Evaluation of Novel Fungicides and Irrigation Methods for Grey Mould Control on *Calluna vulgaris*©

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Grey mould, caused by *Botrytis cinerea*, is a common and damaging disease affecting many ornamental plants, including *Calluna vulgaris* (calluna). Trials were conducted to investigate the efficacy and crop safety of novel fungicides, and the effect of different irrigation regimes on disease development on calluna unrooted cuttings and potted plants. New anilinopyrimidine and strobilurin fungicides were compared with a grower-standard treatment of iprodione as two- and three-spray programmes. Protectant spray programmes of azoxystrobin, cyprodinil, and tolylfluanid were most effective, while iprodione gave no control. Calluna cuttings were sensitive to fungicide treatment. Although rooting of cuttings was unaffected, foliar sprays of azoxystrobin, pyrimethanil, and tebuconazole reduced the size of some cultivars. Watering cuttings during propagation by sub-irrigation (sandbed) significantly reduced disease compared with overhead hand watering. On potted plants, grey mould was significantly reduced when plants were watered by sub-irrigation compared with overhead or drip line irrigation. The importance of these findings for the integrated control of grey mould on calluna is discussed.

INTRODUCTION

Grey mould, caused by *Botrytis cinerea*, is a common and damaging disease affecting many U.K. greenhouse crops of ornamentals. During the past decade, damaging infections on *Calluna vulgaris* (calluna) have increased on growers' holdings, with serious damage on cuttings, potted-on plants, and stock plants (McQuilken, 1999). The disease develops on leaf tips, within the crown and around the stem base causing necrosis, death of the foliage and extensive sporulation of the pathogen on affected plant parts. Fungicides currently available to growers provide incomplete control, especially when the disease is at its worst during the winter (O'Neill, 1999; O'Neill and McQuilken, 2000). The number of fungicide treatments applied against grey mould can exceed eight in long-season crops of calluna, with the inherent risk of selecting fungicide-resistant strains.

Sirjusingh and Sutton (1996) have shown that prolonged high humidity and/or leaf wetness favours infection by *B. cinerea*. Such observations imply that irrigation methods, which result in different crop wetness characteristics, could affect disease development. Crops grown with reduced leaf wetness are likely to be less at risk to infection. As part of a project to develop integrated chemical and cultural control of grey mould, a series of trials were conducted on calluna to investigate the efficacy and crop safety of novel fungicides, and to determine the effect of overhead, drip line, and sub-irrigation on calluna crops grown under commercial conditions.

MATERIALS AND METHODS

Crop Production. Trials were conducted on calluna cuttings and mature potted plants at The Scottish Agricultural College (SAC), Auchincruive and at Highland Heathers Ltd., Lochgilphead, Argyll. Cuttings were grown in module trays (140 cells each of 5 cm^3) of propagation compost (fine peat and superfine perlite (80 : 20, v/v) on capillary sandbeds, under low polythene tunnels within a glasshouse. Rooted plants were grown in 1-litre pots containing medium sphagnum peat amended with dolomitic limestone (1.8 kg m^{-3}) and Osmocote Plus 8-9 month (3 kg m^{-3}) in an unheated, net-sided polythene tunnel.

Fungicide and Crop Safety Trials. The following formulated fungicides were tested against grey mould (rates of product per litre of water): azoxystrobin (as Amistar; 25% a.i. s.c.; Syngenta) at 4 ml on cuttings and 1 ml on potted plants; cyprodinil (as Unix; 75% a.i. w.g.; Syngenta) at 2.7 g on cuttings and 0.67 g on potted plants; iprodione (as Rovral WP; 50% a.i. w.p.; Rhone Poulenc) at 4 g on cuttings and 1 g on potted plants; mepanipyrim (as experimental; Hortichem) at 3.2 g on cuttings and 0.8 g on potted plants; pyrimethanil (as Scala; 40% a.i. s.c.; Aventis) at 8 ml on cuttings and 2 ml on potted plants; tebuconazole (as Folicur; 25% a.i. e.w.; Bayer) at 0.8 ml on cuttings and 0.2 ml on potted plants; tolylfluanid (as experimental; Bayer) at 6.8 g on cuttings and 1.7 g on potted plants; CGA 245704 (as experimental plant resistance elicitor; Syngenta) at 0.24 g on cuttings and 0.06 g on potted plants.

A two-spray programme of each fungicide was applied (250 litres ha^{-1}) to cuttings 'Arran Gold' at striking (16 Oct.) and 14 days later (Trial 1). A three-spray programme of each fungicide was applied to potted plants 'Orange Queen' at potting (17 July), and at 14-day intervals to the point of run-off (approximately 1000 litres ha^{-1}) (Trial 2). Fungicides were also assessed for crop safety in separate trials on six commonly grown cultivars. In all trials, sprays were applied using an Azo Precision sprayer at 3 bar pressure. A medium flat fan nozzle and single cone nozzle were used for cuttings and potted plants, respectively. Plants were watered by overhead irrigation as required.

Irrigation Trials. Irrigation treatments on cuttings 'Sunrise' (Trial 3) were hand-watering from overhead, or sub-irrigation using capillary sandbeds. Irrigation was applied when required for 12 weeks (February to May). Irrigation treatments on potted plants of 'Flamingo' (Trial 4) were: (1) overhead watering by sprinkler at 1.6 litres per pot (100 ml per plant); (2) sub-irrigation using capillary sandbeds; (3) drip line irrigation at 100 ml per plant (low rate); (4) drip line irrigation at 200 ml per plant (high rate). Plants were watered approximately every 3 days from late April to early November. No fungicides were applied against grey mould in any of the crops.

Trial Design, Disease Assessments, and Statistical Analyses. All trials were randomised block designs with four replicates per treatment. Plot size was 40 × 25 cm (140 cuttings) for cuttings and 1 m^2 (16 plants) for potted plants. Potted plants severely affected by grey mould were placed evenly between plots at establishment of trials. Plants were examined at regular intervals to determine the incidence and severity of grey mould. Foliar browning and degree of sporulating grey mould (Trial 4 only) were recorded by estimating the proportion of each plant affected.

An analysis of variance (ANOVA) was performed on non-transformed or on angularly transformed data when required. Treatment means were compared with the least significant difference (LSD) at a probability of 5% (P = 0.05).

RESULTS

Fungicide and Crop Safety Trials. On cuttings (Trial 1), grey mould was first confirmed 2 weeks after the start of the trial and, after 8 weeks, the disease had progressed to affect most treatments. All fungicide treatments except iprodione significantly reduced the degree of foliar browning, compared with the untreated control (Table 1). However, tolylfluanid was the most effective and completely prevented foliar browning. Azoxystrobin, cyprodinil, mepanipyrim, tebuconazole, and the elicitor were equally effective in reducing foliar browning and generally better than pyrimethanil.

On potted plants (Trial 2), grey mould occurred 1 week after the start of the trial and, after 8 weeks, the disease had progressed to cause browning on approximately 52% of the foliage on untreated plants. All fungicide treatments except iprodione and pyrimethanil significantly reduced foliar browning, compared with the untreated control (Table 1). Azoxystrobin was the most effective, with browning affecting less than 5% of the foliage. Cyprodinil was slightly more effective than mepanipyrim, which was equivalent to tebuconazole, tolylfluanid, and the elicitor.

In crop safety trials, most fungicides had no detrimental effect on the growth of rooted plants, except for azoxystrobin and cyprodinil, which slightly reduced shoot growth of 'Dark Beauty' and 'Bognie', respectively (data not shown). None of the fungicides affected rooting of cuttings, but the size was affected slightly on some of the more sensitive cultivars. For example, applications of azoxystrobin and

Table 1. Trials 1 and 2: Effect of fungicide sprays on grey mould (foliar browning %) on calluna cuttings and potted plants 8 weeks after applying the first spray.

Treatment	Cuttings (Trial 1)[a]	Potted plants (Trial 2)[b]
Control (nil)	71.7[c]	52.2
Iprodion	65.0	45.2
Azoxystrobin	5.0	4.6
Cyprodinil	11.7	17.2
Elicitor	25.0	38.2
Mepanipyrim	20.5	27.8
Pyrimethanil	45.3	51.2
Tebuconazole	25.0	31.6
Tolyfluanid	0.0	32.6
LSD (P=0.05)[d]	20.1	10.4

[a] A two–spray programme was applied to cuttings at striking (16 Oct.) and 14 days later.
[b] A three-spray programme was applied to potted plants at potting (17 July), and at 14-day intervals.
[c] Values are means of four replicate plots.
[d] LSD is the least significant difference at a probability of 5%.

Table 2. Trial 3: Effect of irrigation methods on grey mould on calluna cuttings.

	Cuttings affected (%)		Foliar browning (%)	
Irrigation	8 weeks	12 weeks	8 weeks	12 weeks
Overhead	18.0 (24.9)[a]	49.9 (45.5)	21.8 (27.9)	36.4 (37.2)
Sand bed	7.8 (16.0)	23.7 (29.6)	11.9 (20.2)	26.3 (30.9)
LSD (P=0.05)[b]	(3.85)	(5.68)	(4.05)	(4.66)

[a] Values are means of four replicate plots. Figures in parenthesis are angular transformed values.
[b] LSD is the least significant difference at a probability of 5%.

Table 3. Trial 4: Effect of irrigation methods on grey mould on potted calluna plants.

	Sporulating botrytis (%)		Foliar browning (%)	
Irrigation	13 weeks	26 weeks	13 weeks	26 weeks
Overhead	21.2 (26.7)[a]	13.6 (16.2)	37.6 (37.6)	76.4 (61.7)
Sandbed	15.4 (21.4)	4.4 (5.9)	32.6 (34.6)	68.0 (55.8)
Drip line				
(low rate)	28.2 (27.9)	18.4 (22.1)	48.2 (43.8)	78.0 (62.4)
(high rate)	24.4 (27.9)	15.0 (20.0)	43.0 (40.7)	80.4 (64.2)
LSD (P=0.05)[b]	(3.98)	(5.62)	(3.08)	(2.72)

[a] Values are means of four replicate plots. Figures in parenthesis are angular transformed values.
[b] LSD is the least significant difference at a probability of 5%.

tebuconazole reduced the size of rooted cuttings of 'Roland Haagen', and mepanipyrim and pyrimethanil reduced the size of 'Silver Queen'.

Irrigation Trials. On cuttings (trial 3), grey mould was first confirmed 2 weeks after the trial was established and, after 12 weeks, when cuttings were removed in preparation for potting, the disease had progressed to affect approximately 50% of overhead-watered cuttings (Table 2). The disease usually occurred on the tips of cuttings. Eight and 12 weeks after the start of the trial, sub-irrigation significantly reduced both incidence of cuttings affected and the degree of foliar browning, compared with overhead irrigation.

On potted plants (Trial 4), grey mould occurred in mid-May, 6 weeks after the start of the trial and affected most plants by September. Foliar browning and sporulating grey mould generally occurred within the crown and on foliage around the stem base. The disease was consistently less on plants grown by sub-irrigation compared with those watered by drip line or from overhead (Table 3). There was no significant difference between the low and high regimes of drip line irrigation.

DISCUSSION

The fungicide trials clearly demonstrated that azoxystrobin, cyprodinil, mepanipyrim, and tolylfluanid were highly effective against grey mould on calluna, and performed significantly better than the standard fungicide iprodione. Consequently, different programmes and timings of these leading fungicides can be recommended for further evaluation, based on their good performance in these preliminary trials.

Cuttings were more sensitive than were rooted plants to foliar sprays of fungicides. None of the fungicides caused visual phytotoxicity or affected rooting, but size of sensitive cultivars, such as 'Roland Haagen' and 'Silver Queen', was reduced. These results corroborate the importance of test treating sensitive cultivars of cuttings before large-scale foliar applications of fungicides are made for disease control during propagation.

Irrigation was shown to affect the development of grey mould on cuttings and rooted potted plants. Disease incidence was less on plants watered by sub-irrigation compared with watering from overhead. Assuming the greater disease severity was associated with increased leaf wetness, and the reduced disease on sub-irrigated plants with reduced leaf wetness, it was most surprising that drip line irrigation did not reduce grey mould. It is possible that drip irrigation may have created a more humid microclimate within the plant canopy, especially at the plant base, sufficient to encourage infection by *B. cinerea*. Testing of within crop humidity confirmed higher humidity with drip line than sub-irrigation. Previous trials have also revealed that other foliar diseases of calluna, including *Pestalotiopsis* and *Cylindrocarpon*, are encouraged by overhead irrigation.

Adoption of sub-irrigation rather than overhead watering would appear to be a useful component for integrated control of grey mould on calluna. However, sub-irrigation alone is unlikely to provide commercially acceptable disease control. Future trials are planned to investigate the integration of the best fungicides with irrigation method.

Acknowledgements. I thank Jim Thomson (SAC) for technical assistance, Nigel Willis (Highland Heathers Ltd., Argyll, Scotland) for providing healthy cuttings and potted plants, and the agrochemical companies who supplied the fungicides. The work formed part of a Horticulture LINK project (HortLINK 25), undertaken in collaboration with ADAS (Dr. T. M. O'Neill), HRI (Dr. T. R. Pettitt), Silsoe Research Institute (Dr. B. J. Bailey), the University of Reading, the Horticultural Development Council, Campbell Scientific Ltd. and Stuart Coutts. The Government Sponsor was the Ministry of Agriculture, Fisheries and Food (MAFF).

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