Stockbridge House, Cawood, Selby, North Yorkshire

FINAL REPORT

To:
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Evaluation of novel fungicides for the control of pink rot (*Sclerotinia sclerotiorum*) in protected celery

PC 131

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Project title:	Evaluation of novel fungicides for the control of pink rot (*Sclerotinia sclerotiorum*) in protected celery.
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The results and conclusions in this report are based on a series of single experiments. The conditions under which these experiments were carried out and the results have been reported with detail and 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 my supervision according to the procedures described herein and that this report represents a true and accurate record of the results obtained.

Signature .....

Dr G M McPherson
Project Leader
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Date 17/9/97

Report authorised by .....
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Objectives and Background

The primary objective of this project was to identify novel fungicides with activity against the fungus, *Sclerotinia sclerotiorum*, which causes pink rot in protected celery.

Pink rot, caused by the soil and air-borne fungus *S. sclerotiorum* is one of the most important diseases of both protected and outdoor celery. Under optimum conditions for infection and subsequent development severe losses can, and do, occur. Infection arises either directly via resting bodies (sclerotia) from previous susceptible crops or via air-borne ascospore deposition on the celery foliage from apothecia (from germinating sclerotia) developing on the soil-surface of other crops in the vicinity. The incidence of *Sclerotinia* infection in winter oilseed rape, for example, has increased in recent years and the residual sclerotial population has increased as a result.

Previously, growers have relied heavily on the dicarboximide fungicide vinclozolin (Ronilan) for effective control. However, the use of this fungicide was suspended in most horticultural crops recently, due to increased safety concerns. The only other dicarboximide fungicide currently available in the UK is iprodione (Rovral WP) but it is regarded to be inferior in its performance against *S. sclerotiorum*, and it is, in any case, phytotoxic on celery (Griffin, M., J., & Hims, M. J., 1982). The only fungicides remaining with approval for use on celery which are claimed to have some activity against *Sclerotinia* are carbendazim (eg Bavistin) and chlorothalonil (eg Bravo 500). Under conditions of high disease pressure these fungicides are claimed to be insufficient in preventing disease establishment and secondary spread. This may be due to the presence of resistant strains, and currently growers have no alternative means of protecting the crops.

Summary of Results

The aim of this project was to evaluate a range of novel fungicides with contrasting modes of action, alongside standard commercial treatments, for the control of pink rot (*S. sclerotiorum*) in protected celery. Eight novel fungicides were selected in 1996 including fenpropimorph (Aura 750 EC), prochloraz-manganese (Octave), azoxystrobin (Amistar), cyprodinil (Unix), pyrimethanil (Scala), diethofencarb + carbendazim (Jonk), tebuconazole (Folicur), and quintozene (Terraclor 45 Flo) and applied as high volume sprays to run-off in both self-blanching cv. Celebrity and green cv. Claudius celery alongside untreated (uninoculated and inoculated controls) and the standard fungicides carbendazim, (Derosal WDG), and chlorothalonil (Bravo 500)

Eight 'infector' plants in each plot (uninoculated control excluded) were inoculated with a virulent isolate of *Sclerotinia sclerotiorum* and the disease allowed to progress naturally. A low level of infection occurred in the uninoculated control either from a residual, but small sclerotial population in the soil or as air-borne ascospores from external sources. No apothecia were observed in the glasshouse trial area throughout the duration of the experiment.

Following inoculation, the disease established successfully on the infector plants in the inoculated control; the pathogen subsequently spreading from plant to plant by mycelial contact. Disease levels in the self-blanching cv. Celebrity were much higher (Disease Index 48.7) than on the green cv. Claudius (Disease Index 23.3).

Several of the fungicides evaluated provided effective control of *Sclerotinia*, even under the heavy disease pressure in the trial. Of the experimental fungicides diethofencarb + carbendazim (Jonk); prochloraz-manganese (Octave), azoxystrobin (Amistar), tebuconazole (Folicur) and fenpropimorph (Aura) were most effective , though the latter product was highly phytotoxic to celery. Pyrimethanil (Scala) and cyprodinil (Unix), whilst less effective, still provided some suppression particularly on the cv. Celebrity. Diethofencarb + carbendazim (Jonk) was particularly effective reducing the disease index

from 48.7 to 0.4 in the cv. Celebrity and from 23.3 to 0.4 in the cv. Claudius. It would appear to be the latter component of this fungicide mixture which provided the most control as the standard commercial treatment with carbendazim (Derosal) was almost as effective reducing the disease index from 48.7 to 2.5 on the cv. Celebrity and from 23.3 to 3.7 on the cv. Claudius. Chlorothalonil (Bravo 500) was largely ineffective whereas quintozene (Terraclor 45 Flo) provided a moderate suppression even though it couldn't be applied according to commercial practice (for lettuce) in this trial. Derosal, Jonk, and Amistar provided the highest marketable yields in this trial on the cv. Celebrity.

In the second year's trial the most effective products (Amistar, Jonk, Folicur, Octave) were selected for re-evaluation as either two or four-spray programmes on the cv. Celebrity. In addition, another strobilurin fungicide, kresoxim-methyl (BASF) was included for the first time. Terraclor 45 Flo, as used in Year 1, was substituted with Terraclor 20 D and applied as a pre-planting soil incorporation treatment according to manufacturers recommendations for lettuce.

Whilst disease progression was a little slower than in 1996 the disease index in the inoculated control was 31.3 at harvest in July and this provided an effective test for the imposed treatments. Derosal, Jonk and Amistar performed exceptionally well as four-spray programmes though only the latter product reduced the disease incidence to an acceptable level with two early timed sprays.

It is therefore recommended that where there is a risk of secondary infection via asco-spores from either within the cropping environment or from outside crops growers should apply an Approved carbendazim containing product. In view of previous concerns expressed by growers on the poor performance of carbendazim in high disease risk situations and in order to minimise the risk of fungicide resistance it is recommended that growers consider testing the pathogen for resistance to carbendazim. It is also recommended that a Specific Off-Label Approval is sought for azoxystrobin (Amistar) on celery (ideally to include outdoor and protected crops). It should be noted that the use of this broad spectrum fungicide should afford some protection from other leaf/stem diseases.

Unfortunately there are no pesticides currently approved on celery to combat the risk from persistent soil-borne sclerotial inoculum from previously infected crops. Currently, therefore, growers have to resort to the use of soil sterilisation techniques to minimise the inoculum pressure. It is recommended that consideration is given to pursuing an extension of the Terraclor recommendation to include celery, in conjunction with the manufacturers, Hortichem.

NB. It should be noted that since this project commenced the On-Label use of Derosal (50% carbendazim) has been withdrawn and instead a Specific Off-Label Approval (SOLA No. 1002/95) for the use of Bavistin DF (50% carbendazim) has been secured via the HDC/HRI SOLA programme.

Action Points for Growers

1. Minimise the risk of *Sclerotinia* by soil sterilisation on high risk sites.

2. Apply carbendazim as a preventative fungicide to delay the development of ascospore-borne infection arising either from within the cropping area or from outside (eg arable crops).

3. Where infection occurs, ensure infected material is removed as early as possible to minimise the risk of sclerotia maturing and falling into the soil, thereby persisting for many years.

4. Consider submitting a sample of Sclerotinia for carbendazim resistance testing at a diagnostic 'Plant Clinic'.

5. Discuss with your HDC panel member the possibility of pursuing an authorised use of azoxystrobin (Amistar) either as an On-Label Approval to minimise the risk of resistance and maintain suppression of other stem base/leaf disease eg *Botrytis*, *Septoria* and *Rhizoctonia*.

6. Consider the possibility of supporting additional studies, in conjunction with Hortichem Ltd, to extend the use of Terraclor 20D to celery in order to suppress persistent soil-borne sclerotial inoculum which may have occurred following infection in previous susceptible crops.

Practical and Financial Benefits from the Study

Reliable control of pink rot, a potentially devastating disease of sporadic and, at times, unpredictable occurrence, is essential for successful production of both protected and outdoor celery.

If effective control measures for *Sclerotinia* are not available to the industry losses could be considerable. The current acreage of protected celery is ca. 160 ha, with the main production areas in the South East, East Anglian, Lancashire and Yorkshire. The gross value of the industry is ca. £5m. Assuming only 5% loss due to the disease, this equates to £250,000/annum. Losses in individual crops can of course, be considerably higher. In addition, there are indirect losses to consider in subsequent susceptible crops eg lettuce due to the increased deposition of sclerotia in the soil, if control measures are inadequate.

Results from this two-year investigation have demonstrated the aggressive nature of the pathogen when it is allowed to develop unchecked. It has also effectively demonstrated the merit in using carbendazim (Derosal) according to the then manufacturers On-Label recommendation (but see note re. Bavistin DF above). Reports of poor efficacy with this product suggest there may be resistant strains of *S. sclerotiorum* in the population, though this has not been confirmed in this study. To combat resistance it would be advisable to 'ring the changes' and develop an integrated strategy for control alternating fungicides with different modes of action. Azoxystrobin (Amistar) performed particularly well in these trials, and appears well suited as an alternative component in a disease control strategy, particularly as its broad spectrum nature should afford some protection against *Septoria, Rhizoctonia* and *Botrytis* also.

It is recommended that this product should be brought forward into the HDC SOLA programme in 1998 to generate residues data for a Specific Off-Label Approval on the crop.

EXPERIMENTAL SECTION

Introduction

Pink rot caused by *Sclerotinia sclerotiorum* is a persistence soil-borne pathogen with a broad host range, including celery. Fungus resting bodies (sclerotia) which develop on infected plant debris can survive in the soil for many years and routine measures must be taken to prevent their introduction into intensive production areas. Sclerotia germinate to produce apothecia, cup-shaped fruiting bodies, on the soil-surface (indoors or outdoors) and these 'fire' ascospores into the air which may ultimately be deposited downwind onto susceptible crops. Protection of the foliage by application of protectant fungicides is therefore advisable particularly in areas where susceptible crops eg oilseed rape are grown intensively in the vicinity. Where infected plants are found they should be placed in a plastic bag *in situ*, together with a quantity of surrounding soil in case any sclerotia have fallen to the soil surface, and discarded ideally by incineration.

Until fairly recently vinclozolin (Ronilan) was the standard fungicide used on celery for *Sclerotinia* control. However, its use was suspended due to safety concerns and it now seems unlikely that the product will be made available again on this crop. Unfortunately, the only remaining dicarboximide fungicide, iprodione (Rovral), is phytotoxic on celery (Griffin & Hims, 1982) and therefore cannot be used safely on the crop. The only fungicides currently approved for use on protected celery are carbendazim, copper and tolclofos-methyl. Those products with reported activity against sclerotinia, eg carbendazim, chlorothalonil have not previously proven to be totally effective in commercial crops when disease pressure has been high, though whether resistant strains of the fungus are responsible has not been confirmed in this study.

It is important therefore that alternative fungicides are sought in order to maintain effective control of this pathogen. HRI, Stockbridge House were commissioned by HDC to prepare a short-list of candidate fungicides and to conduct a detailed, replicated evaluation in a protected cropping situation.

The scientific targets of the work were to:

- Establish an artificial infection of pink rot (*Sclerotinia sclerotiorum*) in crops of protected celery.

- Evaluate the performance of a range of novel fungicides for the control of pink rot.

- Determine whether the fungicides under evaluation cause phytotoxicity.

- Provide recommendations for further action.

Materials and Methods

	1996	1997
Site:	HRI Stockbridge House Cawood Selby N Yorkshire YO8 OTZ	HRI Stockbridge House Cawood Selby N Yorkshire YO8 0TZ
Location:	Venlo glasshouse (M15)	Polythene tunnel (North)
Cultivars:	Claudius (green) Celebrity (self-blanching)	Celebrity (self-blanching)
Sowing Date:	15 December 1995	9 January 1997
Planting Date:	14 March 1996	27 March 1997
Inoculation Date:	19 April 26 April 10 May	27 March 1997 20 May 1997
Fungicide Application Date:	23 April 7 May* 21 May* 5 June*	25 March 1997+ 23 April 1997 7 May 1997 22 May 1997 5 June 1997
	* Excluding T5	+ Terraclor soil application only
Harvest Date:	18 June 1996	10 July 1997

Trial Design

A randomised block design was used in each year comprising 12 treatments with four replicates (two cultivars in 1996). Each plot comprised 120 plants in 1996 (plot area 4.3 m^2) and 50 plants in 1997 (plot area 2.6 m^2). Tagged 'infector' plants were used in each year to generate an even infection level of disease in the trial area. There were eight and four 'infector' plants/plot in 1996 and 1997 respectively.

Inoculation of *S. sclerotiorum*

A mycelial isolate of *S. sclerotiorum* was used to inoculate 10 cm long cut stalks of celery petioles in the laboratory. After incubation for 48 hours at 20°C under high humidity conditions, during which time infection progressed rapidly the inoculated stalk sections were inserted into the crown of each tagged infector plant in the growing house. In addition in 1997, conditioned sclerotia of *S. sclerotiorum*, provided by Dr J Whipps, HRI Wellesbourne, were enclosed in muslin bags and buried in the guard areas of the trial in an attempt to generate apothecia and subsequent air-borne ascospore inoculum of *S. sclerotiorum* in the crop.

Treatments

		1996	1997
1.	Untreated, uninoculated control.	✓	-
2.	Untreated, inoculated control.	✓	✓
3.	Carbendazim (Derosal WDG) at 0.3 kg product per 1000 litres water. Two applications.	-	✓
4.	Carbendazim (Derosal WDG) at 0.3 kg product per 1000 litres water. Four applications.	✓	✓
5.	Chlorothalonil (Bravo 500) at 3 litres product per 1000 litres water. Four applications.	✓	-
6.	Quintozene (Terraclor 20 D) at 35 ml product per m^2. One application.	✓*	✓

		1996	1997
7.	Fenpropimorph (Aura 750EC) at 1 litre product per 1000 litres water. Four applications.	✓	-
8.	Azoxystrobin (Amistar) at 0.8 litres product per 1000 litres water. Two applications.	-	✓
9.	Azoxystrobin (Amistar) at 0.8 litres product per 1000 litres water. Four applications.	✓	✓
10.	Cyprodinil (Unix) at 0.67 kg product per 1000 litres water. Four applications.	✓	-
11.	Pyrimethanil (Scala) at 1.32 litres product per 1000 litres water. Four applications.	✓	-
12.	Diethofencarb + carbendazim (Jonk) at 2 litres product per 1000 litres water. Two applications.	-	✓
13.	Diethofencarb + carbendazim (Jonk) at 2 litres product per 1000 litres water. Four applications.	✓	✓
14.	Tebuconazole (Folicur) at 1 litre product per 1000 litres water. Two applications.	-	✓
15.	Tebuconazole (Folicur) at 1 litre product per 1000 litres water. Four applications.	✓	✓
16.	Prochloraz-methyl (BAS490F) at 0.2 kg product per 1000 litres water. Two applications.	-	✓
17.	Prochloraz-manganese (Octave) at 0.2 kg product per 1000 litres water. Four applications.	✓	✓
18.	Kresoxim-methyl (BAS490F) at 0.5 kg product per 1000 litres water. Four applications.	-	✓

* Terraclor 45 Flo was applied at a rate of 15 ml per m^2 to an established celery crop as an overhead spray in 1996. A pre-planting soil application was not possible due to the late commissioning in the first year of the project.

Fungicide Application

All fungicides, unless specified otherwise, were applied HV to run-off using an Oxford Precision sprayer (E-Bar Engineering) modified to operate with compressed air at a pressure of 2.5 bar. Treatments were applied at 14 day intervals commencing when ground-cover was achieved.

Crop Husbandry

The crop in each year was grown to a good commercial standard and was maintained in a healthy state (with the exception of the introduced pathogen) according to normal horticultural practice and produced adequate yields for representative purposes. Pesticides were used occasionally as necessary, but were chosen so as not to affect the aims of the investigation.

Disease Assessments

The crop in each year was checked regularly and the rate of disease development monitored. Where necessary re-inoculation was carried out in each plot to ensure effective establishment of the introduced pathogen. At the same time the crop was checked for any evidence of phytotoxicity from the applied sprays. Where present, the symptoms were noted and photographic records taken.

In each year detailed assessments of disease were made at harvest when individual plants were examined closely, and scored for disease severity. Inoculated 'tagged' plants were assessed separately to uninoculated plants.

In 1996, 8 tagged 'infector' plants and 24 uninoculated plants were assessed in each plot. Whereas in 1997, 4 tagged and 20 uninoculated plants were assessed in each plot. The following scale for disease assessment was used in each year.

0 = No evidence of *S. sclerotiorum* on the plant.

1 = Slight infection on outer leaves but base of plant unaffected.

2 = Slight infection on outer leaves/stalks with the plant base affected. Excess trimming not required, plant marketable.

3 = Moderate infection on the plants with base affected. Excess trimming required and marketable yield reduced.

4 = Severe infection, excess trimming required causing unmarketable plant.

5 = Very severe infection, plant dead.

A disease index was subsequently calculated using this data from the formula:

$$\frac{1\,(1) + 2\,(2) + 3\,(3) + 4\,(4) + 5\,(5)}{\text{No. assessed}} \times \frac{100}{5}$$

Statistical Analysis

The data from these trials was subjected to an analysis of variance and significance determined at the 5% level of probability (P = 0.05).

A number of common notations have been used to indicate the degree to which values in the tables of results are significantly different.

NS	=	Not significant.
*	=	P <0.05, ie. the probability of this result occurring by chance is equal to or less than 1 in 20 (0.05 = 5%).
**	=	P <0.01, ie. the probability of this result occurring by chance is equal to or less than 1 in 100 (0.01 = 1%).
***	=	P <0.001, ie. the probability of this result occurring by chance is equal to or less than 1 in 1000 (0.001 = 0.1%).

Where significant differences are present the LSD or, Least Significant Difference, is quoted. this is the least (minimum) difference that is required when comparing any two figures in a column for those figures to be statistically different.

Storage of Data

The raw data from these trials will be stored for a period of not less than 5 years in the HRI Archive at Stockbridge House. Access to the data can only be made by the designated Archivist.

Official Recognition and Quality Assurance

These efficacy trials were conducted in accordance with the draft guidelines for Official Recognition of Efficacy Testing Organisations as outlined by PSD (PSD ref 2400/2996). A specific quality assurance audit was not undertaken in the trial.

Results

In 1996, the artificial inoculation procedure for *S. sclerotiorum*, whilst slow initially, was ultimately very effective in establishing infection. Disease levels were very high in the inoculated untreated controls at harvest. Some, albeit limited, spread occurred to the uninoculated control plots during the course of the experiment.

The fungicides, applied as a four-day programme at 14 day intervals were effective in reducing disease incidence on the 'tagged' infector plants (eradicant activity) and preventing subsequent spread to the adjacent uninoculated plants (protectant activity). Interestingly, disease levels on the self-blanching cultivar Celebrity were much higher than those on the green cultivar Claudius (Table 1).

The most effective treatments which successfully prevented spread of infection from the 'tagged' infector and reduced the disease index (DI) from 48.7 - 23.3 in the inoculated control plants (cvs. Celebrity and Claudius respectfully) were Derosal (DI: 2.5-3.7), Octave (DI:6.7-6.6), Amistar (DI: 13.7-5.4), Jonk (DI: 0.4-0.4) and Folicur (DI: 15.8-5.8). Fungicide treatment with chlorothalonil (Bravo 500), cyprodinil (Unix) and pyrimethanil (Scala) were generally much less effective. Fenpropimorph (Aura 750 EC) was extremely phytotoxic to both cultivars of celery grown in the trial and caused extensive leaf necrosis, stunting and distortion. Ultimately, the crown tissues collapsed due to secondary bacterial rotting prior to harvest and the yield was extremely low. Terraclor 45 Flo was applied as a single overhead foliar application in 1996 as it was not possible to apply the standard soil incorporation treatment to the established crop used in this study. Slight leaf damage occurred following treatment though the crop quickly grew away from the symptom and leaf damage was not apparent at harvest. This single application of Terraclor 45 Flo provided a marked reduction in *Sclerotinia* where disease pressure was high in the cv. Celebrity though surprisingly it was ineffective under lower disease pressure in the cv. Claudius. The occurrence of *S. sclerotiorum* in the crop had a marked effect on yield (Table 2) significantly reducing the trimmed weight/plant in cv. Celebrity from 644 g to 385 g. The lower disease pressure in the cv. Claudius had little or no effect on marketable yield as the infected tissues were trimmed off during the normal commercial

trimming operation. In the cv. Celebrity several of the fungicides significantly increased the trimmed 'marketable' yield. Those most effective were Derosal (745 g/plant), Amistar (697 g/plant) and Jonk (693 g/plant).

In 1997 the most effective treatments from the first year's trial were re-evaluated as either two or four-spray programmes alongside Terraclor 20D (applied as a single soil incorporation treatment pre-planting) and kresoxim-methyl (BAS490F) another novel strobilurin fungicide from BASF applied as a four-spray programme only.

Whilst in the 1996 trial, inoculation and subsequent spread was by mycelial contact. In 1997 an attempt was made to evaluate the performance of the fungicides against air-borne ascospore inoculum. Sclerotia of *Sclerotiorum* were buried in the soil in the guard areas of the trial and irrigated regularly to encourage their germination and subsequent apothecial production. Regular monitoring failed to identify the presence of apothecia and therefore 'tagged' infector plants were subsequently inoculated, as in the 1996 trial, to ensure successful infection of the trial area by *Sclerotinia.*

Due to slightly delayed mycelial inoculation of the 'tagged' plants cv. Celebrity in 1997 disease levels in this susceptible cultivar were slightly lower than in 1996 (DI = 31.3 (1997) as compared with 48.7 (1996)). However, this still provided a good test for the fungicides under evaluation. Terraclor 20D applied pre-planting to the soil caused only a slight reduction in disease in both the 'tagged' plants and adjacent uninoculated plants (Table 3). It should be considered, however, that this treatment is primarily aimed at preventing re-infection from sclerotial populations buried in the soil from previously infected crops rather than preventing secondary spread by mycelial contact or aerial infection from inbound ascospores. As no soil-borne sclerotia, apart from those buried artificially, were present in the plot areas during this study it is perhaps not too surprising that control was relatively poor following this single soil application. Derosal applied as a two-spray programme was largely ineffective and only caused a slight reduction in infection. Applied as a four-spray programme however, it significantly reduced the infection level (Disease Index) from 31.3 to 2.0 and proved to be one of the most effective treatments in the trial. Similarly, Jonk (containing diethofencarb + carbendazim) reduced the *Sclerotinia* infection only slightly following the application of two early sprays (DI =

20.0) yet the four-spray programme reduced the disease index to 1.5. Neither Octave nor Folicur were effective in preventing spread from infector plants and whilst both gave a slight reduction in disease, infection levels at harvest were unacceptable. Amistar (azoxystrobin) however, was extremely effective applied early as a two-spray programme and successfully reduced the disease index from 31.3 (inoculated control) to 5.0. This was improved slightly with the four-spray programme (DI = 2.5). Kresoxim-methyl, another strobilurin fungicide from BASF, was also effective against *Sclerotinia* but less so than azoxystrobin (Amistar). No phytotoxicity was recorded with any of the applied treatments during the second year's evaluation.

The yield in the 1997 crop was somewhat variable between plots and therefore the data presented in Table 4 should be treated with some caution. No significant differences were apparent.

Treatments providing the most effective control of *Sclerotinia* tended to give the highest yield (untrimmed and trimmed) and these were Jonk (two and four-spray programmes), Amistar (two or four spray programmes) and Derosal (four-spray programme only).

Table 1: **Severity of infection by *S. sclerotiorum* and efficacy of fungicide treatments at harvest on 18 June 1996.**

Treatment	Disease Index			
	Celebrity		Claudius	
	Inoculated Plants	Uninoculated Plants	Inoculated Plants	Uninoculated Plants
Uninoculated control	(-)	1.3	(-)	3.3
Inoculated control	95.6	48.7	71.2	23.3
Derosal	91.8	2.5	94.3	3.7
Bravo 500	96.3	37.0	61.8	21.2
Terraclor 45 Flo	70.6	15.8	63.7	26.6
Aura 750 EC	40.0	8.8	51.8	4.7
Octave	37.5	6.7	56.2	6.6
Amistar	85.0	13.7	76.9	5.4
Unix	94.4	27.4	55.0	11.3
Scala	97.5	26.2	93.7	34.5
Jonk	53.7	0.4	50.0	0.4
Folicur	84.3	15.8	50.0	5.8
Significance	***	***	***	***
LSD 5% (22 df)	47.83	14.83	47.83	14.83

Table 2: Untrimmed and trimmed yield of celery at harvest on 18 June 1996.

	Celebrity		Claudius	
	Untrimmed (g/plant)	Trimmed (g/plant)	Untrimmed (g/plant)	Trimmed (g/plant)
Uninoculated control	953	644	857	618
Inoculated control	844	385	943	621
Derosal	1078	745	963	650
Bravo 500	917	511	923	590
Terraclor 45 Flo	974	607	911	513
Aura 750 EC	338	0	293	31
Octave	958	622	953	672
Amistar	1058	697	907	654
Unix	970	561	960	661
Scala	935	526	913	502
Jonk	1059	693	968	740
Folicur	1066	646	948	612
Significance	***	***	***	***
LSD 5% (22 df)	118.55	127.70	118.55	127.70

Table 3: **Severity of infection by *S. sclerotiorum* and efficacy of fungicide treatments at harvest on 10 July 1997.**

Treatment	Disease Index	
	Inoculated Plants	Uninoculated Plants
Untreated	87.5	31.3
Terraclor 20D (x1)	78.8	26.3
Kresoxim-methyl (x4)	70.0	9.8
Folicur (x4)	86.3	15.0
Derosal (x2)	90.0	24.8
Derosal (x4)	41.3	2.0
Jonk (x2)	85.0	20.0
Jonk (x4)	41.3	1.5
Octave (x2)	71.3	16.8
Octave (x4)	80.0	20.3
Amistar (x2)	37.5	5.0
Amistar (x4)	27.5	2.5
Significance	***	***
LSD 5% (30 df)	29.04	10.39

Table 4: Untrimmed and trimmed yield of celery at harvest on 10 July 1997.

	Untrimmed (g/plant)	Trimmed (g/plant)
Untreated	961	555
Terraclor 20D (x1)	891	571
Kresoxim-methyl (x4)	919	616
Folicur (x4)	954	625
Derosal (x2)	851	554
Derosal (x4)	1017	666
Jonk (x2)	1068	677
Jonk (x4)	1022	667
Octave (x2)	971	611
Octave (x4)	972	613
Amistar (x2)	1020	691
Amistar (x4)	1006	640
Significance	NS	NS
LSD 5% (30 df)	(-)	(-)

Discussion

The primary aim of this investigation was to identify novel fungicides for *Sclerotinia* control for which Approval (On or Off-Label) could be sought following the loss of vinclozolin (Ronilan). In this respect the project has been very effective in identifying a number of products with excellent activity against this persistent soil-borne disease.

Carbendazim (Derosal) as used in this trials series was extremely effective when applied as a four-spray programme in both 1996 and 1997, though was disappointing when applied as two early timed sprays in the second year. This might explain the reported previous poor performance of this product experienced by some growers. In addition, resistant strains of the fungus may be present in pathogen populations commercially, though this has not been examined as part of this project. Since this project was commissioned many On-Label uses of carbendazim have been withdrawn, including Derosal. To counter this, a Specific Off-Label approval for the use of Bavistin DF (SOLA No. 1002/95) has been secured as part of the HDC/HRI SOLA programme.

The other outstanding fungicides identified in this investigation were Jonk (diethofencarb + carbendazim) and Amistar (azoxystrobin). Both of these products contain active ingredients with differing modes of action to the benzimidazole fungicides (eg carbendazim) and therefore could be extremely useful in developing an anti-resistance strategy. The former product contains carbendazim and, in view of the performance of this active ingredient alone, it is difficult to ascertain the additional benefit of the diethofencarb component of the mixture. A product containing diethofencarb alone was not available during this study and therefore a direct comparison could not be made. Currently, there are no fungicides containing diethofencarb registered for use in the UK and therefore a minor use authorisation cannot be sought at the present time.

Azoxystrobin (Amistar) is one of a new group of strobilurin fungicides with broad spectrum activity against a range of pathogens and which is now available commercially in the UK for use on cereals. HDC sponsored trials have already demonstrated good activity against *Botrytis cinerea* in tomato (PC 98a) and downy mildew and Botrytis in lettuce (PC 20a and PC 117 respectively). Good activity has also been reported elsewhere against *Rhizoctonia* and some of the leaf-spot diseases eg *Septoria* spp. Currently efficacy against these pathogens on the celery crop has not been tested.

It is recommended therefore that the use of Amistar should be pursued further in order to secure either an On-Label or a Specific Off-Label Approval for use in the celery crop. This would provide excellent broad spectrum protection, in conjunction with carbendazim, against the various diseases affecting the crop and help prevent the development of fungicide resistant strains in the future.

Terraclor 20D was relatively disappointing in this evaluation. However, this is not particularly surprising in view of the intended use of this product against soil-borne sclerotial infection in lettuce. Currently the product has an On-Label Approval on a range of crops including lettuce, though it does not include celery. The product is likely to provide some suppression of the disease in situations where an existing sclerotial population of *S. sclerotiorum* is known to occur in the soil (ie from a previous infected crop). In the study reported here a residual sclerotial population was not present in the soil, apart from the 'conditioned' sclerotia applied artificially. However, increasing residual sclerotial populations would be expected to occur as MeBr use is reduced and ultimately phased out. It should be considered therefore as a potential alternative option for disease control in these specific situations and consideration given, following discussion with Hortichem, to extending the use to include celery.

Conclusions

- Pink-rot (*Sclerotinia sclerotiorum*) was artificially established in protected celery in two successive years and provided a good test for fungicide performance.

- Differences in cultivar susceptibility were apparent. The green cv. Claudius was more tolerant than the susceptible self-blanching cv. Celebrity.

- Disease spread occurred primarily by mycelial infection following leaf to leaf contact, though a low level of air-borne ascospores from outside may have contributed to some of the observed dissemination into guard areas and uninoculated control plots.

- Attempts at generating ascospore infection via apothicia from germinating 'buried' sclerotia was unsuccessful in 1997.

- Several fungicides were identified with good activity against the disease.

- Carbendazim was very effective when applied at a four-spray programme and Bavistin DF should be used according to the Specific Off-Label Approval (No. 1002/95) where there is a risk of *Sclerotinia* in the crop.

- Of the other candidate fungicides evaluated Amistar (azoxystrobin) is considered to be the most promising as it now has a UK approval on cereals and is available commercially. Furthermore, it is claimed to be effective against a broad range of diseases apart from *Sclerotinia* eg *Botrytis*, *Rhizoctonia* and various leaf-spot pathogens such as *Septoria*. With its contrasting mode of action it would be very useful in an anti-resistance strategy. Efforts should be made to secure either an On-Label approval or a Specific Off-Label Approval for use on celery.

- Where existing soil-borne sclerotia of *S. sclerotiorum* are present in the soil the use of Terraclor 20D could be advantageous. It is unlikely to provide much control resulting from secondary mycelial spread from primary 'infector' plants or following secondary infection by air-borne ascospores however. Currently the label recommendation does not extend to celery though consideration should be given following discussion with Hortichem, to pursuing an extension of the current On-Label approval to include celery.

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References

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