Project title:	Outdoor lettuce – evaluation of new fungicides for ringspot control
Project number:	FV 289
Project leader:	Dr Peter Gladders, ADAS UK Ltd
Report:	Final report, January 2008
Previous reports	Annual report, June 2007
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Date project commenced:	1 July 2006
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Key words:	Lettuce ringspot, *Microdochium panattonianum*, fungicide, dose, efficacy

The results and conclusions in this report are based on a series of experiments conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.

AUTHENTICATION

I declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

Dr P Gladders
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Dr W E Parker
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GROWER SUMMARY

Headline

An experimental fungicide (UK379a) and Switch were consistently the most effective treatments for control of lettuce ringspot. Control of ringspot was also demonstrated with Signum, Octave and Amistar. Treatments were most effective when applied two days before, or just prior to an infection event, and when fungicides were used at full rather than half rates.

Background and expected deliverables

Ringspot (also known as anthracnose), caused by the fungus *Microdochium panattonianum,* is a significant problem in some crops of field grown lettuce , rather less so in recent years in protected lettuce. Endive and chicory may also be affected. Epidemiological and disease control studies on ringspot were undertaken in the 1980s and 1990s. This work is now out of date with regard to fungicides. Recent work involving lettuce ringspot has been limited, though azoxystrobin (as Abound Flowable fungicide, Amistar or Quadris) now has a recommendation for lettuce ringspot control in the USA.

Typical symptoms are brown leaf spots that lose their centre and become “shot-holes” and sunken lesions on mid-ribs. Severely affected plants are stunted. Most affected plants are unmarketable. Losses are variable from crop to crop, and are higher after prolonged wet periods. Problems continue in intensive lettuce producing areas particularly in southern England and in Scotland. A national loss in production of 1% is worth £0.4 million.

The fungus survives on crop residues and produces micro-sclerotia that are capable of survival in soil for several months. Seed-borne transmission has proved difficult to verify. After initial infection from soil, ringspot can develop rapidly through splash dispersal. Free moisture from rain, dew or irrigation is required for spore production, germination and infection. Germination occurs over a wide range of temperatures within 24 hours and symptoms can appear in as little as three days.

Control of ringspot relies on crop rotation of lettuce with other crops and use of fungicides. There are some differences in cultivar susceptibility, but this has only been exploited to a limited extent in the UK. Soil sterilisation may provide control of soil-borne inoculum, but its cost is usually prohibitive.

Fungicides offer the opportunity to control the disease within selected crops as required. Previous work in the UK identified activity in Octave and thiram; prochloraz, propiconazole and chlorothalonil showed activity in Australian screening studies. More recently activity has been shown for Amistar in the USA. Information is not available for many currently used or new products. The activity of new fungicides has been investigated in cereals and various other arable crops, particularly in HGCA-funded projects. These enable potential new products for vegetables to be identified at an early stage.

The activity against ringspot of fungicides recommended for other diseases on lettuce is not known e.g. Rovral Flo (iprodione) and Amistar are currently used for control of Sclerotinia on lettuce (SOLA nos. 2004/0513 and 2001/1465 respectively) and Signum has full label approval for Sclerotinia control on outdoor lettuce. Switch is now available as a SOLA (2007/2079) for Botrytis control in lettuce. In additional other new products have been introduced on arable crops which have potential for use on vegetables (e.g. azole products).

Testing and ranking of fungicides will enable growers to select the best products for the range of diseases they encounter. The current choice of fungicides is limited and growers will require a selection of products to minimise risks of selecting fungicide resistant strains.

The project will complement work on other lettuce diseases being considered by HDC so growers have up-to-date information for the control of the major lettuce pathogens.

Overall aim of the project is:

To evaluate the efficacy of current and novel fungicides for ring spot control.

Specific objectives:

1. To define the curative and protectant properties of fungicides.
2. To define the dose response activity in relation to timing of the most promising products.
3. To quantify the persistence of products to guide timing of treatments.

The industry will benefit through reduced losses due to lettuce ringspot, achieved through:

- Increased knowledge of fungicides with activity against ringspot
- Information on fungicide efficacy in relation to dose and timing against ringspot
- Improved understanding of ringspot disease.

Project results will be of relevance to both home and overseas production. When linked to fungicide activity against other diseases (e.g. Sclerotinia), more general disease control benefits may be produced when product choice is optimised.

Summary of the project and main conclusions

The project tested new and existing fungicides for disease control activity against ringspot on outdoor lettuce. Tests were done under controlled conditions on lettuce plants grown in pots under glasshouse conditions and artificially inoculated with ringspot spores.

Experiment 1

Fungicides were tested at full commercial rates and applied at four timings relative to inoculation (5 days before, 2 days before and just prior to inoculation and 2 days after inoculation). Disease assessments were done at weekly intervals for four weeks after inoculation. The percentage plants with ringspot and the percentage leaf area affected were recorded at each assessment. The data for the incidence of ringspot gave better separation of treatments than disease severity; the data for disease incidence are shown in Figure 1 and Figure 2.

All the fungicides gave a significant decrease in ringspot incidence compared with the untreated control (Fig. 1). There were some significant differences between products, with an experimental fungicide showing the lowest incidence overall and showing better control than all the products apart from Unicrop Thianosan DG (thiram).

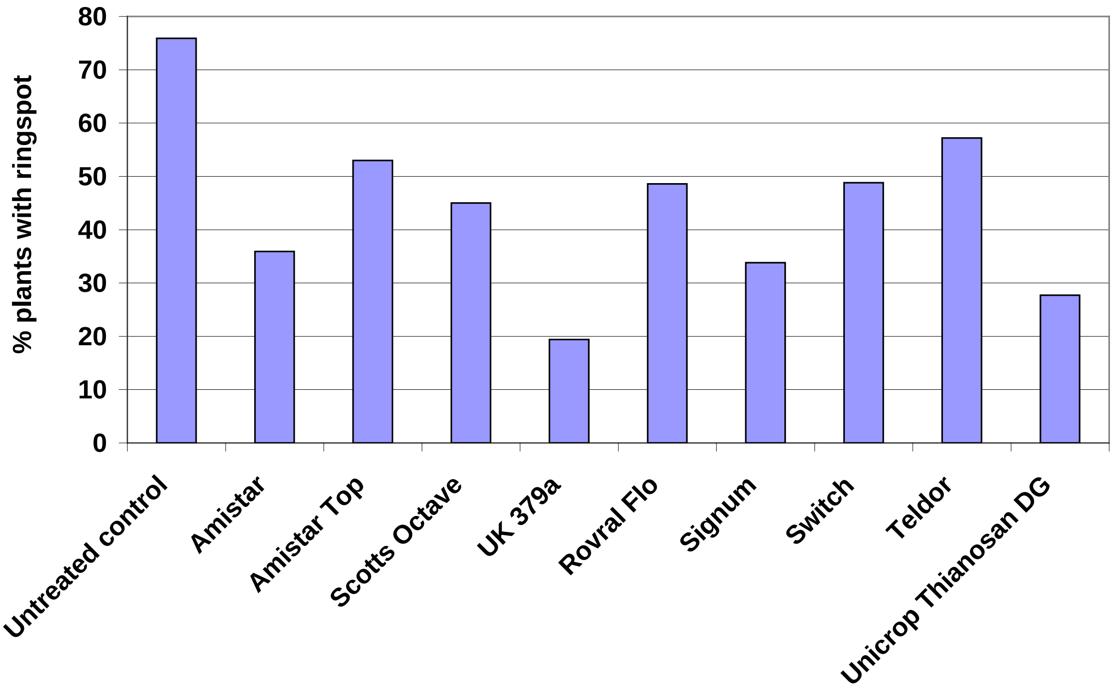

Figure 1. Comparison of fungicides for control of ringspot, 28 days after inoculation.

There was a significant effect of spray timing averaged over all products (Fig. 2). Applications made 5 days before inoculation or 2 days after inoculation were significantly less effective (*P*<0.01) than application just prior to inoculation. Treatment applications 2 days before inoculation gave similar results to those just prior to inoculation.

Treatments generally gave poor control when applied two days after inoculation and this suggests that there is likely to be limited curative ("kick-back") activity against ringspot. This is not surprising given that symptoms can appear in 4 days under optimum conditions.

Interactions between fungicide product and spray timing were also significant. This suggests some differences in the mode of action of fungicides. For example, the experimental fungicide was very effective when applied 5 days before inoculation and Switch was more effective when used 2 or 5 days before inoculation than on the same day as inoculation.

From this first experiment four products were selected for further testing along with Scotts Octave as the standard. These were Amistar, Signum, Switch and an experimental fungicide. Some phytotoxicity was noted with Switch treatments and appears to relate to the test conditions used. Unicrop Thianosan DG was not taken forward for further testing because of the priority to find alternatives to dithiocarbamate products.

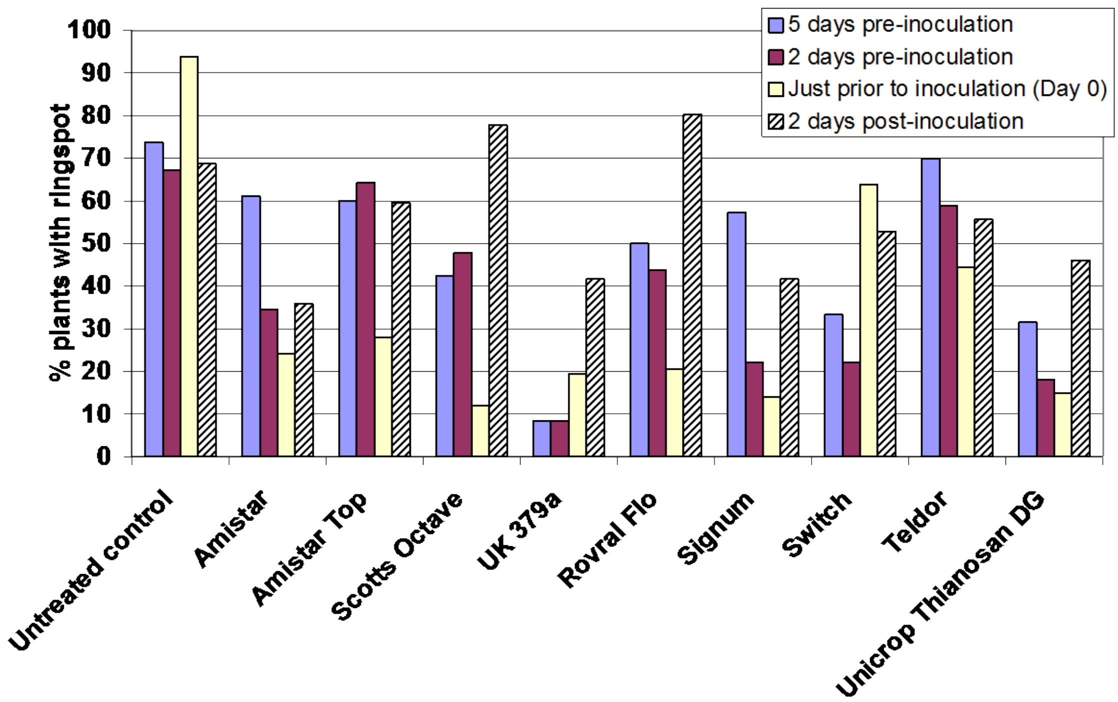

Figure 2. Effect of fungicide timing on ringspot control, 28 days after inoculation (Experiment 1).

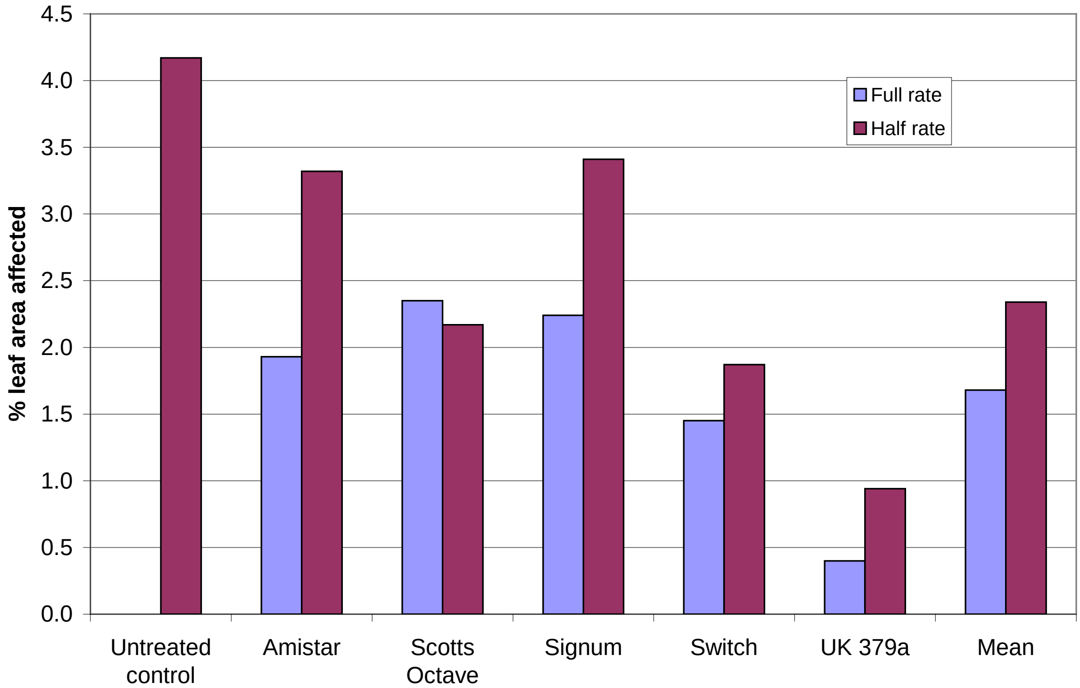

Figure 3 Comparison of fungicides at full and half dose (Experiment 2)

Experiment 2

After the first experiment, fungicides were examined at full and half dose at four dates of application relative to inoculation (Experiment 2). Switch and UK379a were identified as the most active products. Fungicide dose effects indicated significantly poorer control at half dose than at full dose when averaged across products for treatments applied 2 days before inoculation or just before inoculation (Fig. 3). There were indications that ringspot control with Octave and Switch was less sensitive to reductions in dose that the other fungicides.

Experiment 3

The third experiment evaluated the fungicides when a second treatment was applied either 7 or 14 days after the first inoculation. A second spore inoculation was also made 14 days after the first inoculation and plants were watered overhead to encourage further splash dispersal of spores. Disease severity was high in this experiment and the ranking of product activity was clearly demonstrated. UK379a was the most effective product followed by Switch and Signum (Fig. 4). Signum was more effective than Amistar, but not significantly better than Octave. Amistar and Signum also gave partial control of naturally occurring downy mildew in this experiment.

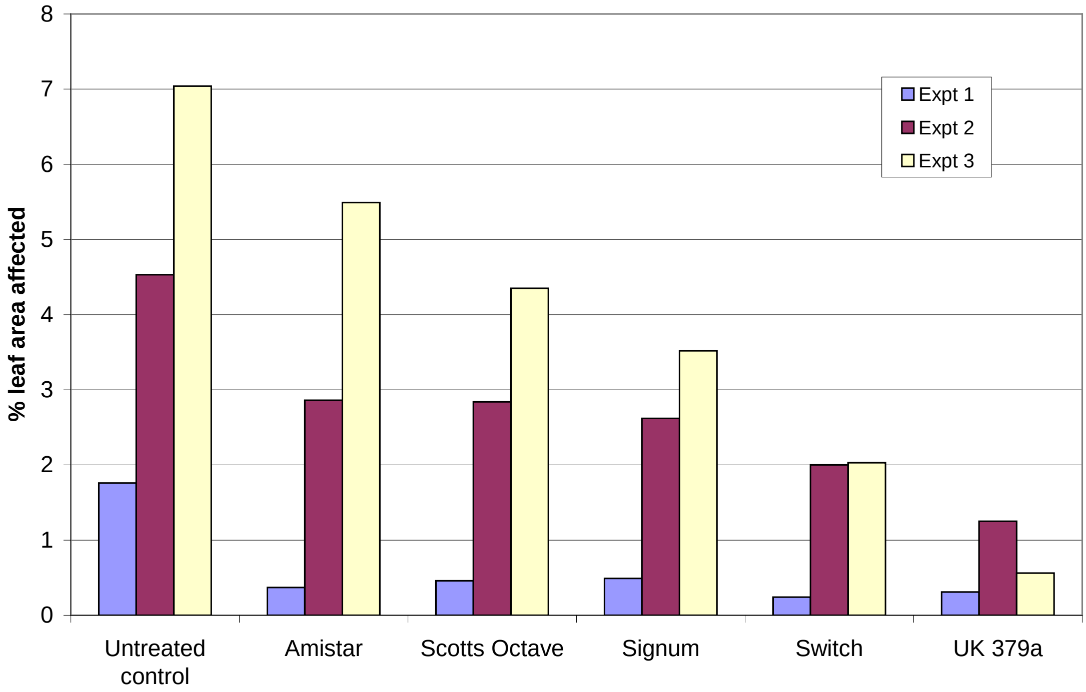

Figure 4 Fungicide performance at full dose in three experiments (x days after inoculation?) (data for Experiment 2 has been angular transformed). - thought it was expt 3 that was transformed?

Treatments applied after 14 days were more effective than those applied after 7 days. Need to explain the interpretation of this as you did in Science Section discussion. This suggests that the persistence of treatment activity is less than 14 days. Further work is required to test spray timing and spray programmes under field conditions.

Where ringspot was controlled some treatments improved crop vigour (e.g. Amistar and Octave). Vigour was slightly reduced early in the experiment where Switch was applied, due largely to test conditions.

Financial benefits

Lettuce growers in England and Scotland continue to suffer losses from ringspot, particularly in Romaine types. An estimated national loss in production of 1% is worth £0.4 million.

Growers can now select products for use against other diseases (e.g. Botrytis) with improved awareness of their ringspot activity. This may save additional or specific applications for ringspot control. Field performance has not been tested, but it appears that spray intervals should be less than 14 days. New recommendations for the experimental fungicide UK379a on lettuce would be beneficial. If losses can be reduced by 50%, benefits are estimated at £0.2 million per annum. The results should also be valuable for growers with protected lettuce

Action points for the industry

- Be aware of environmental conditions that favour ringspot development (prolonged wet weather) and that some lettuce types that are particularly prone to the disease (e.g. cos/romain types).
- Ringspot symptoms develop very rapidly and fungicides show limited curative ("kick-back") activity. Protectant programmes will be required to achieve good control of ringspot.
- A range of fungicides available for use on lettuce showed some activity against ringspot, but only prochloraz (as Scotts Octave (see SOLA 2001/ 06501 for outdoor lettuce) and Mirage 40 EC. (see SOLA 2003/2623 for outdoor lettuce)) carry recommendations for ringspot control.
- Switch and UK379a showed greater activity against ringspot than the existing standard Octave and are candidates for further development on lettuce. Signum and Amstar also have activity against ringspot and may provide broad-spectrum disease control when targeted against other pathogens.
- Further testing of candidate fungicides under field conditions is required within the project to substantiate these promising results under controlled conditions.

SCIENCE SECTION

Introduction

Ringspot (also known as anthracnose), caused by the fungus *Microdochium panattonianum*, is a significant problem in some crops of field grown lettuce, rather less so in recent years in protected lettuce. Endive and chicory may also be affected (Koike *et al.*, 2007). Epidemiological and disease control studies on ringspot were undertaken in the 1980s and 1990s (Galea *et al.*, 1986; Galea and Price, 1988a & b). This work is now out of date with regard to fungicides (Wickes *et al.*, 1994). Recent work involving lettuce ringspot has been limited, though azoxystrobin (as Abound Flowable fungicide and Quadris) now has a recommendation for lettuce ringspot control in the USA.

Typical symptoms are brown leaf spots that lose their centre and become "shot-holes" and sunken lesions on mid-ribs. Severely affected plants are stunted. Most affected plants are unmarketable. Losses are variable from crop to crop, and are higher after prolonged wet periods. Problems continue in intensive lettuce producing areas particularly in southern England and in Scotland. A national loss in production of 1% is worth £0.4 million.

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Control of ringspot relies on crop rotation of lettuce with other crops and use of fungicides. There are some differences in cultivar susceptibility, but this has only been exploited to a limited extent in the UK. Soil sterilisation may provide control of soil-borne inoculum, but its cost is usually prohibitive.

The activity of new fungicides has been investigated in cereals and various arable crops, particularly in HGCA-funded projects. These enable potential new products for vegetables to be identified at an early stage. Fungicides offer opportunity to control the disease within selected crops as required. Previous work in the UK identified activity in Octave and thiram; prochloraz, propiconazole and chlorothalonil showed activity in Australian screening studies. More recently activity has been shown for Amistar in the USA. Information is not available for many currently used or new products.

The activity against ringspot of fungicides recommended for other diseases on lettuce is not known e.g. Rovral Flo and Amistar are currently used for control of Sclerotinia on lettuce (SOLA numbers 2004/0513 and 2001/1465 respectively) and Signum has full label approval for Sclerotinia control on outdoor lettuce. In 2007, Switch (cyprodinil + fludioxonil) received a SOLA for use on outdoor lettuce (SOLA 2007/2079). In addition, other new products have been introduced on arable crops which have potential for use on vegetables (e.g. azole products).

Testing and ranking of fungicides will enable growers to select the best products for the range of diseases they encounter. The current choice of fungicides is limited and growers will require a selection of products to minimise risks of selecting fungicide resistant strains. The project will complement work on other lettuce diseases being considered by HDC so growers have up-to-date information for the control of the major lettuce pathogens.

Results from this project may also be useful for product selection on other horticultural crops affected by similar leaf spots (e.g. *Ramularia*, *Marssonina*).

Overall aim of the project

To evaluate the efficacy of current and novel fungicides for ring spot control.

Specific objectives

1. To define the curative and protectant properties of fungicides

2. To define the dose response activity in relation to timing of the most promising products

3. To quantify the persistence of products to guide timing of treatments

Materials and Methods

Experiment 1

The fungicide screening experiments were done on young lettuce plants grown in pots and artificially inoculated under glasshouse conditions. Lettuce seedlings (var. Frisco) were obtained from a commercial propagator (2-3 true leaf stage) and transplanted into F1 compost in 13 cm pots, four plants per pot. A total of 360 pots were used for the main experiment, with a further 9 pots used for the uninoculated control. A plot consisted of a group of three pots (each containing four plants) in a tray. Pots for the uninoculated control were placed 3-5 m away from the inoculated experiment in the same glasshouse. The plots were at least 0.5 m apart and arranged in a randomised complete block design on the glasshouse floor, with three replicate blocks. The plants were allowed to establish in the pots after transplanting for approximately 2 weeks and used in the experiment at the 3-4 true leaf stage. Watering was to the trays rather than overhead, to achieve moist but not waterlogged compost. The glasshouse temperature was set at a minimum of 10°C, with venting at 20°C. A data logger was set up to record air temperature and relative humidity for the duration of the trial.

Ringspot was obtained from a natural field outbreak of field lettuce in spring 2006. On the day of inoculation, a spore suspension of *M. panattonianum* was prepared from cultures on potato dextrose agar amended with streptomycin (PDA+S). Plates were flooded with sterile distilled water and a sterile scalpel or loop used to scrape the surface of 6-week old cultures of *M. panattonianum* to prepare a spore suspension. In addition, spores of *M.*

panattonianum were collected from lettuce leaves with typical spores of ringspot that had been incubated for 24 h at approximately 20°C in a plastic tray sealed in a polythene bag. The spore suspension was filtered through muslin and adjusted to a concentration of 1 x 10^5 spores/ml. A 2 L volume of the spore suspension was prepared and applied to the point of run-off to each of 360 pots using a hand-held mister. Immediately after spore inoculation, the trial area was covered with a 'tent' of polythene sheeting (avoiding contact with plants) that was kept over the trays for approximately 48 h (until the last spray) to prolong leaf wetness duration and produce high relative humidity. Uninoculated control plants sprayed with water only were covered with separate sheeting.

Fungicide treatments (Table 1) were applied either 5 days before, 2 days before, immediately prior to artificial inoculation (Day 0), or 2 days after inoculation. The fungicides were applied in 1000 L water/ha (100 ml/m^2) using an Oxford precision sprayer with single nozzle (plus guard to prevent spray drift) at 2 bar pressure. Product rates are shown in Table 1.

The plants were monitored for disease development daily from five days after inoculation. The number of plants with ringspot symptoms (out of 4) and the severity of symptoms (percentage leaf area affected) were recorded for each plant 7, 15, 22 and 28 days after inoculation. Plants were inoculated on 13 December 2006 and assessments were completed on 10 January 2007. Observations were made on phytotoxic symptoms or growth effects at each assessment.

Table 1. Fungicides used in the first fungicide evaluation (Experiment 1).

Product	Active ingredient	Product rate
Untreated control	-	-
Amistar*	Azoxystrobin	1 L/ha
Amistar Top	Azoxystrobin + difenoconazole	1 L/ha
Scotts Octave*	Prochloraz	0.2 kg/ha
UK 379a*	Not disclosed	1.44 kg/ha
Rovral Flo	Iprodione	2.3 L/ha
Signum*	Boscalid + pyraclostrobin	1.5 kg/ha

Switch*	Cyprodinil + fludioxonil	0.8 kg/ha
Teldor	Fenhexamid	1.5 kg/ha
Unicrop Thianosan DG	Thiram	4 kg in 1000 L water

*These fungicides were tested in Experiments 2 and 3

Notes:

Amistar	SOLA 1465/01 for outdoor lettuce
Amistar Top	Administrative Experimental Approval
Octave	SOLA 20032623 for outdoor lettuce; specifies ringspot
UK 379a	Administrative Experimental Approval
Rovral Flo	SOLA 0513/04 for outdoor lettuce
Signum	Outdoor lettuce on label
Switch	Administrative Experimental Approval (rate based on expected outdoor lettuce rate, B. Hall, Syngenta, pers. comm.). SOLA 20072079 in outdoor lettuce given in 2007 specifies for Botrytis ( ), maximum rate 0.8 kg/ha.
Teldor	SOLA 0026/05 for outdoor lettuce
Unicrop Thianosan DG	Outdoor lettuce on label

Experiment 2

Table 2. Fungicide treatments used at full and half rate (Experiment 2).

	Product	Rate of product
1	Water control	-
2	Amistar	1.00L/ha
3	Amistar	0.50 L/ha
4	Octave	0.20 kg/ha
5	Octave	0.10 kg/ha
6	Signum	1.50 kg/ha
7	Signum	0.75 kg/ha
8	Switch	0.80 kg/ha
9	Switch	0.40 kg/ha
10	UK379a	1.44 kg/ha
11	UK379a	0.72 kg/ha

The second of the fungicide screening experiments was done using the methods described for Experiment 1, using the five most promising fungicides at full and half rate with four application dates (-5, -2, 0 and +2 days relative to inoculation) in comparison with a water-sprayed control (Table 2). Three-fold replication was used. An experiment inoculated on 11 April 2007, failed to produce satisfactory ringspot infection and was therefore repeated when more inoculum had been produced. Plants were sprayed with the fungicide treatments on four dates during 10-17 August 2007 and inoculated with a ringspot spore suspension adjusted to a concentration of 6.8 x 10^4 spores/ml on 15 August 2007. Disease incidence and severity were recorded on 23 and 31 August 2007. Toppel was applied to control aphids and caterpillars on 14 August and Aphox for aphid control on 22 August 2007. A total of 414 pots were used for the main experiment, with a further 9 pots used for the uninoculated control. A plot consisted of a group of three pots (each containing four plants) in a tray. Pots for the uninoculated control were placed 3-5 m away from the inoculated experiment in the same glasshouse.

Experiment 3

The third fungicide screening experiment continued evaluation of the five most promising fungicides by using two spray programmes at full rate applied either 7 or 14 days apart with corresponding water-sprayed controls (Table 3). There was an additional inoculated control (treatment 13 in each block) that did not receive a water spray, but data have not been included in the factorial analyses. The methods were similar to those used in the first two experiments with more assessments to evaluate treatments after the second spray applications. A total of 260 pots were used for the main experiment, with a further 9 pots used for the uninoculated control. A plot consisted of a group of four pots (each containing three plants) in a tray. Pots for the uninoculated control were placed 3-5 m away from the inoculated experiment in the same glasshouse. The plots were at least 0.5 m apart and arranged in a 2-way factorial randomised block design on the glasshouse floor, with five replicate blocks.

Plants were sprayed with the fungicide treatments on 18 October 2007 (day 0) and again on 25 October (day 7) or 1 November (day 14) and assessed for diseases at weekly intervals up to 23 November 2007 (day 35). A ringspot spore suspension adjusted to a concentration of 4.0 x 10^5 spores/ml was applied after the first fungicide treatments had been applied and products had dried. Plants were kept covered with polythene sheeting for 48 h to provide good conditions for infection. Plants were watered overhead on day 7 to encourage splash dispersal of ringspot spores and kept covered for

36 h After the 14 day fungicide treatments had been applied and allowed to dry off, all plants were re-inoculated with a spore suspension (4.0 x 10^5 spores/ml) and then kept covered with polythene for 36 h.

When the polythene sheet was taken off approximately 48 hours after the first inoculation, plants had developed symptoms of downy mildew which was sporulating. It was decided to apply Aliette 80WG at weekly intervals for three consecutive weeks to limit further spread of downy mildew which might interfere with the development of ringspot. The downy mildew was assessed weekly along with ringspot.

Table 3. Fungicide treatments and timings (Experiment 3).

	Fungicide/product rate	Times of application with respect to 1st artificial inoculation (days)*
1	Water control	0 and 7 days
2	Water control	0 and 14 days
3	Amistar (1 L/ha)	0 and 7 days
4	Amistar (1 L/ha)	0 and 14 days
5	Octave (0.2 kg/ha)	0 and 7 days
6	Octave (0.2 kg/ha)	0 and 14 days
7	Signum (1.5 kg/ha)	0 and 7 days
8	Signum (1.5 kg/ha)	0 and 14 days
9	Switch (0.8 kg/ha)	0 and 7 days
10	Switch (0.8 kg/ha)	0 and 14 days
11	UK379A (1.44 kg/ha)	0 and 7 days
12	UK379A (1.44 kg/ha)	0 and 14 days
13	Untreated	-

*a 2nd artificial inoculation was applied on the day of application for treatments 2, 4, 6, 8, 10 & 12, and 7 days after application for treatments 1, 3, 5, 7, 9 and 11

Data for disease severity (% plant area affected by symptoms) and disease incidence (% plants affected) were analysed by analysis of variance (ANOVA) using Genstat. Where data showed a skewed distribution, angular transformed data were analysed and are presented in the results.

Results and Discussion

Experiment 1

When the polythene sheet was taken off approximately 48 hours after inoculation, plants that had developed symptoms of grey mould due to *Botrytis cinerea* were removed to prevent subsequent spread of the disease (1-2 plants from each of 13 plots). These were treated as missing values in statistical analyses.

All the fungicide products except Rovral Flo gave significant decreases in the percentage of plants which developed ringspot after inoculation (Table 4). The differences in ringspot incidence between Rovral Flo and other fungicides were significant for Scotts Octave, UK379a, Signum, Switch and Unicrop Thianosan DG. The application of fungicides 2 days after inoculation gave significantly poorer control than applications 0, 2 and 5 days before inoculation. There was no significant interaction between fungicide and timing. UK379a, Switch, Signum and Scotts Octave reduced disease incidence to less than 10% when applied 5 days before inoculation. These products generally gave low disease incidence when used at the pre-inoculation timings. Control with Amistar Top and Unicrop Thianosan DG showed encouraging trends with activity improving as spray timing was closer to inoculation. Amistar and Switch showed the lowest disease incidence at the 2 days post-inoculation timing.

Table 4. Incidence of ringspot in relation to fungicide product and timing in Experiment 1, 15 days after inoculation.

Product	Ringspot (% plants affected)				
	5 days pre-inoculation	2 days pre-inoculation	Just prior to inoculation	2 days post-inoculation	Mean
Untreated control	46.1	52.4	69.4	51.7	54.9
Amistar	33.3	3.0	21.0	11.1	17.1
Amistar Top	30.6	8.8	2.8	44.4	21.7
Scotts Octave	8.3	11.1	2.8	44.4	16.7
UK 379a	0.0	0.0	2.8	30.6	8.3
Rovral Flo	36.4	27.3	11.9	74.0	37.4
Signum	3.0	9.4	0.0	41.7	13.5
Switch	2.8	0.0	27.8	5.6	9.0

Teldor	23.3	30.6	27.8	22.2	26.0
Unicrop Thianosan DG	24.2	8.3	2.8	28.3	15.9
Mean	20.8	15.1	16.9	35.4	22.0
SED (78 df)	5.83 (timing); 18.45 (interaction)				9.22
P	0.003 (timing); NS (interaction)				<0.001

The severity of ringspot lesions was low at the first assessment and no significant treatment differences were identified (Table 5). Ringspot was particularly severe in the untreated control for day 0.

The overall mean incidence of ringspot increased from 22% of plants affected 15 days after inoculation to 44% plants affected 28 days after inoculation. Amistar, UK379a, Signum and Unicrop Thianosan DG gave significant decreases in ringspot compared with the untreated control. There were significant differences between individual fungicides (LSD = 16.23), with UK379a, Unicrop Thianosan DG, Signum and Amistar being more effective than Teldor and Amistar Top (Table 6). There was a significant effect of fungicide timing with the lowest incidence of disease resulting from fungicide application just prior to inoculation (day 0). This gave significantly better control than either 5 days pre-inoculation or 2 days post inoculation. There was a significant interaction between fungicide and timing (LSD = 32.45) indicating differences in fungicide activity. UK379a was very effective when applied 5 days before inoculation and up to day 0, whilst Switch was more effective when applied 2 and 5 days before inoculation than at day 0 or 2 days after inoculation. Signum was most effective when used 2 and 0 days before inoculation than at day 5 before inoculation; Amistar showed a similar trend.

Table 5. Severity of ringspot in relation to fungicide product and timing, in Experiment 1, 15 days after inoculation.

Product	Ringspot (% leaf area affected)				
	5 days pre-inoculation	2 days pre-inoculation	Just prior to inoculation	2 days post-inoculation	Mean
Untreated control	0.49	0.77	4.00	0.33	1.40
Amistar	0.27	0.01	0.11	0.04	0.11

Amistar Top	0.06	0.02	0.01	0.29	0.11
Scotts Octave	0.02	0.06	0.01	0.24	0.08
UK 379a	0.00*	0.00*	0.01	0.17	0.04
Rovral Flo	0.15	0.23	0.03	1.75	0.54
Signum	0.01	0.02	0.00*	0.58	0.15
Switch	0.01	0.00*	0.10	0.02	0.03
Teldor	1.57	0.16	0.23	0.07	0.51
Unicrop Thianosan DG	0.13	0.02	0.01	0.30	0.11
Mean	0.27	0.13	0.45	0.38	0.31
SED (78df)		0.292 (timing)	0.924 (interaction)		0.462
P		NS (timing)	NS (interaction)		NS

*trace only

The severity of ringspot increased from 0.3% leaf area affected to 0.4% between 15 and 28 days after inoculation. This represented a considerable increase in the number of lesions as the leaf area of the lettuce plants also increased as new leaves were produced. All fungicides significantly decreased ringspot severity compared with the untreated control. The largest treatment difference between Rovral Flo and Switch did not quite reach significance LSD = 0.78). There were no significant effects of fungicide timing or fungicide x timing interactions. There were a few leaves where the disease developed strongly and this has influenced severity data and treatment trends compared with ringspot incidence data. This was most apparent for UK379a applied 2 days before inoculation and Unicrop Thianosan DG applied on day 0 (Table 7).

There were some symptoms of phytotoxicity in the Switch treatments that resulted in cupping and reduced growth of the developing leaves. This is associated with the rate of product used in the experiment (the field lettuce rate is higher than the rate for protected crops) combined with the use of high humidity conditions at inoculation.

Table 6. Incidence of ringspot in relation to fungicide product and timing in Experiment 1, 28 days after inoculation.

Product	Ringspot (% plants affected)				
	5 days pre-inoculation	2 days pre-inoculation	Just prior to inoculation	2 days post-inoculation	Mean

	(Day 0)				
Untreated control	73.7	67.3	93.9	68.7	75.9
Amistar	61.1	34.6	24.2	35.9	35.9***
Amistar Top	60.1	64.3	28.0	59.6	53.0**
Scotts Octave	42.4	47.9	12.0	77.8	45.0***
UK 379a	8.3	8.3	19.4	41.7	19.4***
Rovral Flo	50.0	43.8	20.5	80.3	48.6**
Signum	57.3	22.1	14.1	41.7	33.8***
Switch	33.3	22.2	63.9	52.8	48.8**
Teldor	70.0	58.8	44.4	55.6	57.2*
Unicrop Thianosan DG	31.6	18.1	15.0	46.1	27.7***
Mean	48.8**	38.7	33.6	56.0***	44.3
SED (78df)	5.15 (timing) 16.30 (interaction)				8.15
P	<0.001 (timing) 0.014 (interaction)				<0.001

*= Significant at 5% level ; ** = Significant at 1% level; ***= Significant at 0.1% level

Table 7. Severity of ringspot in relation to fungicide product and timing, in Experiment 1, 28 days after inoculation

Product	Ringspot (% leaf area affected)				
	5 days pre-inoculation	2 days pre-inoculation	Just prior to inoculation	2 days post-inoculation	Mean
Untreated control	0.82	1.98	2.94	1.29	1.76
Amistar	0.98	0.17	0.17	0.18	0.37
Amistar Top	0.36	0.27	0.26	0.92	0.45
Scotts Octave	0.22	0.34	0.06	1.21	0.46
UK 379a	0.03	0.79	0.13	0.30	0.31
Rovral Flo	0.59	0.80	0.22	2.23	0.96
Signum	0.14	0.13	0.04	1.62	0.49
Switch	0.12	0.11	0.52	0.22	0.24
Teldor	1.42	0.16	0.23	0.07	0.51
Unicrop Thianosan DG	0.13	0.49	1.06	0.32	0.82
Mean	0.79	0.43	0.09	0.32	0.41
SED (78df)	0.248 (timing) 0.784 (interaction)				0.392
P	NS (timing) NS (interaction)				0.009

* trace only

Promising products, Amistar, Switch, Signum and UK379a, were taken forward for further screening in Experiment 2 together with Octave (industry standard). Despite reducing disease incidence, Unicrop Thianosan DG was not further evaluated because it was less effective in decreasing disease severity than Octave and priority was given to finding alternatives to dithiocarbamate products.

Experiment 2

Ringspot lesions were evident 7 days after inoculation. There was also some leaf distortion and cracking indicative of severe infection on young leaves. The first assessment was done 8 days after inoculation. Switch and UK379a (at both rates) were the only fungicides that significantly decreased disease severity averaged over all treatment timings (Table 8). UK379a had the lowest disease severity and this was significantly lower than all the other fungicides except Switch at full rate. There were significant effects of spray timing averaged over all treatments. Treatments applied 2 days after inoculation were significantly less effective than those applied just prior to inoculation or up to 5 days before inoculation (Table 8). There were no significant interactions between spray timing and fungicides.

Table 8. Severity of ringspot in relation to fungicide product and timing, in Experiment 2, 8 days after inoculation.

Product	Ringspot (% leaf area affected)				
	5 days pre-inoculation	2 days pre-inoculation	Just prior to inoculation	2 days post-inoculation	Mean*
Water	3.3	4.4	4.9	5.6	4.54 (0.79)
Amistar 1 L/ha	3.8	2.1	2.9	6.2	3.74 (0.61)
Amistar 0.5 L/ha	3.6	4.3	3.2	4.1	3.78 (0.51)
Octave 0.2 kg/ha	3.9	5.2	2.0	3.8	3.70 (0.51)
Octave 0.1 kg/ha	4.2	2.0	3.8	3.1	3.30 (0.42)
Signum 1.5 kg/ha	5.7	4.5	2.0	3.6	3.90 (0.60)
Signum 0.75 kg/ha	2.5	4.9	4.6	4.4	4.09 (0.63)
Switch 0.8 kg/ha	1.7	2.9	1.8	4.3	2.66 (0.31)
Switch 0.4 kg/ha	1.9	3.2	0.8	3.4	2.34 (0.23)
UK379a 1.44 kg/ha	2.0	0.7	0.7	4.2	1.88 (0.24)
UK379a 0.72 kg/ha	2.3	2.2	0.8	4.3	2.37 (0.29)

Mean*	3.16 (0.427)	3.30 (0.444)	2.48 (0.338)	4.26 (0.659)	3.30 (0.467)
SED (86df)	0.484 (timing) 1.605 (interaction)				0.802
P	0.005 (timing) NS (interaction)				0.021

+ data were skewed – angular transformation used – original means in brackets.

Only Switch and UK379a (at both rates) significantly decreased ringspot incidence compared with the water control. The full rate of UK379a had significantly fewer plants with ringspot than all the other fungicides except Switch (Table 9). There were significant effects of spray timing. Sprays applied just before inoculation showing only 21% plants affected compared with 41% when fungicides were applied 2 days later (Table 9).

Table 9. Incidence (% plants affected) of ringspot in relation to fungicide product and timing in Experiment 2, 8 days after inoculation.

Product	Ringspot (% plants affected)				
Fungicide	5 days pre-inoculation	2 days pre-inoculation	Just prior to inoculation	2 days post-inoculation	Mean
Water	30.6	50.0	33.3	59.1	43.2
Amistar 1 L/ha	36.1	27.8	33.3	52.8	37.5
Amistar 0.5 L/ha	36.1	41.7	26.3	44.4	37.1
Octave 0.2 kg/ha	41.7	38.9	16.7	49.2	36.6
Octave 0.1 kg/ha	33.3	27.8	36.1	33.3	32.6
Signum 1.5 kg/ha	45.7	34.8	22.2	38.9	35.4
Signum 0.75 kg/ha	19.4	55.6	41.7	36.1	38.2
Switch 0.8 kg/ha	11.1	28.3	8.6	28.3	19.1
Switch 0.4 kg/ha	13.9	27.8	5.6	33.3	20.1
UK379a 1.44 kg/ha	16.7	2.8	5.6	30.6	13.9
UK379a 0.72 kg/ha	19.4	11.1	5.6	44.4	20.1
Mean	27.6	31.5	21.3	41.0	30.4
SED (86df)	5.25 (timing) 17.41 (interaction)				8.71
P	0.003 (timing) NS (interaction)				0.007

The second assessment was 16 days after inoculation. In water control plots, disease severity had increased from 0.8% to 4.5% leaf area affected and ringspot incidence from 43% to 87% plant affected since the first assessment. All fungicides gave significant control of ringspot averaged over all timings. UK379a had the lowest ringspot severity and was better than Amistar (2 rates), Signum (2 rates) and Octave (higher rate) (Table 10). Sprays applied 2 days after inoculation were significantly less effective than the three earlier timings.

Table 10. Severity of ringspot in relation to fungicide product and timing, in Experiment 2, 16 days after inoculation.

Product	Ringspot (% leaf area affected)				
Fungicide	5 days pre-inoculation	2 days pre-inoculation	Just prior to inoculation	2 days post-inoculation	Mean
Water	3.5	3.3	5.0	6.3	4.53
Amistar 1 Lha	3.1	1.9	2.0	4.5	2.86
Amistar 0.5 L/ha	2.1	3.6	3.0	2.8	2.88
Octave 0.2 kg/ha	3.5	3.4	1.4	3.2	2.84
Octave 0.1 kg/ha	4.1	2.0	2.4	1.7	2.53
Signum 1.5 kg/ha	3.6	2.9	1.6	2.4	2.62
Signum 0.75 kg/ha	2.4	3.2	3.6	3.5	3.16
Switch 0.8 kg/ha	2.1	1.7	1.3	3.0	2.00
Switch 0.4 kg/ha	0.8	2.6	1.2	2.7	1.80
UK379a 1.44 kg/ha	1.0	0.5	0.3	3.2	1.25
UK379a 0.72 kg/ha	1.2	1.3	0.6	2.9	1.48
Mean	2.48	2.39	2.02	3.27	2.54
SED (86df)	0.396 (timing) 1.313 (interaction)				0.656
P	0.017 (timing) NS (interaction)				<0.001

Table 11. Incidence (% plants affected) of ringspot in relation to fungicide product and timing in Experiment 2, 16 days after inoculation.

Product	Ringspot (% plants affected)				
Fungicide	5 days pre-inoculation	2 days pre-inoculation	Just prior to inoculation	2 days post-inoculation	Mean
Water	72.2	91.2	88.9	94.2	86.6
Amistar 1 L/ha	86.1	64.9	86.1	91.7	82.2
Amistar 0.5 L/ha	86.1	83.3	69.4	72.2	77.8
Octave 0.2 kg/ha	74.7	69.4	61.1	72.2	69.4
Octave 0.1 kg/ha	91.7	61.9	77.8	61.1	73.1
Signum 1.5 kg/ha	75.0	83.3	55.6	72.2	71.5
Signum 0.75 kg/ha	78.8	88.9	80.6	83.3	82.9
Switch 0.8 kg/ha	77.8	58.3	57.1	80.1	68.3
Switch 0.4 kg/ha	50.0	61.1	62.6	75.0	62.2

UK379a 1.44 kg/ha	58.3	38.4	23.5	69.4	47.4
UK379a 0.72 kg/ha	50.5	41.7	30.6	69.4	48.0
Mean	72.8	67.5	63.0	76.4	69.9
SED (86df)		4.65 (timing) 15.42 (interaction)			7.71
P		0.026 (timing) NS (interaction)			<0.001

Most treatments had little effect on disease incidence. Switch, UK379a and the higher rate of Octave were the only treatments that reduced the incidence of ringspot significantly. Sprays applied just prior to inoculation or 2 days before inoculation were more effective than those applied 2 days after inoculation (Table 11).

There were no significant interactions between treatment and timing. Further analyses were done to examine the effect of fungicide dose as trends in the severity assessments (Table 10) suggested control was less effective at half dose. Data for treatments applied just after inoculation did not show significant dose responses, but combined data for timings 2 and 3 showed significant differences between fungicides and dose (averaged over products). Ringspot severity was 1.7% at full dose and 2.3% at half dose (P=0.040; LSD 0.64). There were no significant fungicide x dose interactions though trends suggested Octave and Switch were less sensitive to reductions in dose than the other products.

Experiment 3

Ringspot started to appear 6 days after inoculation and incidence increased from 3% after 7 days to 58% after 14 days and 84% after 21 days in control plots (Table 12a). There were small increases in ringspot up to the final assessment 35 days after inoculation when 98% plants were affected (Table 12b). There were significant decreases in ringspot incidence after 14, 21, 28 and 35 days from Switch and UK379a (Tables 12 and 12 b), whilst Signum decreased incidence at 14 and 21 days and Octave at 14, 21 and 35 days. Spray timing effects were significant after 28 and 35 days when ringspot incidence was lower in the 14 day treatments than in the 7 day treatments (Table 12b). There was a significant fungicide x timing interaction at the 35 day assessment and the interaction approached significance after 28 days. This interaction was most apparent for UK379a which had 52% plants affected in the 7 day treatment and 17% affected in the 14 day treatment. Switch, Octave and Signum also showed lower incidence in the 14 day treatment after 35 days. It should be noted that the second inoculation and infection event was applied at the same time as the 14-day fungicide treatments, but 7 days after the 7-day fungicide treatments.

Table 12a - Incidence (% plants affected) of ringspot in relation to fungicide product and fungicide timing in Experiment 3 at 7, 14 and 21 days after first inoculation.

Product	Ringspot (% plants affected)								
Fungicides	7 day assessment*			14 day assessment			21 day assessment		
Timing of Spray	7 day	14 day	Mean	7 day	14 day	Mean	7 day	14 day	Mean
1. Control (Water)	5.0	1.7	3.3	55.0	60.0	57.5	85.0	83.3	84.2
2. Amistar	3.3	6.7	5.0	46.7	50.0	48.3	88.3	66.7	77.5
3. Octave	3.3	3.3	3.3	25.0	30.0	27.5	48.3	70.0	59.2
4. Signum	6.7	10.0	8.3	26.7	36.7	31.7	65.0	58.3	61.7
5. Switch	6.7	0.0	3.3	16.7	18.3	17.5	40.0	51.7	45.8
6. UK379A	3.3	3.3	3.3	13.3	13.3	13.3	21.7	21.7	21.7
Mean	4.7	4.2		30.6	34.7		58.1	58.6	
Factor	Fung	Timing	Fung x Timing	Fung	Timing	Fung x Timing	Fung	Timing	Fung x Timing
SED (44df)	2.907	1.678	4.111	8.17	4.72	11.56	7.91	4.57	11.19
P	NS	NS	NS	<0.001	NS	NS	<0.001	NS	NS

Table 12b - Incidence (% plants affected) of ringspot in relation to fungicide product and fungicide timing in Experiment 3 at 28 and 35 days after first inoculation.

Product	Ringspot (% plants affected)					
Fungicides	28 day assessment			35 day assessment*		
Timing of Spray	7 day	14 day	Mean	7 day	14 day	Mean
1. Control (Water)	93.3	90.0	91.7	100	95.0	97.5
2. Amistar	90.0	88.3	89.2	96.7	90.0	93.3
3. Octave	91.7	70.0	80.8	96.7	71.7	84.2
4. Signum	90.0	76.7	83.3	100	80.0	90.0
5. Switch	70.0	38.3	54.2	88.3	63.3	75.8
6. UK379A	35.0	8.3	21.7	51.7	16.7	34.2
Mean	78.3	61.9		88.9	69.4	
Factor	Fung	Timing	Fung x Timing	Fung	Timing	Fung x Timing
SED (44df)	5.73	3.31	8.10	4.55	2.63	6.43
P	<0.001	<0.001	NS 0.058	<0.00 1	<0.00 1	0.014 skew

Ringspot severity increased from 0.02% after 7days to 1.0% after 14 days, 1.9% after 21 days and a maximum of 7.0% after 35 days. This was the most severe disease produced within the project. There were significant fungicide differences after 14, 21, 28 and 35 days and significant spray timing effects after 28 and 35 days (Tables 13 a and 13b). There were no significant interactions between fungicides and spray timing.

Table 13a. Severity of ringspot in relation to fungicide product and timing, in Experiment 3 at 7, 14 and 21days after inoculation.

Product	Ringspot (% leaf area affected)								
Fungicides	7 day assessment*			14 day assessment**			21 day assessment**		
Timing of Spray	7 day	14 day	Mean	7 day	14 day	Mean	7 day	14 day	Mean
1. Control (Water)	0.03	0.02	0.02	5.2 (0.94)	5.6 (1.04)	5.41 (1.00)	7.4 (1.77)	7.6 (1.93)	7.49 (1.85)
2. Amistar	0.09	0.07	0.08	3.7 (0.46)	3.6 (0.45)	3.66 (0.46)	5.2 (0.88)	5.7 (1.08)	5.48 (0.98)
3. Octave	0.06	0.02	0.04	2.5 (0.29)	2.9 (0.40)	2.51 (0.34)	2.6 (0.26)	4.9 (0.81)	3.71 (0.54)
4. Signum	0.06	0.28	0.17	2.4	2.9	2.35	2.9	4.0	3.46

				(0.12)	(0.29)	(0.20)	(0.28)	(0.54)	(0.41)
5. Switch	0.08	0.00	0.04	1.3 (0.10)	1.1 (0.06)	1.25 (0.03)	2.1 (0.15)	2.6 (0.21)	2.34 (0.18)
6. UK379A	0.03	0.02	0.02	0.8 (0.04)	0.9 (0.02)	0.82 (0.38)	1.2 (0.05)	0.8 (0.03)	1.00 (0.04)
Mean	0.055	0.065		2.51 (0.324)	2.83 (0.376)		3.58 (0.564)	4.25 (0.765)	
Factor	Fung	Timing	Fung x Timing	Fung	Timing	Fung x Timing	Fung	Timing	Fung x Timing
SED (44df)	0.0711	0.0410	0.1005	0.701	0.405	0.992	0.691	0.399	0.977
P	NS	NS	NS	<0.001	NS	NS	<0.001	NS 0.099	NS

*data were skewed but did not transform.
**data were skewed and transformed with an angular transformation. Original means in brackets.

All the fungicides decreased ringspot severity compared with the untreated control after 14, 21, 28 and 35 days except for Amistar at 28 days. Switch and UK379a gave the lowest disease severity and were significantly more effective than Amistar at all five assessments. Switch and UK379a were also significantly more effective than Signum and Octave after 28 days (Table 13b). After 28 and 35 days, the 14 day treatments showed lower severity than the 7 day treatments, but the differences were not significant (though they had been for ringspot incidence).

Table 13b. Severity of ringspot in relation to fungicide product and timing, in Experiment 3 at 28 and 35 days after inoculation.

Product	Ringspot (% leaf area affected)					
Fungicides	28 day assessment*			35 day assessment		
Timing of Spray	7 day	14 day	Mean	7 day	14 day	Mean
1. Control (Water)	14.5 (6.55)	12.9 (5.11)	13.69 (5.83)	8.0	6.0	7.04
2. Amistar	13.5 (5.55)	9.2 (2.60)	11.32 (4.07)	7.0	4.0	5.49
3. Octave	12.9 (5.15)	7.3 (1.77)	10.08 (3.46	6.6	2.1	4.35

			)			
4. Signum	11.9 (4.27)	6.8 (1.46)	9.35 (2.86)	5.2	1.8	3.52
5. Switch	8.5 (2.36)	3.54 (0.40)	6.02 (1.38)	3.4	0.6	2.03
6. UK379A	4.0 (0.68)	0.5 (0.01)	2.28 (0.35)	1.0	0.1	0.56
Mean	10.9 (4.09)	6.70 (1.89)		5.23	2.4	
Factor	Fung	Timing	Fung x Timing	Fung	Timing	Fung x Timing
SED (44df)	0.914	0.528	1.292	0.675	0.389	0.954
P	<0.001	<0.001	NS	<0.001	<0.001	NS

*data were skewed and transformed with an angular transformation. Original means in brackets.

Downy mildew remained high throughout the experiment but its development was restricted by the use of Aliette spays. Downy mildew was mostly confined to the oldest leaves and ringspot infection was still satisfactory. There were small but significant fungicide differences after 28 and 35 days when Amistar and Signum gave a lower downy mildew incidence than the other products and the untreated control (Table 14a). Amistar and Signum also significantly decreased the severity of downy mildew 21, 28 and 35 days after inoculation and both were more effective than Switch and UK379a (Table 14b).

Table 14a. Incidence of downy mildew in relation to fungicide product and timing, in Experiment 3 at 7, 14 and 21 days after inoculation.

Product	Downy mildew (% plants affected)								
	7 day assessment*			14 day assessment**			21 day assessment**		
Timing of Spray	7 day	14 day	Mean	7 day	14 day	Mean	7 day	14 day	Mean
1. Control (Water)	96.7	98.3	97.5	86.6 (98.3)	81.8 (95.0)	84.2 (96.7)	77.1 (88.3)	86.6 (98.3)	81.9 (93.3)
2. Amistar	98.3	100.0	99.2	83.3 (96.7)	78.5 (93.3)	80.9 (95.0)	73.9 (90.0)	67.1 (83.3)	70.5 (86.7)
3. Octave	96.7	98.3	97.5	79.9 (95.0)	78.5 (93.3)	79.2 (94.2)	83.3 (96.7)	83.3 (96.7)	83.3 (96.7)
4. Signum	96.7	95.0	95.8	80.4 (93.3)	74.6 (88.3)	77.5 (90.8)	73.8 (86.7)	76.2 (86.7)	75.0 (86.7)
5. Switch	98.3	96.7	97.5	75.8 (90.0)	80.6 (93.3)	78.2 (91.7)	85.2 (96.7)	74.4 (88.3)	79.8 (92.5)
6. UK379A	98.3	95.0	96.7	77.0 (91.7)	76.2 (90.0)	76.6 (90.8)	79.9 (95.0)	83.3 (96.7)	81.6 (95.8)
Mean	97.5	97.2		80.5 (94.2)	78.4 (92.2)		78.9 (92.2)	78.5 (91.7)	
Factor	Fung	Timing	Fung x Timing	Fung	Timing	Fung x Timing	Fung	Timing	Fung x Timing
SED (44df)	2.552	1.473	3.609	5.30	3.06	7.50	4.61	2.66	6.52
P	NS	NS	NS	NS	NS	NS	0.061	NS	NS

*data were skewed but did not transform.
**data were skewed and transformed with an angular transformation. Original means in brackets.

Table 14b. Incidence of downy mildew in relation to fungicide product and timing, in Experiment 3 at 28 and 35 days after inoculation.

Product	Downy mildew (% plants affected)					
	28 day assessment*			35 day assessment		
Timing of Spray	7 day	14 day	Mean	7 day	14 day	Mean
1. Control (Water)	90.0 (100)	85.8 (97.9)	87.9 (99.0)	85.2 (96.7)	73.9 (90.0)	79.6 (93.3)
2. Amistar	57.6	63.5	60.5	59.4	64.4	61.9

	(70.8)	(79.2)	(75.0)	(73.3)	(80.0)	(76.7)
3. Octave	78.0 (91.7)	85.8 (97.9)	81.9 (94.8)	80.4 (93.3)	81.8 (95.0)	81.1 (94.2)
4. Signum	66.3 (79.2)	75.2 (87.5)	70.8 (83.3)	55.6 (66.7)	75.0 (85.0)	65.3 (75.8)
5. Switch	85.8 (97.9)	81.2 (91.7)	83.5 (94.8)	81.8 (95.0)	74.4 (88.3)	78.1 (91.7)
6. UK379A	85.8 (97.9)	85.8 (97.9)	85.8 (97.9)	80.6 (93.3)	81.8 (95.0)	81.2 (94.2)
Mean	77.3 (89.6)	79.5 (92.0)		73.8 (86.4)	75.2 (88.9)	
Factor	Fung	Timing	Fung x Timing	Fung	Timing	Fung x Timing
SED (44df)	4.79	2.77	6.78	4.87	2.81	6.88
P	<0.001	NS	NS	<0.001	NS	0.049

Table 15a. Severity of downy mildew in relation to fungicide product and timing, in Experiment 3 at 7, 14 and 21 days after inoculation.

Product	Downy mildew (% leaf area affected)								
	7 day assessment*			14 day assessment			21 day assessment		
Timing of Spray	7 day	14 day	Mean	7 day	14 day	Mean	7 day	14 day	Mean
1. Control (Water)	7.6	6.8	7.19	3.5	3.6	3.58	4.3	4.4	4.37
2. Amistar	7.3	7.9	7.59	3.4	3.1	3.28	2.6	2.2	2.38
3. Octave	8.0	7.9	7.90	3.3	3.5	3.37	3.1	3.5	3.31
4. Signum	6.4	6.8	6.60	2.8	3.2	3.03	2.1	2.9	2.48
5. Switch	7.5	7.0	7.27	3.0	4.3	3.65	3.8	4.1	3.94
6. UK379A	7.3	8.8	8.05	3.2	3.6	3.43	3.9	3.9	3.92
Mean	7.34	7.52		3.21	3.56		3.30	3.50	
Factor	Fung	Timing	Fung x Timing	Fung	Timing	Fung x Timing	Fung	Timing	Fung x Timing
SED (44df)	0.661	0.382	0.935	0.308	0.178	0.436	0.438	0.253	0.620
P	NS	NS	NS	NS	NS 0.056	NS	<0.001	NS	NS

*data were skewed but did not transform.

Table 15b. Severity of downy mildew in relation to fungicide product and timing, in Experiment 3 at 28 and 35 days after inoculation.

Product	Downy mildew (% leaf area affected)					
	28 day assessment			35 day assessment		
Timing of Spray	7 day	14 day	Mean	7 day	14 day	Mean
1. Control (Water)	5.1	5.5	5.28	4.0	3.6	3.82
2. Amistar	2.1	2.3	2.20	1.7	1.8	1.72
3. Octave	3.5	4.6	4.04	3.0	3.3	3.15
4. Signum	3.0	3.5	3.24	1.9	2.5	2.18
5. Switch	5.1	5.2	5.12	4.1	3.4	3.74
6. UK379A	4.5	5.2	4.85	3.5	3.3	3.37
Mean	3.87	4.37		3.01	2.98	
Factor	Fung	Timing	Fung x Timing	Fung	Timing	Fung x Timing
SED (44df)	0.594	0.343	0.840	0.387	0.223	0.547
P	<0.001	NS	NS	<0.001	NS	NS

There were some treatment effects on plant growth that were quantified using vigour assessments (Table 16). Some of the differences in vigour reflected the impact of ringspot particularly in the untreated control plots. The vigour of the controls relative to treated plants declined during the course of the experiment as ringspot became more severe. Treatment differences were significant after 14, 21 and 28 days and approached significance (P=0.060) after 35 days (Table 16). Switch and Signum reduced vigour after14 days and remained the fungicide treatments with the lowest vigour thereafter. Switch appeared to reduce leaf size and produce a darker green colour as reported in Experiment 1. Amistar and Octave showed the highest vigour particularly after 21 and 28 days. There were significant effects of spray timing or fungicide x timing interactions.

Table 16. Vigour scores (0-9) in relation to fungicide product and timing, in Experiment 3 at 14, 21, 28 and 35 days after inoculation.

Product	Vigour score (0-9)											
	14 day assessment			21 day assessment			28 day assessment			35 day assessment		
Timing of Spray	7 day	14 day	Mean	7 day	14 day	Mean	7 day	14 day	Mean	7 day	14 day	Mean
1. Control (Water)	7.2	7.4	7.30	6.8	7.0	6.90	6.8	6.8	6.80	6.8	6.8	6.80
2. Amistar	7.2	7.4	7.30	8.0	7.4	7.70	7.6	8.0	7.80	7.4	7.8	7.60
3. Octave	7.8	7.6	7.70	8.0	7.6	7.80	8.0	7.6	7.80	7.8	7.4	7.60
4. Signum	6.4	6.8	6.60	6.6	7.4	7.00	6.8	7.4	7.10	6.8	7.6	7.20
5. Switch	7.0	6.6	6.80	6.8	7.2	7.00	6.8	7.0	6.90	7.0	7.0	7.00
6. UK379A	7.0	7.0	7.00	7.2	7.2	7.20	7.0	7.4	7.20	7.2	7.4	7.30
Mean	7.10	7.13		7.23	7.30		7.17	7.37		7.17	7.33	
Factor	Fung	Timing	Fung x Timing	Fung	Timing	Fung x Timing	Fung	Timing	Fung x Timing	Fung	Timing	Fung x Timing
SED (44df)	0.238	0.137	0.336	0.297	-	-	0.265	0.153	0.375	0.30	0.173	0.424
P	<0.001	NS	NS	0.011	NS	NS	<0.001	NS	NS	NS 0.06	NS	NS

Discussion

This project has identified the activity of a range of fungicides against ringspot. There were more significant differences between products under high disease pressure in Experiment 3. This has implications for product choice under field conditions. Clearly, the five selected products have useful activity against ringspot and would be expected to show disease suppressive effects if used soon after planting under low disease pressure. Where ringspot occurs regularly, interest will focus on the most active products. There are products showing greater activity against ringspot than the standard Octave, though support from manufacturers and industry will be required to establish specific recommendations for the most promising treatments, Switch and UK379a.

Field evaluation of treatments is still required to support this glasshouse study. Products generally showed lower efficacy at half dose than full dose, though Octave may be an exception. Previous work in England showed that prochloraz (as Sportak) gave very good control of ringspot in outdoor lettuce when applied 3, 15, 23 and 32 days after planting (Jones, 1986). Thiram and iprodione (as Rovral WP) gave no significant control in the same experiment. Prochloraz, chlorothalonil and propiconazole were identified as the most effective products out of 16 fungicides evaluated in Australia (Wickes *et al*., 1994). These three fungicides were more effective than products that were being used commercially that included mancozeb, propineb and cupric hydroxide. Chlorothalonil has not been used on lettuce in the UK and did not control ringspot in previous work (Jones, 1986). In USA, strobilurin products azoxystrobin (as Amistar or Quadris) and pyraclostrobin (as Cabrio), together with dithiocarbamate products such as Maneb (see http://ipmnet.org/plant-disease Oregon State University Extension website)....incomplete sentence. Pyraclostrobin is present in Signum in mixture with boscalid.

There would seem to be limited flexibility to manipulate the dose of fungicides, particularly as Experiment 3 indicated that persistence may be short on actively growing young plants. Spray timing and the interval between treatments is the key area to examine in field studies. Fungicides applied weekly were more effective than those applied at 14-day intervals in Australian work (Wicks *et al*., 1994), which supports the conclusions drawn from this project about short persistence of fungicides The observation in Experiment 3 that a second spray after 14 days gave better control than one after 7 days requires careful interpretation. New spore inoculum and an infection period was imposed on the crop after 14 days (soon after fungicide application), but not after 7 days. Treatments applied very close to an infection event are likely to be most effective as the previous spray timing experiments (Experiment 1 and Experiment 2) demonstrated. Wickes *et al.* (1994) observed that weekly sprays were more effective than those applied only after periods of leaf wetness. Early applications at planting are likely to be very important to prevent ringspot becoming established from soil-borne inoculum. As the disease develops on the underside of the leaves and within the head of the lettuce, fungicides are likely to give mainly protection against secondary spread between plants. Early spray timing would also fit in with fungicide programmes used for the control of Sclerotinia on lettuce.

The range of treatments available for ringspot control has diverse fungicide chemistry including azoles (Octave), strobilurins (in Amistar, Signum and UK379a) and anilinopyrimidine (in Switch). There are opportunities to diversify fungicide programmes to reduce the risk so selecting fungicide resistant strains of ringspot and other pathogens.

Conclusions

All the test fungicides showed some activity against ringspot. Five products were tested in three separate experiments and their relative performance was consistent. Switch and UK379a were identified as products that showed more effective control of ringspot than the 'standard' Octave. Signum gave comparable results to Octave. Product differences were most apparent under high disease pressure.

As ringspot symptoms can develop in 4-8 days, there is limited opportunity to exploit curative activity against ringspot. There were significant effects of fungicide timing with the most effective sprays being applied 2 days before or just prior to inoculation. Some products were effective when applied up to 5 days before inoculation. Treatments applied 2 days after inoculation are unlikely to be very successful when the disease is developing rapidly. Commercially, it is appropriate to maintain protectant spray programmes when ringspot is present.

There was significantly poorer control of ringspot when fungicide dose was reduced from full to half rate. Robust rates of fungicides are likely to be required at each treatment application to maintain control of ringspot.

There were significant differences in ringspot control when second fungicide applications were made either 7 or 14 days after the first spray and plants were re-inoculated after 14 days. This suggests that fungicide protection had decreased significantly after 5-7 days. Further work is required to establish optimum spray intervals under field conditions. Previous research suggests than fungicides should be applied at weekly intervals where disease risk is high.

Scotts Octave (prochloraz) and Mirage 40 EC (prochloraz) are currently available for ringspot treatment and performed well. Switch, UK379a, Signum and Amistar are the most promising alternatives, but further support from growers and agro-chemical companies may well be required for the development of specific label recommendations or SOLAs for ringspot control. Some caution about field performance of new products is required given that these results are based on glasshouse screening experiments only.

The most effective fungicides are from a range of different fungicide groups and should allow spray programmes to be diversified and reduce the risk of fungicide resistance problems developing.

Technology transfer

An article was produced for HDC News in January 2008 for publication in February 2008. There have been telephone responses to growers, consultants and fungicide manufacturers requesting information on fungicide effects. Project highlights will be presented to the Speciality Produce Growers Association at their Technical Meeting in February 2008.

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