FINAL REPORT
PROJECT FV136

CARROTS:

CONTROL OF FOLIAR AND STORAGE DISEASES

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INDEX

	Page
Relevance to growers and practical applications	1
Application	1
Summary	1
Action points for growers	2
Practical and financial benefits anticipated	3
Experimental Section	4
Introduction	4
Materials and Methods	5
1. Powdery mildew experiments	5
2. Alternaria experiment	7
Results	9
1. Powdery mildew experiment 1993	9
Site 1, Burscough, Lancs	9
Site 2, Methwold Hythe, Norfolk	11
Site 3, West Row, Suffolk	13
2. Alternaria experiment 1993	15
3. Powdery mildew experiments 1994	17
Site 1, ADAS Arthur Rickwood	17
Site 2, Burscough, Lancs	21
4. Alternaria and crown rot experiment 1994	25
Discussion	29
References	31
Appendix - site details	32
Contract	

RELEVANCE TO GROWERS AND PRINCIPLE APPLICATIONS

Application

This project investigated the effects of fungicides on foliar disease, crown rot and yield.

A range of fungicides controlled powdery mildew and delayed senescence of the foliage but had no effect on yield. In 1993/94 control of crown rot was achieved at 2 out of 3 sites with the fungicides Corbel, Mildothane and Compass. Crown rot was not controlled in 1992/93. Crown rot was confirmed for the first time in East Anglia in 1993/94. Off-label approval has been granted for the use of Compass and Corbel on carrots, but further work is needed to identify critical timings of these fungicides for crown rot control.

Summary

This project investigated the benefit of controlling foliar disease of carrots before and after over-wintering crops under straw. Experiments were located in commercial carrot crops in Lancashire and East Anglia during 1992/93 and 1993/94 in areas with a recent history of powdery mildew, alternaria blight and crown rot.

In 1992/93,three experiments were carried out on powdery mildew control and one experiment concentrated on control of alternaria blight. Powdery mildew occurred at low levels and was controlled by single and double spray treatments of Spinnaker and a range of other fungicides. In Lancashire, infection in early August did not develop further because of late wet weather conditions. Leaf dieback caused by *Alternaria dauci* and natural senescence was partially delayed by including Bravo, Rovral Flo, Ronilan and Corbel. There were no benefits in terms of yield or quality from applying fungicides. Foliar diseases were only encountered at low level and fungicides may produce benefits if more severe disease epidemics occur earlier in the season. Treatments did not control severe crown rot which developed at the Lancashire site.

In 1993/94, foliar diseases were present at low levels but foliar dieback was apparent from late August onwards. Crown rot was detected prior to strawing down (0.2 - 3.1% roots affected) at all 3 sites and this included the first confirmed record in East Anglian crops. Crown rot affected 11.6 - 43.3% roots at these sites by late March. Foliar dieback was reduced by all but the two spray treatment of Mildothane at one Lancashire site and by all treatments except Corbel at Arthur Rickwood. At a second Lancashire site, the combination of late August + late October sprays did not affect foliar dieback. *Itersonilia perplexans* was associated with dieback of foliage in Lancashire and an *Itersonilia* sp. was confirmed at ADAS Arthur Rickwood. Good control of crown rot was achieved with two sprays of Corbel, Mildothane and Compass applied in early October and late

October in Lancs. Crown rot control with the same fungicides applied in mid September and mid October was also demonstrated at ADAS Arthur Rickwood. A two spray programme applied in late August and late October at a second site in Lancs did not give significant control of crown rot but trends in the data were comparable to the other sites. Further work is needed to identify optimum use timing for crown rot control with Corbel which has now an off-label approval for use on carrots. Reliable experimental sites are available for such work.

Action points for growers

- Control of crown rot with fungicides was demonstrated for the first time in 1993/94 and provides support for this problem being a disease rather than a nutritional or physiological disorder.

- The fungus *Itersonilia perplexans* was found readily on carrot crowns in the autumn and is a candidate causal pathogen.

- Crown rot was confirmed for the first time in East Anglia and poses a threat to carrot production in Eastern Counties. The disease may be present but unrecognised in carrot crops and can only be detected reliably by slicing off the crown.

- Growers should check for crown rot symptoms especially before crops are selected for strawing down. Symptoms can be detected by slicing off the crown.

- Corbel, Mildothane and Compass produced the most effective control of crown rot in 1993/94, a two spray programme in October appeared to be rather more effective than two spray programmes starting in August or September.

- Further work is needed to identify optimum timing of Corbel (Corbel now has off-label approval for use on carrots - Approval No. 1058/94) and Compass (off-label approval for use on carrots - Approval number 1264/94).

- Control of low levels of powdery mildew and alternaria blight and delaying senescence of the foliage had no effect on yield or quality. Studies are required in crops with severe foliar disease epidemics.

Practical and financial benefits anticipated

The project provides strong circumstancial evidence that crown rot is a fungal disease and that the problem can be controlled with fungicides such as Corbel and Compass. Further fundamental studies of *Itersonilia* spp. on carrots are now being funded by HDC and results from this project support the need to investigate their pathogenicity. This project offers immediate practical benefits to carrot growers by identifying the first case of crown rot in East Anglia and suggests that a routine search is made for symptoms by slicing off carrot crowns. Given that crown rot develops most rapidly after strawing down, it is important that crops for strawing down are selected after examination for crown rot. Corbel and Compass have now received off-label approval for use on carrots but it is clear that further work in the timing of applications of these product is needed to optimise its use.

Recommendations to scrutinise crops, select crops for over-wintering more carefully and use Corbel could lead to a 50% reduction in crown rot problems. Perhaps more importantly a threat to the carrot industry in Eastern Counties has been identified and strategic action is needed to ensure that this does not develop further. Direct benefits to the carrot industry whose output is valued at about £80m per annum, are estimated to be £2million per annum by direct reduction of crown rot severity. The benefits of maintaining production in Eastern Counties would be substantially larger.

EXPERIMENTAL SECTION

INTRODUCTION

Research work on carrot diseases in the UK has concentrated mainly on cavity spot and other root problems; little has been performed on foliar diseases. The main foliar diseases of carrots are powdery mildew, *Alternaria* blight and Carrot Motley Dwarf Virus. Powdery mildew is becoming increasingly common in carrot growing areas, e.g. East Anglia and Lancashire. If there is a gradual climatic change to warmer, drier summer weather, then powdery mildew could become more wide spread and attacks more severe. The effect of the disease on root yield and quality has not been investigated. There is a Specific Off-Label Approval for the fungicide Spinnaker and this, and other mildewicides, need to be evaluated in trials to determine efficacy and effect on yield and quality of carrots.

Alternaria blight (*A. dauci)* occurs sporadically, usually in warm, wet summers; work on its control and effect on yield have not been performed. There is a label recommendation for Chiltern Kocide 101 but other fungicides, e.g. Rovral, Ronilan, Bravo, need to be evaluated. Other species of *Alternaria* (e.g. *A. radicina*) also occur and could be causing loss of foliage and affecting root yield in some situations.

Foliar die-back and subsequent crown rotting overwinter have been a problem in Lancashire since 1987. Further work on control of the foliage stage of this problem prior to covering for overwintering field storage needs to be performed.

The objective of the project is to quantify the effects of foliar diseases on yield and to determine the best fungicides for control. The relationship between health of foliar tissue and subsequent condition of roots under field storage can also be examined.

In the 1992-93 growing season, 4 field experiments were carried out. One in Lancashire and two in East Anglia were aimed primarily at powdery mildew control and a further one in East Anglia was performed on *Alternaria* control. Crown, and other root rots were also assessed at each site. During 1993-94 a further 3 experiments were carried out with two sites in Lancashire and one in East Anglia at ADAS Arthur Rickwood Research Centre.

MATERIALS AND METHODS - 1993/94 Experiments

1. Powdery Mildew Experiments 1993/94

Two experiments were carried out in commercial crops, one in Lancashire and one at ADAS Arthur Rickwood, Cambs. A randomised block design with four replicates was used at both sites.

Table 1. Treatment details.

1. Untreated control
2. Spinnaker (0.5 l/ha) at first signs of mildew only
3. Spinnaker (0.5 l/ha) at first signs of mildew + 3 weeks only
4. Corbel (1.0 l/ha) at first signs of mildew + 3 weeks only
5. Fungaflor (0.5 l/ha) at first signs of mildew + 3 weeks only
6. Bravo 500 (3.0 l/ha) at first signs of mildew + 3 weeks only
7. Mildothane (2.2 l/ha) at first signs of mildew + 3 weeks only
8. Bravo (3 l/ha) mid August followed by Spinnaker (0.5 l/ha) mid-September
9. Bravo (3 l/ha) early September, following by Spinnaker (0.5 l/ha) early October
10. Compass (3 l/ha) mid-August and mid-September

Table 2. Dates of treatment application in powdery mildew experiments 1993-94.

	Site 1. ADAS Arthur Rickwood	Site 2. Lancashire
1.	-	-
2.	15 September	7 October
3.	15 September and 15 October	7 October and 26 October
4.	15 September and 15 October	7 October and 26 October
5.	15 September and 15 October	7 October and 26 October
6.	15 September and 15 October	7 October and 26 October
7.	15 September and 15 October	7 October and 26 October
8.	13 August and 15 September	16 August and 20 September
9.	10 September and 15 October	1 September and 7 October
10.	13 August and 15 September	16 August and 20 September

Treatment application

ADAS Arthur Rickwood, Cambs.

All treatments were applied in 250 l/ha of water using an Oxford Precision sprayer with 11003 nozzles used on 8 September or 11002 nozzles on other dates at 200 kPa (2 bar) pressure.

Burscough, Lancs.

Treatments were applied in 250 l/ha water using an Oxford Precision sprayer fitted with F80-02 nozzles operated at 200 kPa (2 bar) pressure.

Husbandry and assessments

ADAS Arthur Rickwood, Cambs.

The crop cv. Nandor, drilled on 30 April 1993, was grown to a commercial standard but without any fungicides except Fubol 58WP which was applied on 13 May for cavity spot control. Full site details are given in the Appendix.

Plant counts were made on 30 June 1993 from 1 m x 4 rows. On 18 October 1993, each plot was assessed for percentage of leaves with powdery mildew, percentage with necrotic foliage, 'foliage browning' or with healthy green foliage.

A similar assessment of powdery mildew and foliage browning was made on 10 individual plants per plot on 18 October 1993.

On 10 November 1993, the incidence of crown rotting was assessed on 40 plants per plot by cutting horizontally across the carrot just below the crown. Severity of crown rot was recorded on a 0 - 3 scale (where 0 = no crown rot and 3 = severe crown rot).

The first harvest was taken on 9 November 1993 from 2 m x 2 rows (1.83 m^2). At this harvest, yields in diameter size grades (<19, 19-25, 25-32, 32-44, >44 mm) were recorded. The number (%) of roots which were fanged, split, affected by violet root rot, or cavity spot was recorded.

After harvesting in November, the experiment was protected from frost using 25 t/ha of straw. A second harvest (2 m x 2 rows) was taken on 28 March 1994. Yields in size grades were recorded as for the first harvest.

A detailed assessment of crown rotting was also made on every plant taken from the 2 m x 2 row area (at least 150 plants per plot). Disease severity data were summarised as a disease index (0 - 100).

Burscough, Lancs.

The crop cv. Narman was drilled on 24 April 1993 and was grown to a commercial standard with Fubol 58WP applied overall at time of drilling for cavity spot control.

Powdery mildew did not occur in the crop and treatments due to be applied at the first signs of mildew were applied on 7 October.

A whole plot assessment was made of the percentage foliar die-back on 26 October. Yield by diameter size grades (<19, 19-25, 25-32, 32-44 and >44 mm) were taken from 1 m lengths of two centre rows within each plot (9.925m²) on 28 October. The crop was then overwintered under 50 t/ha straw. Crown rot was assessed on all lifted roots (mean 110 roots/plot) using a 0 - 3 index as described for the ADAS Arthur Rickwood site.

A second yield and crown rot assessment was made on 23 March 1994.

2. Alternaria and Crown Rot Experiment 1993/94

This experiment was carried out at Burscough, Lancs and is referred to as Expt. 2. in tables of results.

Table 3. Treatment details.

1. Untreated control
2. Rovral Flo (2.0 l/ha) at first signs of die-back and pre-strawing down
3. Compass (3.0 l/ha) at first signs of die-back and pre-strawing down
4. Corbel (1.0 l/ha) at first signs of die-back and pre-strawing down
5. Bravo 500 (3.0 l/ha) at first signs of die-back and pre-strawing down
6. Storite Clear (2.0 l/ha) at first signs of die-back and pre-strawing down
7. Rovral Flo (2.0 l/ha) at first signs of die-back and Storite Clear (2.0 l/ha) pre-strawing down
8. Compass (3.0 l/ha) at first signs of die-back and Storite Clear (2.0 l/ha) pre-strawing down
9. Corbel (1.0 l/ha) at first signs of die-back and Storite Clear (2.0 l/ha) pre-strawing down
10. Bravo 500 (3.0 l/ha) at first signs of die-back and Storite Clear (2.0 l/ha) pre-strawing down

Treatments were applied on 24 August (first signs of die-back) and 26 October (pre-strawing down).

Treatment application

Treatments were applied in 250 l/ha water using Oxford Precision Sprayer with F80-02 nozzles operated at 200 kPa (2 bar) pressure.

Husbandry and assessments

The crop cv. Narman was drilled on 24 April 1993 in four row beds. Foliar disease assessments were made on the whole plot and on 10 plants/plot and expressed as percentage foliar die-back. Foliar die-back was first noticed in the third week of August and first sprays were applied at that stage. Yield by diameter size grades (<19, 19-25, 25-32, 32-44 and >44 mm) was assessed pre-strawing down on a one metre row length from the two centre drills (0.925m^2) on 28 October. Crown rot was assessed on all lifted roots using a 0 - 3 index and data was used to calculate a disease index (0 - 100 scale).

A second yield and crown rot assessment was made on 23 March 1994 using the methods described above.

3. 1992/93 Experiments

Details of Materials and Methods were provided in the first report of this project. Summary data are provided in tables in the Results section.

Design and statistical analysis

All experiments were a randomised block with four replicates. Where necessary assessment data were transformed for statistical analysis. Comparisons between treatments made using these transformed data are presented in the Results section.

RESULTS

Summary of Experiments in 1992 - 93

1. Powdery Mildew Trials

Site 1 - Burscough, Lancs

Powdery mildew was first noted in the trial in the first week of August. This prompted the first spray which was applied on 14 August. By the time of the next spray applications on 5 September, powdery mildew was noticeable on the unsprayed plots but levels had declines and by 25 September mildew had disappeared completely.

There was reasonable agreement between the percentage of foliar die-back assessed by the whole plot and individual plant methods (Table 4). Bravo significantly reduced the percentage of foliar die-back, assessed by the whole plot method.

No treatments significantly affected yield at either the November or March harvest (Table 5).

No treatment significantly affected the resulting crown rot levels after winter although all treatments except Spinnaker tended to reduce the disorder (Table 6). It was noteworthy that the lowest crown rot index was achieved by the Bravo treatment.

Table 4. Effect of fungicide treatments on foliar die-back Burscough, Lancs, 1992.

Treatment		Whole plot assessment % foliar die-back 20 October 1992	Ten plants per plot % foliar die-back 23 October 1992
1.	Control	36.0	40.5
2.	Spinnaker 14/8 and 5/9	34.8	39.9
3.	Spinnaker 5/9 and 25/9	31.8	41.0
4.	Spinnaker 14/8	37.5	41.2
6.	Corbel 14/8 and 5/9	31.8	37.9
7.	Fungaflor 14/8 and 5/9	38.0	40.9
8.	Mildothane 14/8 and 5/9	32.5	35.9
9.	Bravo 500 14/8 and 5/9	25.2	30.2
10.	Storite 14/8 and 5/9	31.0	36.0
LSD (5%)		5.33	NS

NS = No significant differences between treatment means

Table 5. Effect of fungicide treatment on total yield of carrots on 3 November 1992 and 23 March 1993, Burscough, Lancs.

Treatment		Total yield (t/ha) 3 November	Total yield (t/ha) 23 March
1.	Control	65.23	67.21
2.	Spinnaker 14/8 and 5/9	62.05	66.78
3.	Spinnaker 5/9 and 25/9	64.15	68.04
4.	Spinnaker 14/8	63.70	72.00
6.	Corbel 14/8 and 5/9	56.43	71.13
7.	Fungaflor 14/8 and 5/9	59.07	72.02
8.	Mildothane 14/8 and 5/9	62.93	70.87
9.	Bravo 500 14/8 and 5/9	58.86	68.30
10.	Storite 14/8 and 5/9	65.64	71.37
LSD (5%)		NS	NS

NS - no significant differences between treatment means

Table 6. Effect of fungicide treatment on crown rot at Burscough, Lancs, 23 March 1993.

Treatment		% Healthy roots	Crown rot index
1.	Control	26.0	51.9
2.	Spinnaker 14/8 and 5/9	22.5	53.8
3.	Spinnaker 5/9 and 25/9	30.5	46.3
4.	Spinnaker 14/8	33.0	46.6
6.	Corbel 14/8 and 5/9	29.3	47.6
7.	Fungaflor 14/8 and 5/9	34.2	44.8
8.	Mildothane 14/8 and 5/9	43.8	37.8
9.	Bravo 500 14/8 and 5/9	49.0	32.9
10.	Storite 14/8 and 5/9	38.8	39.8
LSD (5%)		NS	NS

NS - No significant differences between treatment means

Site 2 - Methwold Hythe, Norfolk

When whole plots were assessed on 16 October there were very low levels of powdery mildew (Table 7). There was a higher ($P<0.05$) level of powdery mildew on the untreated plots than on all fungicide treated plots. However this data showed a skewed distribution and some caution is needed particularly when comparing the various products. Spinnaker performed consistently well.

When whole plots were assessed on 16 October (Table 8) there was a greater degree of foliar die-back on the untreated plots than on all fungicide treatments except Storite Clear. When individual plants were assessed, there were similar levels of foliar die-back in all treatments.

The marketable yields of carrots (over 25 mm) were also similar for all treatments at both harvest (Table 9).

In December there were, on average, 8.7% of carrots with rots but no differences between fungicide treatments (Table 10). In January there were 11.6% of carrots with rots. This level was not reduced by fungicide treatment. In fact, treatment 2 (two early applications of Spinnaker) had more ($P<0.05$) carrots with rots.

Rhizoctonia carotae, Sclerotinia and *Fusarium* were found in the rots at the tops of the carrots. There were low levels of *Thielaviopsis* but these were not always associated with the crown area of the carrot. *Chalaropsis* was sought, but not found on these samples. No crown rot similar to that found in Lancashire was present.

Table 7. Effects of treatments on percentage of foliage with powdery mildew at Methwold Hythe on 16 October 1992.

Treatment	% Powdery Mildew Whole plot assessment
1. Untreated	1.63
2. Spinnaker 26/8 and 14/9	0.25
3. Spinnaker 14/9 and 5/10	0.10
4. Spinnaker 28/9	0.13
5. Spinnaker 28/9 and 15/10	0
6. Corbel 28/9 and 15/10	0.88
7. Fungaflor 28/9 and 15/10	0.13
8. Mildothane 28/9 and 15/10	0.50
9. Bravo 500 28/9 and 15/10	0.25
10. Storite Clear 28/9 and 15/10	0
LSD (5%)	Data skewed

Table 8. Effect of treatment on percentage of foliage showing foliar 'die-back; at Methwold Hythe, Norfolk on 19 October 1992. (Angular transformated data in brackets).

Treatment	% Foliar die-back		
	Whole plot assessment		Means of 10 plants
1. Untreated	12.50	(20.2)	3.97
2. Spinnaker 26/8 and 14/9	5.50	(13.1)	7.87
3. Spinnaker 14/9 and 5/10	5.98	(13.9)	7.69
4. Spinnaker 28/9	6.00	(13.3)	6.92
5. Spinnaker 28/9 and 15/10	5.75	(13.0)	5.37
6. Corbel 28/9 and 15/10	4.50	(11.3)	5.62
7. Fungaflor 28/9 and 15/10	5.50	(12.1)	5.67
8. Mildothane 28/9 and 15/10	6.00	(13.4)	6.07
9. Bravo 500 28/9 and 15/10	7.50	(14.8)	4.95
10. Storite Clear 28/9 and 15/10	8.25	(14.9)	3.87
LSD (5%)		4.94	NS

NS - No significant differences

Table 9. Effect of treatment on total yield at Methwold Hythe on 11 December 1992 and 11 January 1993.

Treatment	Total yield (t/ha)	
	December	January
1. Untreated	69.4	74.8
2. Spinnaker 26/8 and 14/9	81.1	61.1
3. Spinnaker 14/9 and 5/10	59.9	72.1
4. Spinnaker 28/9	69.2	58.4
5. Spinnaker 28/9 and 15/10	74.9	82.4
6. Corbel 28/9 and 15/10	77.2	79.4
7. Fungaflor 28/9 and 15/10	85.1	75.2
8. Mildothane 28/9 and 15/10	76.2	71.4
9. Bravo 500 28/9 and 15/10	64.2	69.8
10. Storite Clear 28/9 and 15/10	68.4	66.7
SED (26 df)	NS	NS
CV (%)	17.0	17.2

NS - No significant differences

Table 10. Effects of fungicide treatments on percentages of rotten carrots (data angular transformed) at Methwold Hythe, Norfolk 1992 - 93.

Treatment	% Rotten carrots	
	11 December	11 January
1. Untreated	8.1	8.9
2. Spinnaker 26/8 and 14/9	10.0	18.1
3. Spinnaker 14/9 and 5/10	10.0	8.3
4. Spinnaker 28/9	8.7	16.9
5. Spinnaker 28/9 and 15/10	9.4	9.6
6. Corbel 28/9 and 15/10	11.4	10.1
7. Fungaflor 28/9 and 15/10	4.8	6.4
8. Mildothane 28/9 and 15/10	8.0	11.6
9. Bravo 500 28/9 and 15/10	10.3	13.1
10. Storite Clear 28/9 and 15/10	7.2	13.3
LSD (5%)	NS	7.64

NS - No significant differences

Site 3 - West Row, Suffolk

When first assessed for disease on 26 August 1992, prior to application of the first fungicide treatments, there were no discernable differences between plots. When assessed again on 23 September, *Botrytis cinerea* (grey mould) was present at very low levels and 0.1 to 0.5% of plants showed yellowing and necrosis of foliage. *Alternaria radicina* and trace levels of *Alternaria dauci* were confirmed in the crop.

A whole plot assessment on 15 October showed that there were very low levels of powdery mildew (Table 11). There was a significantly higher ($P<0.05$) level of powdery mildew on the untreated plots than on treatments 2 (two applications of Spinnaker on 14 September and 5 October) and 8 (two applications of Rovral). At the next assessment on 25 November, the overall severity of powdery mildew had slightly increased but there were no differences between treatments.

When whole plots were assessed on 15 October and 25 November (Table 12), treatments did not significantly reduce foliar die-back. There were no differences between treatments within any individual size grade nor in total marketable yield of carrots (Table 12).

There were on average, 3.18% of carrots with rots but with no differences between fungicide treatments (Table 13). There were only 0.2% of carrots affected by rots in the crown area.

Table 11. Effects of treatments on percentage of foliage with powdery mildew at West Row, Suffolk on 15 October and 25 November 1992.

Treatment		% Powdery Mildew		
		15 October		25 November
1.	Untreated	0.88	(5.3)*	0.62
2.	Spinnaker 14/9 and 5/10	0	(0.0)	0.25
3.	Spinnaker 28/9 and 19/10	0.25	(1.4)	0.25
4.	Spinnaker 28/9 and 19/10	0.63	(3.1)	0.75
5.	Fungaflor 28/9 and 19/10	0.38	(2.5)	1.37
6.	Mildothane 28/9 and 19/10	0.38	(2.5)	0.25
7.	Bravo 500 28/9 and 19/10	0.75	(4.3)	0.25
8.	Rovral 28/9 and 19/10	0.13	(1.0)	1.25
LSD (5%)		0.42	3.82	NS

* Angular transformed data analysed

NS - No significant differences

Table 12. Effect of treatment on percentage of foliage showing foliar die-back at West Row, Suffolk on 15 October and 25 November 1992 and total yield on 14 December 1992.

Treatment		% Foliage die-back		Total yield
		15 October	25 November	(t/ha)
1.	Untreated	7.75	16.2	46.8
2.	Spinnaker 14/9 and 5/10	4.50	11.7	48.2
3.	Spinnaker 28/9 and 19/10	3.50	12.5	47.1
4.	Corbel 28/9 and 19/10	4.00	10.0	50.5
5.	Fungaflor 28/9 and 19/10	4.50	13.7	49.2
6.	Mildothane 28/9 and 19/10	5.25	15.0	48.1
7.	Bravo 500 28/9 and 19/10	4.00	13.7	49.4
8.	Rovral 28/9 and 19/10	5.25	22.5	51.1
LSD (5%)		NS	NS	NS

NS - No significant differences

Table 13. Effects of treatments on percentages of total rots and 'crown' rots at West Row, Suffolk on 14 December 1992 (Angularly transformed data in brackets).

Treatment		% Rotten carrots	
		Total	Crown rots
1.	Untreated	0.82 (5.7)	0.19 (1.24)
2.	Spinnaker 14/9 and 5/10	2.73 (7.9)	0.34 (2.86)
3.	Spinnaker 28/9 and 19/10	2.38 (6.2)	0.12 (1.01)
4.	Corbel 28/9 and 19/10	1.87 (6.6)	0.00 (0.00)
5.	Fungaflor 28/9 and 19/10	5.76 (11.2)	0.10 (0.91)
6.	Mildothane 28/9 and 19/10	2.43 (8.4)	0.36 (2.44)
7.	Bravo 500 28/9 and 19/10	3.25 (9.7)	0.00 (0.00)
8.	Rovral 28/9 and 19/10	6.22 (11.9)	0.45 (1.92)
LSD (5%)		(9.94)	(3.31)

2. Alternaria Trial

Alternaria radicina was found on samples from the site on 29 September and *Alternaria dauci* was found on 15 October. When assessed on 4 November, after both treatment application dates, the carrots generally had 7 mature leaves and 1-2 immature leaves. The oldest leaves were invariably dead (and of a smaller size than the later leaves). In the worst affected plots, there was considerable leaf tipping and die-back. In some plots there were small patches where most of the foliage was dead.

Powdery mildew was observed at 0.5% on only two plots (one untreated, and one where two applications of Rovral had been applied).

The fungicides tended to reduce the amount of foliar die-back, recorded as dead tissue (Table 14) and to increase the percentage of green tissue into November. One application of Rovral Flo and two sprays of Corbel and Bravo 500 had less ($P<0.05$) dead tissue. Rovral Flo and Ronilan FL gave more ($P<0.05$) active green tissue than the untreated carrots.

There were no effects of treatments on total yield (Table 15) or rotted carrots.

Table 14. Effect of fungicide on percentage of foliage with dead and green tissue at ADAS Arthur Rickwood on 4 November 1992.

Treatment		% Foliage	
		Dead	Green
1.	Untreated	46.2	35.2
2.	Rovral Flo 8/10	31.5	53.7
3.	Rovral Flo 8/10 and 29/10	37.5	46.2
4.	Ronilan Fl 8/10 and 29/10	37.0	50.0
5.	Compass 8/10 and 29/10	40.0	42.5
6.	Corbel 8/10 and 29/10	32.5	48.7
7.	Bravo 500 8/10 and 29/10	32.5	47.5
LSD (5%)		13.33	14.60

Table 15. Effects of fungicide applications on total yield of carrots at ADAS Arthur Rickwood on 11 November 1992 and 12 March 1993.

Treatment		% Rotted carrots	Total yield (t/ha)	
		March 1993	11 November	12 March
1.	Untreated	0.8 (3.57)	110	106
2.	Rovral Flo 8/10	2.1 (5.76)	95	96
3.	Rovral Flo 8/10 and 29/10	0.2 (1.32)	101	107
4.	Ronilan Fl 8/10 and 29/10	0.7 (4.08)	98	108
5.	Compass 8/10 and 29/10	0.8 (3.42)	107	118
6.	Corbel 8/10 and 29/10	0 (0.0)	106	110
7.	Bravo 500 8/10 and 29/10	0.5 (3.42)	109	107
LSD (5%)		NS	12.4	27.1

Angularly transformated data in brackets

RESULTS

1. Powdery mildew experiments 1993/94

Site 1. ADAS Arthur Rickwood

Plant population and yield

On 30 June 1993, there were on average 97 plants per m^2 with no differences between plots. On 28 March 1994, there were 93 plants/m^2 with no differences between fungicide treatments. At harvest on 9 November, there were on average 111.1 t/ha of carrots with no differences between fungicide treatments (Table 16). On 28 March 1994 after a period of storage under straw in the field, there were 66.3 t/ha of carrots. Again, there were no significant differences between treatments (Table 17).

There were very few split or fanged carrots at either harvest and with no differences between the fungicide treatments.

Rotting

On 9 November 1993 there were 0.04 t/ha or 2.4% of rotten carrots (exterior rots). There were no differences between treatments.

Powdery mildew

The disease was present in the field at very low levels (< 1%). No differences between treatments were detected.

Foliage die-back

On 18 October 1993, 28.1% of the carrot foliage on the whole plot had turned brown due to *Alternaria* spp. Treatments 2 (Spinnaker 15/9), 6 (Bravo 15/9 + 15/10), 8 (Bravo 10/9 + Spinnaker 15/10) and 9 (Bravo 10/9 + Spinnaker 15/10) had less foliage browning than the untreated plots (Table 18). These treatments and treatment 5 (Fungaflor 15/9 + 15/10) also had more green foliage than the untreated plots.

Table 16. Fungicide treatment effects on yields (t/ha) in diameter (mm) size grades at ADAS Arthur Rickwood on 10 November 1993.

Treatment		Date of application	Yield (t/ha)				
			19-25	25-32	32-44	>44	Total
1.	Untreated		5.9	25.3	41.0	33.2	111.4
2.	Spinnaker	15/9	4.0	22.0	38.6	36.2	118.2
3.	Spinnaker	15/9, 15/10	4.3	25.9	36.5	29.3	104.1
4.	Corbel	15/9, 15/10	6.1	27.9	44.4	27.9	112.7
5.	Fungaflor	15/9, 15/10	4.4	25.3	35.5	36.1	108.2
6.	Bravo 500	15/9, 15/10	4.3	23.2	43.3	33.5	111.9
7.	Mildothane	15/9, 15/10	4.5	22.7	35.7	38.5	109.0
8.	Bravo, Spinnaker	13/8, 15/9	3.5	25.1	40.5	32.6	108.3
9.	Bravo, Spinnaker	10/9, 15/10	4.4	22.3	48.6	32.8	114.6
10.	Compass	13/8, 15/9	4.7	20.7	45.6	31.9	111.2
	Mean						111.1
	LSD (5%)		NS	NS	NS	NS	NS
	CV (%)		59.3	23.0	11.6	16.1	9.3

NS - No significant differences

Table 17. Fungicide treatment effects on yields (t/ha) in diameter (mm) size grades at ADAS Arthur Rickwood on 28 March 1994.

Treatment		Date of application	Yield (t/ha)				
			19-25	25-32	32-44	>44	Total
1.	Untreated		6.6	26.5	44.7	27.1	109.5
2.	Spinnaker	15/9	2.9	20.0	39.9	38.0	105.9
3.	Spinnaker	15/9, 15/10	4.0	18.9	47.5	31.7	106.3
4.	Corbel	15/9, 15/10	3.3	21.2	44.8	31.6	103.5
5.	Fungaflor	15/9, 15/10	5.4	18.8	41.9	32.6	104.5
6.	Bravo 500	15/9, 15/10	4.0	23.4	41.9	35.8	112.4
7.	Mildothane	15/9, 15/10	3.5	21.9	42.9	33.6	108.4
8.	Bravo, Spinnaker	13/8, 15/9	3.6	25.4	42.0	31.8	110.3
9.	Bravo, Spinnaker	10/9, 15/10	3.4	27.0	44.3	32.5	112.8
10.	Compass	13/8, 15/9	2.6	24.9	45.6	29.8	110.6
	Mean						108.4
	LSD (5%)		NS	NS	NS	NS	NS
	CV (%)		48.4	18.8	13.9	16.1	5.2

NS - No significant differences

Table 18. Foliage browning and green foliage on whole plot (data angularly transformed with actual data in brackets) at ADAS Arthur Rickwood on 18 October 1993.

Treatment		Date of application	% foliage browning		% green foliage	
1.	Untreated		32.1	(20)	57.9	(71)
2.	Spinnaker	15/9	21.6	(11)	68.4	(86)
3.	Spinnaker	15/9, 15/10	27.0	(14)	63.0	(79)
4.	Corbel	15/9, 15/10	26.5	(18)	63.5	(80)
5.	Fungaflor	15/9, 15/10	24.3	(14)	68.2	(85)
6.	Bravo 500	15/9, 15/10	16.8	(9)	73.2	(91)
7.	Mildothane	15/9, 15/10	23.9	(14)	66.1	(83)
8.	Bravo, Spinnaker	13/8, 15/9	21.8	(14)	70.3	(88)
9.	Bravo, Spinnaker	10/9, 15/10	17.9	(13)	73.2	(91)
10.	Compass	13/8, 15/9	28.1	(13)	61.9	(78)
	LSD (5%)		8.99		9.19	

The individual plant assessments of foliage browning are shown in Table 19. All fungicide treatments except programme 4 (Corbel) reduced the amount of foliage browning.

Table 19. Foliage browning on individual plants (data angularly transformed with actual figures in brackets) at ADAS Arthur Rickwood, 18 October 1993.

Treatment		Date of application	% foliage browning on individual plants	
1.	Untreated		26.7	(21)
2.	Spinnaker	15/9	19.4	(11)
3.	Spinnaker	15/9, 15/10	21.5	(14)
4.	Corbel	15/9, 15/10	24.7	(18)
5.	Fungaflor	15/9, 15/10	22.0	(14)
6.	Bravo 500	15/9, 15/10	17.1	(9)
7.	Mildothane	15/9, 15/10	21.5	(14)
8.	Bravo, Spinnaker	13/8, 15/9	22.1	(14)
9.	Bravo, Spinnaker	10/9, 15/10	20.8	(13)
10.	Compass	13/8, 15/9	21.1	(13)
	LSD (5%)		4.35	

Crown rot

Internal black-brown discoloration around the core of the carrot, typical of 'crown rot', has not been observed at assessable levels before at ADAS Arthur Rickwood. When assessed before storage on 9 November 1993, there was a very low incidence of crown rot (0.19% of the 1600 carrots assessed). It occurred on only 3 plots (treatments 6, 8 and 10).

When assessed after field storage on 28 March 1994, 11.6% of carrots had crown rot. The incidence of crown rot was reduced by treatments 4 (two applications of Corbel), 7 (two applications of Mildothane) and 10 (two applications of Compass). These three programmes also reduced ($P<0.05$) the crown rot index, which combined severity as well as incidence of the symptoms (Table 20).

Table 20. Percentage of healthy roots and crown rot index at ADAS Arthur Rickwood on 28 March 1994.

Treatment		Date of application	% Healthy roots	Crown rot index
1.	Untreated		87.2	15.7
2.	Spinnaker	15/9	90.8	14.0
3.	Spinnaker	15/9, 15/10	92.7	12.1
4.	Corbel	15/9, 15/10	96.6	7.6
5.	Fungaflor	15/9, 15/10	90.8	13.4
6.	Bravo 500	15/9, 15/10	91.3	12.3
7.	Mildothane	15/9, 15/10	97.7	6.4
8.	Bravo, Spinnaker	13/8, 15/9	88.3	14.3
9.	Bravo, Spinnaker	10/9, 15/10	92.2	12.4
10.	Compass	13/8, 15/9	96.0	8.4
	LSD (5%)		4.90	4.47

Site 2. Burscough, Lancs

Yield

There were no significant effects of treatment on yield within any size category or on total yield at either 28 October or 23 March assessments (Tables 21 and 22).

Powdery mildew

No powdery mildew was found in the experiment.

Foliage die-back

Foliar die-back affected 51% of foliage by 26 October and this was reduced by all treatments except Mildothane (treatment 7) and one spray of Spinnaker (treatment 2), (Table 23). Bravo followed by Spinnaker (treatment 8) was more effective than all the other treatments except 4 (2 sprays of Corbel) and 9 (Bravo in early September followed by Spinnaker).

Crown rot

There was a low incidence of crown rot (3.1% roots affected in untreated control) on 26 October and some symptoms were present in all treatments (Table 24). By late March, crown rot affected 43.3% of roots in the untreated control plots (31.5 index) and this was reduced to 9.9% by 2 sprays of Corbel (Table 25). Good control was also apparent after two sprays of Compass, Mildothane and Bravo (August) followed by Spinnaker. Only Spinnaker as a single spray and two sprays of Fungaflor gave no significant control.

Table 21. Effect of fungicide treatment on yield (t/ha) on diameter (mm) size grades at first harvest, Burscough, Lancs, 28 October 1993.

Treatment		Weight of carrots in each size category (t/ha)					
		<19 mm	19-25	25-32	32-44	>44	Total
1.	Control	0.86	10.27	35.67	14.05	2.05	62.91
2.	Spinnaker (Oct)	0.76	13.94	36.65	12.86	0.65	64.86
3.	Spinnaker (Oct x 2)	0.54	13.40	35.46	20.11	1.51	71.02
4.	Corbel (Oct x 2)	0.86	11.03	35.13	16.43	3.46	66.91
5.	Fungaflor (Oct x 2)	0.86	10.81	36.54	16.65	2.70	67.56
6.	Bravo 500 (Oct x 2)	1.19	10.81	35.46	18.05	0.22	65.72
7.	Mildothane (Oct x 2)	0.65	12.97	30.81	21.30	0.00	65.72
8.	Bravo 500 (Aug) + Spinnaker (Sep)	1.08	9.62	35.02	21.51	1.95	69.18
9.	Bravo 500 (Sep) + Spinnaker (Oct)	0.76	10.38	35.67	21.51	1.84	70.27
10.	Compass (Aug + Sep)	0.86	11.35	38.59	17.94	1.08	69.83
LSD (5%)		NS	NS	NS	NS	NS	NS
CV (%)		46.9	28.2	12.4	35.4	207.6	10.5

NS - No significant differences between treatment means

Table 22. Effect of fungicide treatment on yield (t/ha) in diameter (mm) size grades at second harvest, Burscough, Lancs, 23 March 1994.

Treatment		Weight of carrots in each size category (t/ha)					
		<19 mm	19-25	25-32	32-44	>44	Total
1.	Control	.65	9.08	32.11	28.32	2.27	72.54
2.	Spinnaker (Oct)	.86	12.00	33.19	17.84	4.32	68.21
3.	Spinnaker (Oct x 2)	.97	13.62	32.75	23.13	0.0	70.59
4.	Corbel (Oct x 2)	.54	9.51	36.86	21.08	1.95	69.94
5.	Fungaflor (Oct x 2)	.86	10.59	38.16	21.62	1.41	72.64
6.	Bravo 500 (Oct x 2)	.65	11.57	33.73	24.75	2.59	73.18
7.	Mildothane (Oct x 2)	.86	13.40	31.78	18.81	1.73	66.48
8.	Bravo 500 (Aug) + Spinnaker (Sep)	.65	11.03	34.59	29.72	2.38	78.37
9.	Bravo 500 (Sep) + Spinnaker (Oct)	.86	10.16	36.00	22.92	2.59	72.43
10.	Compass (Aug + Sep)	.65	9.30	38.38	24.21	0.65	73.08
LSD (5%)		NS	NS	NS	NS	NS	NS
CV (%)		57.7	27.1	18.9	31.3	191.7	12.9

NS - No significant differences between treatment means

Table 23. Foliar assessments at Burscough, Lancs, 26 October 1993.

Treatment		Whole plot assessment % foliar die-back
1.	Control	51.2
2.	Spinnaker (early Oct)	46.8
3.	Spinnaker (early Oct + late Oct)	40.8
4.	Corbel (early Oct + late Oct)	34.2
5.	Fungaflor (early Oct + late Oct)	38.2
6.	Bravo 500 (early Oct + late Oct)	35.0
7.	Mildothane (early Oct + late Oct)	45.8
8.	Bravo 500 (mid Aug) + Spinnaker (mid Sep)	27.0
9.	Bravo 500 (early Sep) + Spinnaker (early Oct)	33.8
10.	Compass (mid Aug + mid Sep)	37.0
LSD (5%)		6.92

Table 24. Effect of fungicide treatments on crown rot, Burscough Lancs, 26 October 1993.

Treatment		% Healthy roots	Crown rot index
1.	Control	96.8	1.3
2.	Spinnaker (Oct)	96.4	1.5
3.	Spinnaker (Oct x 2)	98.0	0.9
4.	Corbel (Oct x 2)	97.4	1.5
5.	Fungaflor (Oct x 2)	97.7	0.9
6.	Bravo 500 (Oct x 2)	95.4	2.1
7.	Mildothane (Oct x 2)	98.8	0.5
8.	Bravo 500 (Aug) + Spinnaker (Sep)	95.7	1.9
9.	Bravo 500 (Sep) + Spinnaker (Oct)	98.7	0.9
10.	Compass (Aug + Sep)	97.6	1.0
LSD (5%)		NS	NS

NS - No significant differences between treatment means

Table 25. Effect of fungicide treatments on the percentage of healthy roots and crown rot index, Burscough, Lancs, 23 March 1994.

Treatment		% Healthy roots	Crown rot index
1.	Control	56.7	31.5
2.	Spinnaker (Oct)	66.8	22.6
3.	Spinnaker (Oct x 2)	75.8	17.7
4.	Corbel (Oct x 2)	90.3	5.8
5.	Fungaflor (Oct x 2)	60.8	28.2
6.	Bravo 500 (Oct x 2)	79.2	12.9
7.	Mildothane (Oct x 2)	88.0	8.9
8.	Bravo 500 (Aug) + Spinnaker (Sep)	78.7	12.8
9.	Bravo 500 (Sep) + Spinnaker (Oct)	71.9	19.3
10.	Compass (Aug + Sep)	86.8	9.2
LSD (5%)		11.70	9.28

2. Alternaria and crown rot experiment 1994

Yield

There were no significant effects of treatments on total yield or yield within individual size categories before strawing down (Table 26) or after over-wintering (Table 27).

Foliar die-back

Die-back of foliage was first seen in the third week of August and first sprays were applied at that time (24 August). Assessments on 10 plants per plot on 26 October showed some control of foliar die-back with Bravo, Rovral Flo and Storite Clear (Table 28). No powdery mildew was seen in the experiment.

Crown rot

Crown rot was present at a low incidence on 26 October 1993 when 2.9% roots were affected in the control plots. All treatments showed a similar low crown rot index at this stage (Table 29). After over wintering under straw, crown rot had developed to affect 36% roots (27.5 index) in control plots. Treatment differences were not significant in this experiment but trends in the data with Corbel, Compass and Storite were comparable with results at the other sites (Table 30).

Table 26. Effect of fungicide treatments on yield (t/ha) on diameter (mm) size grades at first harvest Burscough, Lancs, Expt. 2 - 28 October 1993.

Treatment		Weight of carrots in each category (kg)					
		<19 mm	19-25	25-32	32-44	>44	Total
1.	Control	0.97	14.16	29.19	26.05	1.51	71.89
2.	Rovral Flo (x 2)	0.65	15.46	27.03	25.73	0.76	69.62
3.	Compass (x 2)	1.30	13.19	32.86	18.38	1.08	66.81
4.	Corbel (x 2)	0.86	10.70	32.86	30.27	2.38	77.08
5.	Bravo 500 (x 2)	1.08	12.86	36.54	19.35	2.92	72.75
6.	Storite Clear (x 2)	1.51	13.84	32.97	20.21	0.54	69.18
7.	Rovral Flo + Storite Clear	0.65	9.73	26.70	27.03	3.57	67.67
8.	Compass + Storite Clear	0.86	10.16	34.48	23.46	1.08	70.04
9.	Corbel + Storite Clear	0.97	9.84	30.48	22.92	5.62	69.83
10.	Bravo 500 + Storite Clear	0.97	10.05	30.70	20.32	2.92	64.97
LSD (5%)		NS	NS	NS	NS	NS	NS
CV (%)		56.2	26.8	18.2	39.7	144.3	10.6

NS - No significant differences between treatment means

Table 27. Effect of fungicide treatments on yield (t/ha) in diameter (mm) size grades at second harvest, Burscough, Lancs, Expt. 2 - 23 March 1994.

Treatment		Weight of carrots in each size category (t/ha)					
		<19 mm	19-25	25-32	32-44	>44	Total
1.	Control	0.76	9.95	32.75	25.40	4.86	73.72
2.	Rovral Flo (x 2)	1.08	12.22	32.86	24.54	4.76	75.45
3.	Compass (x 2)	0.86	10.92	34.27	18.70	2.16	66.91
4.	Corbel (x 2)	0.65	11.67	34.16	27.78	2.16	76.43
5.	Bravo 500 (x 2)	0.65	11.78	28.54	27.57	3.03	71.56
6.	Storite Clear (x 2)	0.97	13.19	32.00	28.65	4.22	79.02
7.	Rovral Flo + Storite Clear	0.54	12.11	33.08	27.13	2.70	75.56
8.	Compass + Storite Clear	0.76	13.40	31.89	22.59	1.84	70.48
9.	Corbel + Storite Clear	1.19	10.92	33.73	27.24	3.13	76.21
10.	Bravo 500 + Storite Clear	0.76	10.05	33.40	27.35	5.73	77.29
LSD (5%)		NS	NS	NS	NS	NS	NS
CV (%)		42.0	22.5	14.3	29.6	90.2	12.4

NS - No significant differences between treatment means

Table 28. Effect of fungicide treatments on foliar die-back Burscough, Lancs, Expt. 2 - 26 October 1994.

Treatment		Whole plot assessment % foliar die-back	Ten plants per plot % foliar die-back
1.	Control	46.7	51.0
2.	Rovral Flo (x 2)	39.0	39.2
3.	Compass (x 2)	41.2	52.2
4.	Corbel (x 2)	43.8	45.0
5.	Bravo 500 (x 2)	43.0	41.6
6.	Storite Clear (x 2)	39.5	40.1
7.	Rovral Flo + Storite Clear	47.0	42.2
8.	Compass + Storite Clear	44.2	56.4
9.	Corbel + Storite Clear	42.5	52.8
10.	Bravo 500 + Storite Clear	39.8	39.5
LSD (5%)		NS	8.24

NS - No significant differences between treatment means.

Table 29. Effect of fungicide treatments on crown rot, Burscough, Lancs, Expt. 2 - 28 October 1993.

Treatment		% Healthy roots	Crown rot index
1.	Control	97.1	1.2
2.	Rovral Flo (x 2)	96.8	1.3
3.	Compass (x 2)	98.2	0.7
4.	Corbel (x 2)	97.6	1.3
5.	Bravo 500 (x 2)	98.2	0.6
6.	Storite Clear (x 2)	97.0	1.2
7.	Rovral Flo + Storite Clear	97.8	1.1
8.	Compass + Storite Clear	97.5	0.9
9.	Corbel + Storite Clear	96.4	1.6
10.	Bravo 500 + Storite Clear	98.4	0.9
LSD (5%)		NS	NS

NS - No significant differences between treatment means.

Table 30. Effect of fungicide treatments on the percentage of healthy roots and crown rot index, Burscough, Lancs, Expt. 2 -23 March 1994.

Treatment		% Healthy roots	Crown rot index
1.	Control	64.0	27.5
2.	Rovral Flo (x 2)	71.5	19.3
3.	Compass (x 2)	78.7	17.2
4.	Corbel (x 2)	81.7	12.2
5.	Bravo 500 (x 2)	74.0	20.0
6.	Storite Clear (x 2)	84.2	11.6
7.	Rovral Flo + Storite Clear	79.7	14.5
8.	Compass + Storite Clear	86.3	9.7
9.	Corbel + Storite Clear	75.5	18.6
10.	Bravo 500 + Storite Clear	74.2	18.5
LSD (5%)		NS	NS

NS - No significant differences between treatment means.

DISCUSSION/CONCLUSIONS

1992 - 93 Experiments

Although powdery mildew levels were low in all 3 trials, they were typical of those encountered in crops in 1992. At site 1 in Lancashire, infection occurred unusually early in August but subsequently disappeared in wet conditions. At sites 2 and 3, mildew was reduced by most fungicide treatments, with Spinnaker performing well. Control was not associated with any increase in yield or quality.

There was a tendency for the degree of foliar die-back, caused by a combination of natural senescence and *Alternaria* spp. infection, to be reduced by most fungicide treatments with accompanying prolonging of green tissue retention. The effect of Bravo at the Lancashire site was particularly noteworthy and although it appeared to give a reduction in crown rot incidence following field storage the effect was not significant statistically.

Low levels of various types of other rots, diseases and damage were found at the East Anglia sites (2 and 3) but there were no significant effects of treatment.

In the *Alternaria* trial at ADAS Arthur Rickwood, both *A. radicina* and *A. dauci* were associated with leaf die-back. All fungicide treatments reduced the percentage of dead tissue and increased the green tissue retention as assessed in November. Rovral Flo, Ronilan FL, Corbel and Bravo were the most promising treatments for reducing foliar die-back. However, there were no ensuing effects of treatment on yield or quality at either the November or March harvest. Levels of rots after field storage were low and there was no significant effect of treatment.

1993 - 94 Experiments

Foliar die-back was noted at all the experimental sites and *Alternaria* spp. and *Itersonilia* sp. were associated with dead or dying foliage. An isolate of *Itersonilia* from Lancashire carrots showing foliar die-back has been identified by the International Mycological Institute as *Itersonilia perplexans*. This species is distinct from that causing parsnip canker.

Powdery mildew was only detected at ADAS Arthur Rickwood and did not reach assessable levels. Moderate control of die-back was noted in mid October especially where Bravo was applied during September (but not August) at ADAS Arthur Rickwood. In Lancashire, a range of sprays on 7 October at one site gave differences on 26 October, whilst the most effective sprays applied on 24 August at a second site still gave about 20% control of die-back on 26 October. Bravo was effective at all sites and sequences of Bravo in August and September followed by Spinnaker were equally

effective. Corbel, Fungaflor and the benzimidazole fungicides (Mildothane, Storite Clear) appeared to be more variable.

Crown rot developed to moderate or severe levels after strawing down at all 3 sites. Significant control was demonstrated at 2 sites and trends were similar in data from a third site where the disease occurrence was more variable. The demonstration of crown rot control with fungicides is a significant breakthrough and adds weight to theories that the problem is a disease rather than a nutritional or physiological disorder. Corbel, Mildothane and Compass were the most effective treatments at both ADAS Arthur Rickwood and at Burscough, Lancashire. Other fungicides also appeared to be giving some control.

In the absence of a Rovral Flo treatment it is not clear whether the iprodione component of Compass is contributing to disease control. The activity of Corbel and Mildothane against crown rot would support current theories that *Itersonilia* is the cause of crown rot. *Itersonilia* species are basidiomycete fungi (these include the rusts, smuts and many larger fungi) and both Corbel and Mildothane have activity against this group of fungi. However, *Itersonilia* has not been isolated from internal tissue of affected roots and detailed studies of its pathogenicity are required. A range of other fungi including *Rhizoctonia* spp., *Fusarium* spp. and *Altenaria* spp, are commonly found on carrot crowns and foliage and many of these could also be controlled by Compass, Corbel and Mildothane treatments.

Itersonilia perplexans has now been confirmed from carrots which subsequently developed crown rot. This species has been recorded previously on carrots (Channon, 1963) but further work is needed to establish if this is the only *Itersonilia* species involved and why the crown rot problem has developed relatively recently.

Corbel now has off-label approval for use on outdoor carrot, parsnips, parsley root, satisfy and horseradish (Approval number 1058/94). There is a harvest interval of 28 days and a maximum of 3 applications at 1 litre product/hectare. Optimum rate and timing of fungicide sprays for crown rot control have not been established. Two sprays in October were effecive at Burscough in 1993-94, but two of Corbel (mid September - mid October) gave only about 50% control of crown rot at Arthur Rickwood, late August + late October sprays were ineffective at Burscough site 2 in 1993-94. All sprays were ineffective in 1992/93 at Burscough when applied in mid August and early September.

Compass has just received off-label aproval for use on carrots (Approval number 1264/94). Good control of crown rot was given by a two-spray programme (August + September) of Compass in Lancs.(Table 25) but only partial control was recorded at ADAS Arthur Rickwood (Table 20).

Note that these treaments were made at 3l/ha which is higher than the off-label rate. In addition, Compass was applied earlier than the two-spray programme of Corbel and comparative data for the same dates of application are therefore not available from this project.

Seasonal whether factors may well influence the incidence, severity and dispersal of *Itersonilia* and other pathogens in carrot crops. The most appropriate treatment may well vary from year to year. It is therefore not possible to offer firm guidelines on the optimum timing or sequences of Compass or Corbel for crown rot control. However crown rot was found at signigicant levels in both years of this project and there are now good prospects for successful fields experimentation on this problem.

It is also of concern that control of crown rot has been incomplete. Even a small percentage of affected roots will lead to rejection by consumers and further work is needed to ensure that control is very effective and that high risk crops are not overwintered. The first symptoms of crown rot were evident prior to strawing down and examination of crops in September/October would alert growers of potential problems. Testing of carrot crowns for the presence of *Itersonilia* in the autumn might also be considered.

Crown rot was confirmed for the first time in East Anglia and there is now concern that the problems could now threaten the main area of carrot production. Careful monitoring of this situation is now advised. Experienced gained during this project will now enable rapid progress to be made on field evaluation of pesticides and other treatments for control of crown rot.

REFERENCES

CHANNON, A.. G. (1963). Studies on parsnip canker. I. The causes of the diseases. *Annals of Applied Biology*, **51,** 1-15.

APPENDIX - SITE DETAILS 1993/94 EXPERIMENTS

Site details:	ADAS Arthur Rickwood, Cambs 1993 - 94	
Previous cropping:	1992 Sugar beet 1991 Wheat 1990 Wheat	
Soil texture:	Loamy peat over fen clay	
Soil indices:	P 4 K 2 Mg 3 pH 6.6 OM% 37.3	
Cultivation:	2 February 1993	trial site ploughed
Sowing:	30 April 1993	trial drilled cv. Nandor
Plot size:	4.0 x 1.7 m	
Herbicides:	2 June 17 June 6 July	5.6 l/ha cp Atlas Brown in 250 l/ha water 2.4 l/ha cp Liquid Linuron in 250 l/ha water 3.5 l/ha cp Liquid Linuron + 5.5 l/ha Disaflo in 600 l/ha water
Fungicides:	13 May 13 August - 15 October	12 kg/ha cp Fubol 58WP in 1000 l/ha water Experiment
Insecticides:	30 April 6 July 5 August 19 August	28 kg/ha cp Phorate 250 ml/ha cp Ambush C in 800 l/ha water 1.25 l/ha cp Hostathion in 1000 l/ha water 1.25 l/ha cp Hostathion in 1000 l/ha water
Fertilisers:	2 February 10 May	50 kg/ha Phosphate + 50 kg/ha Potash 40 kg/ha Nitrogen
Trace elements:	4 June 26 June 21 July	8 kg/ha Manganese sulphate in 250 l/ha water as above as above
Irrigation:	9 July	25 mm
Harvest:	9 November 1993 28 March 1994	

APPENDIX - 1993/94 EXPERIMENTS

Site details:	Powdery Mildew Experiment 1993/94 Alternaria and Crown Rot Experiment 1993/94 Burscough, Lancashire
Soil texture:	Loamy sand
Soil analysis:	P 4 K 0 Mg 3 pH 6.0 OM% 5.0
Cultivar:	Narman
Sowing date:	24 April 1993
Design:	Randomised block x 4 replicates
Plot size:	4.0 m x 1.5 m (Bed centres 1.85 m)
Fertiliser:	80 kg/ha Nitrogen, 200 kg/ha Phoshate, 100 kg/ha Potash in seedbed
Herbicide:	23 May Dosaflo + Bronze (3 l/ha + 3 /ha)
Insecticide:	23 May Aphox (280g/ha)
Fungicide:	24 April Fubol 58WP applied at time of drilling
Harvest dates:	28 October 1993 23 March 1994

APPENDIX - SITE DETAILS 1992/93 EXPERIMENTS

1. Powdery Mildew Experiment

Site 1 - Burscough, Lancashire

Soil texture:	Organic sandy loam	
Soil analysis:	P	4
	K	1
	Mg	3
	pH	6.3
	OM%	7.0
Cultivar:	Narman	
Sowing date:	26 April 1992	
Design:	Randomised block x 4 replicates	
Plot size:	5.0 m x 1.5 m	
Fertiliser:	Standard farm practice	
Herbicide:	Standard farm practice	
Insecticide:	Standard farm practice	
Fungicide:	Standard Fubol treatment at drilling	
Harvest dates:	3 November 1992	
	23 March 1993	

Site 2 - Methwold Hythe, Norfolk

Soil texture:	Peat	
Soil analysis:	Not available	
	OM%	35
Cultivar:	Nantes type	
Sowing date:	Not available	
Design:	Randomised block x 4 replicates	
Plot size:	4.0 m x 2.0 m	
Fertiliser:	Standard farm practice	
Herbicide:	Standard farm practice	
Insecticide:	Standard farm practice	
Fungicide:	Fubol at drilling	
Harvest dates:	11 December 1992	
	11 January 1993	

Site 3 - West Row, Suffolk

Soil texture:	Peat	
Soil analysis:	Not available	
	OM%	35
Cultivar:	Nantes type	
Sowing date:	Not available	
Design:	Randomised block x 4 replicates	
Plot size:	6.0 m x 2.0 m	
Fertiliser:	Standard farm practice	
Herbicide:	Standard farm practice	
Insecticide:	Standard farm practice	
Fungicide:	Fubol at drilling	
Harvest dates:	14 December 1992	

2. Alternaria Experiment

Site 1 - ADAS Arthur Rickwood

Soil texture:	Peat	
Soil analysis:	P	4
	K	4
	Mg	3
	pH	6.5
	OM%	35
Cultivar:	Nandor	
Sowing date:	24 April 1992	
Design:	Randomised block x 4 replicates	
Plot size:	4.0 m x 1.7 m	
Fertiliser:	Standard farm practice	
Herbicide:	Standard farm practice	
Insecticide:	Standard farm practice	
Fungicide:	Fubol at drilling	
Harvest dates:	11 November 1992	
	12 March 1993	