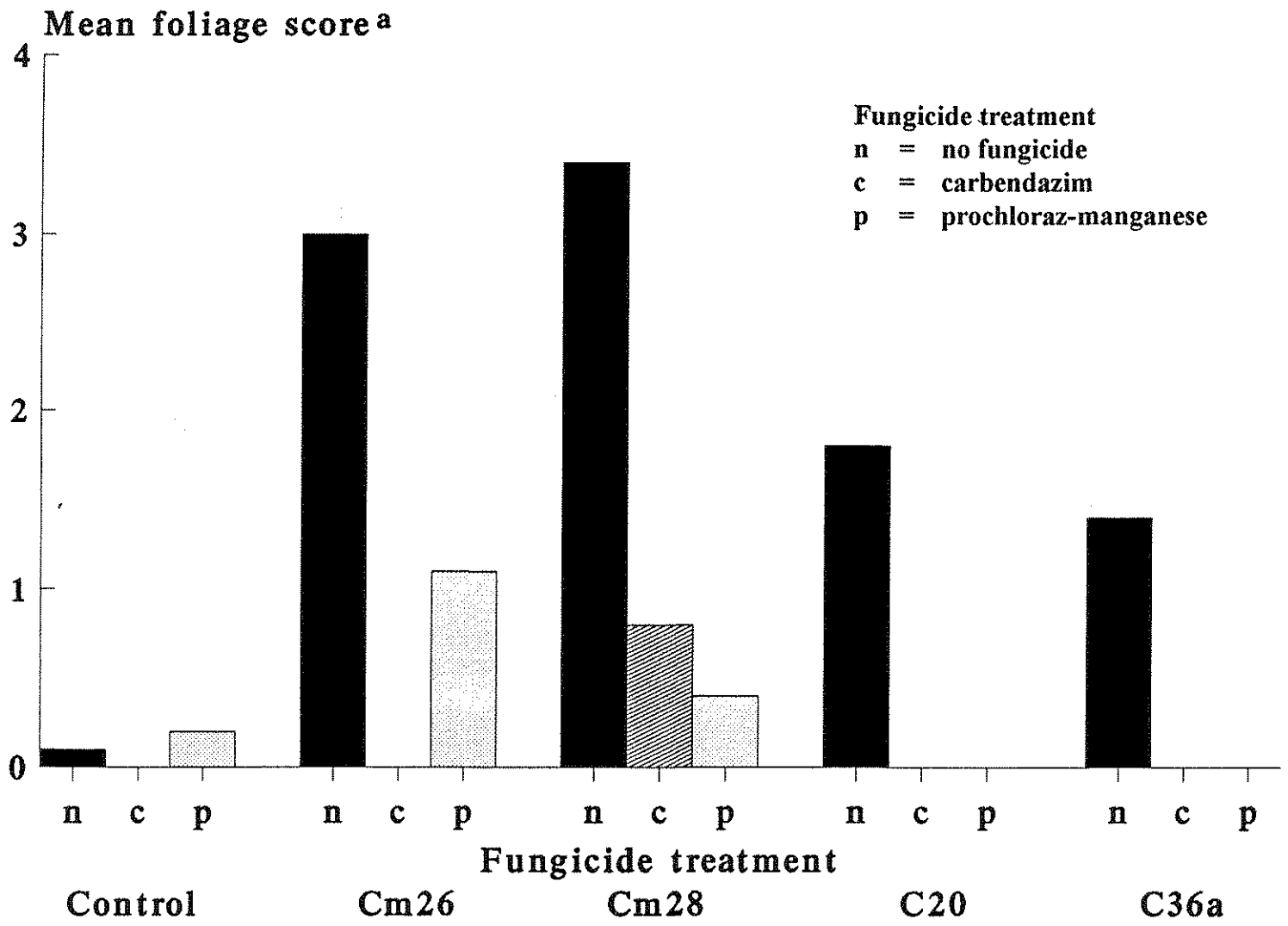

Fig 5. The effect of fungicides on the foliage condition[a] of hather cuttings (mean scores taken from three cultivars) grown in fungicide treated compost containing Cylindrocarpon or Cylindrocladium isolates assessed 8 weeks after potting. (Experiment 5)

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

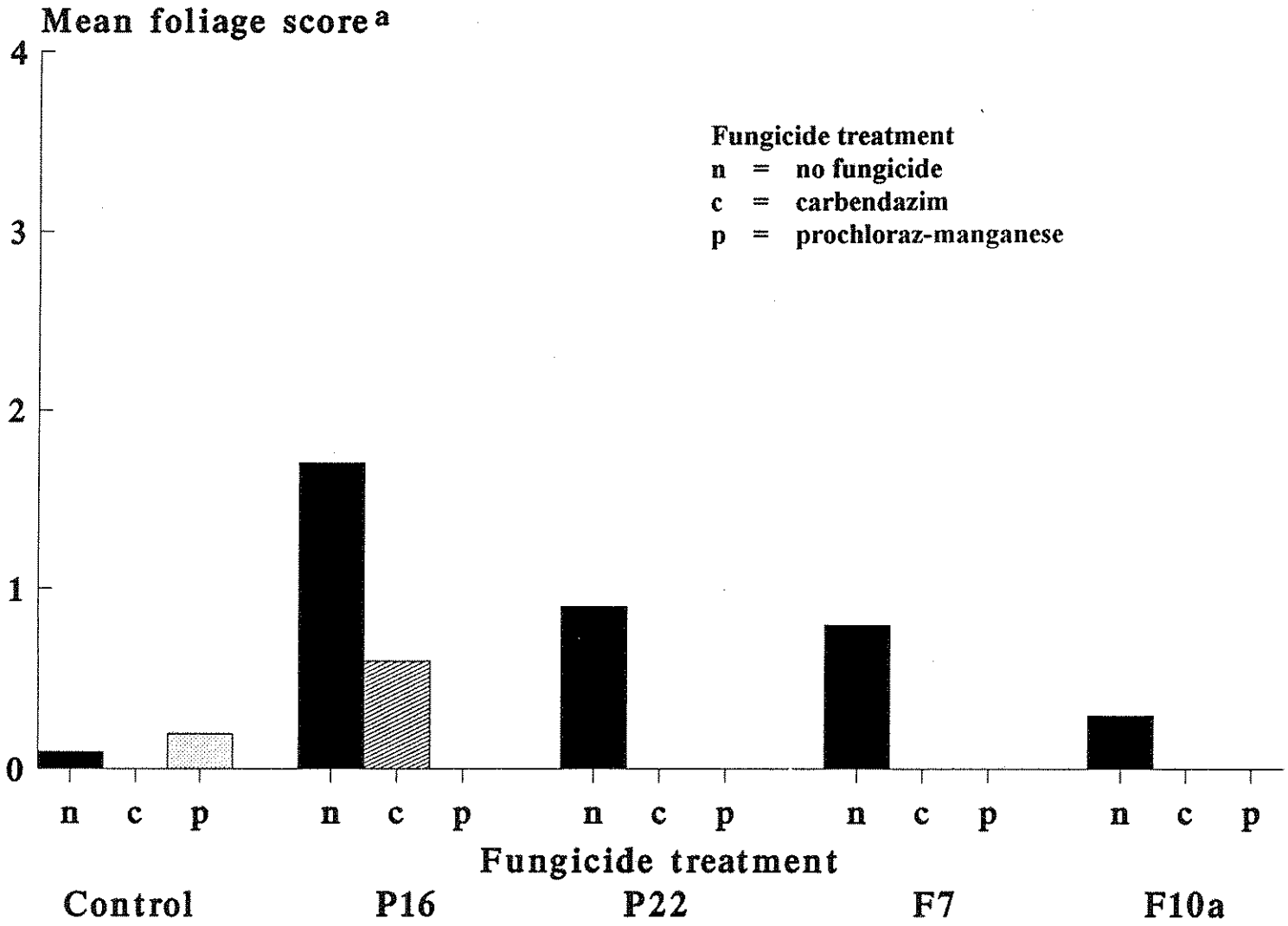

Fig 4. The effect of fungicides on the foliage condition[a] of heather cuttings (mean scores taken from three cultivars) grown in fungicide treated compost containing *P. sydowiana* or Fusarium isolates assessed 8 weeks after potting. (Experiment 5)

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

Table 3. The presence of root pathogens[a] on stem-bases of heather cuttings (two cuttings tested per box of twelve) grown in fungicide -treated compost containing *P. sydowiana*, Fusarium, Cylindrocladium or Cylindrocarpon isolates assessed 8 weeks after potting. (Experiment 5)

	Isolate								
Fungicide	Control	P16	P22	Cm26	Cm28	C20	C36a	F7	F10a
None	-	+	+	+	+	+	+	+	+
Carbendazim	-	+	-	-	+	-	-	-	-
Prochloraz-manganese	-	-	-	+	-	-	-	-	-

[a] + = inoculated pathogen re-isolated from cutting
- = inoculated pathogen no isolated from cutting

caused by *Cylindrocladium scoparium* was acheived through the use of benlate (an mbc fungicide which has the same mode of action as carbendazim).

The results obtained in Experiment 5 showed clearly that the development of disease caused by the isolates of *P sydowiana,* Cylindrocladium, Cylindrocarpon and Fusarium tested was restricted or controlled completely by the two fungicides prochloraz-manganese and carbendazim. The effect of these fungicides on a wider range of host/pathogen combinations should be examined before conclusions can be reached on their efficacy on the fungal genera as a whole.

OVERALL DISCUSSION AND CONCLUSIONS

Work carried out in The Crop Health Centre over the past seven years has shown that the main root pathogens of heaths and heathers are Phytophthora, Pythium, Rhizoctonia, Cylindrocarpon, Cylindrocladium, Fusarium and Pestalotiopsis. *Phytophthora* species and *Rhizoctonia* species are acknowledged as damaging and economically important diseases (Hoitink & Powell, 1990; Litterick & Holmes, 1990a & b). The ways in which these diseases spread and their control is now relatively well documented.

Prior to this investigation, very little work had been carried out on the so-called 'minor' root diseases of heaths and heathers, i.e. those caused by Cylindrocarpon, Pythium, Cylindrocladium, Fusarium and Pestalotiopsis. During the course of this project, 41 isolates of root pathogens have been taken from nursery stock (mainly heathers and other ericaceous species). These have been identified as *Fusarium sporotrichioides* Sherbak., *Fusarium tricinctum* (Corda) Sacc. *Fusarium avenaceum* Fr.) Sacc., *Cylindrocarpon destructans* (Zinssm.) Sholten., *Cylindrocladium ilicicola* (Hawley) Boed. & Reitsma., *Cylindrocladium scoparium* Morgan. and *Pestalotiopsis sydowiana* (Bresad.) B.Sutton. Due to the cost and time involved in identifying fungal isolates to species level, only 23 of the isolates used have been identified in this way.

The decision was made to omit Pythium from this investigation, since the methods used for carrying out experiments with Pythium differ greatly from those used with the other root pathogens. In addition, the biology and control of Pythium species is relatively well-documented.

Although Cylindrocarpon, Cylindrocladium, Fusarium and Pestalotiopsis are sometimes isolated singly from the roots and stem-base of dead and dying ericaceous plants, they are most often present in combination (i.e. together with another two, three or more fungal species). It is very important to determine which fungus or fungi are present in order to formulate effective control measures. The symptoms caused by these fungal

pathogens and Rhizoctonia and Phytophthora can be very similar and include rotten, brown or discoloured roots, stem-base and lower foliage, a lack of fine roots, and (at a more advanced stage of disease), pale, discoloured or brown foliage. It is not possible to distinguish between root-rots caused by different fungal pathogens simply by examining plants with the naked eye. Detailed lab diagnostic tests are necessary.

Diseases caused by Cylindrocarpon, Cylindrocladium, Fusarium and Pestalotiopsis are generally thought to be secondary (Hurford, 1979; Lambe & Wills, 1980). That is they only occur on plants which are suffering stress due to adverse environmental or cultural conditions or another disease. Results from work carried out in this study showed that some isolates of all four genera investigated could act as primary pathogens on healthy cuttings maintained under good growing conditions. In general, Cylindrocladium isolates caused severe foliar browning and frequent cutting death. Fusarium isolates caused low levels of foliar damage. There was a great deal of variation between damage caused by the isolates of Pestalotiopsis and Cylindrocarpon tested.

It was found that the level of damage and disease on heather cuttings varied depending on the environment in which cuttings were grown. In general disease levels were lower where cuttings were grown in 'good' conditions. For example, cuttings kept in a tunnel or cool glasshouse, in well-drained compost with adequate irrigation, were less susceptible to disease than cuttings in a glasshouse which was heated (temperatures up to 24^{o}C). Inadequate irrigation, cold temperatures or poorly drained compost increased the susceptibility of cuttings to disease.

In order to formulate control measures for root diseases caused by Cylindrocarpon, Cylindrocladium, Fusarium and Pestalotiopsis, it is necessary to understand how these fungi live naturally and spread. They are all capable of existing as saprophytes. That is, they can live on dead and decaying plant material in the absence of a living host. Unlike Rhizoctonia, (which spreads in the UK only as mycelium or by the dissemination of hard resting bodies known as sclerotia), all of the pathogens studied in this project produce spores which facilitate their spread. The fungi exist on diseased and dying plant material and in soil. There is no evidence to suggest that they are present in fresh, loamless composts, but this cannot be discounted. Standard nursery hygiene procedures will help reduce the incidence and spread of these diseases. New or sterilised nursery materials and equipment should be used and sand and gravel beds should be sterilised regularly. The health of stock plants is of great importance, since it is known that many fungal diseases can be passed from mother to daughter plants during propagation (Litterick & Holmes, 1990a & b; MacDonald, 1986).

Prochloraz-manganese (Octave) and carbendazim (Bavistin) gave good control of disease on heather cuttings grown in compost containing isolates of Cylindrocarpon, Cylindrocladium, *P. sydowiana* or Fusarium. Octave has full approval for use on heathers. Bavistin is approved for use on protected ornamentals and can be used on heathers at the growers' own risk. It is important to realise however that ericaceous species (heathers in particular) are very susceptible to damage from crop protection

chemicals (Litterick & Holmes, 1990a & b). Experience gained through several years of trials work has shown that strict nursery hygiene along with the use of a full fungicide programme to control all likely diseases (including Phytophthora, Pythium, Rhizoctonia, Cylindrocarpon, Cylindrocladium, Fusarium and Pestalotiopsis) on stock plants ensures that cutting material is relatively free from disease (unpublished data). Fungicides should not normally be necessary to treat root diseases other than Pythium during propagation.

Preventative fungicide use on cuttings or liners may be necessary where the risk of root disease is high. For example on a nursery with a history of root disease, or where stock plant health is in question, or where plants are bought in from an outside supplier.

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