CARROTS: THE MANAGEMENT OF *ALTERNARIA* BLIGHT ON CARROTS

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The results and conclusions in this report are based on an investigation conducted over one year. The conditons under which the experiment was carried out and the results obtained 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. Therefor care must be taken with interpretation of the results especially of they are used as the basis for commercial product recommendations.

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To date, this project has investigated the potential of *Alternaria* forecasting systems to reduce the number of sprays applied to control the disease while maintaining the same level of control and yield benefit as routine prophylactic sprays. The relative efficacy of different fungicide treatments has been compared and the effects of the disease on carrot yield and quality evaluated. In addition, the level of susceptibility of carrot varieties has been investigated. The results indicate that forecasting systems can reduce spray frequency on average by 0.9 per season. There were significant differences in the degree of disease control given by various products, with a protectant spray of Amistar followed by Folicur sprays giving the best overall control. A moderately serious epidemic was found to cause maximum losses of 3kg in weight per 100 marketable roots. There were large differences in the levels of disease developing on different varieties. These findings provide the basis for growers to save on fungicide costs, optimise product choice, and implement an integrated approach for the management of *Alternaria*.

Background and objectives

Foliar diseases of carrots have become of increasing concern in recent seasons, principally due to the occurrence of *Alternaria* blight, caused by the fungus *Alternaria dauci,* which has occurred progressively earlier in the life of the crop, and in a wide range of growing regions. Yield and root quality losses have been attributed to *Alternaria* blight, and it may sometimes create harvesting difficulties due to weakened foliage. The extent of yield loss in the UK is not fully understood, and probably depends to a large extent on the time of appearance of the disease. A 5% yield loss would be worth £2.25 million to growers in the UK. Foliar fungicides can be applied to carrots for *Alternaria* control, but there is little information available which can identify high risk situations where yield and quality losses might be expected. Given the increasing pressure for appropriate use of fungicide, and the needs of the industry for economically justified inputs, there is now a need for a robust and practical system which can identify situations where control of *Alternaria* blight is warranted. This project is aimed at evaluating and validating a developed forecasting system for *A dauci,* identifying varieties which are at risk of developing high levels of *A dauci*, assessing the effectiveness of new and existing products against Alternaria, and estimating the effects of the disease on yield and quality.
The project also provides an opportunity to monitor other foliar diseases of carrot, in particular *Sclerotinia sclerotiorum* and powdery mildew (*Erysiphe heraclei*) which have caused problems in some areas recently.

Summary of results and conclusions

1. Disease forecasting

A desk study of the output of two forecasting models, PLANT Plus and DSV, has been completed. PLANT Plus was selected as the operating system for 2000, and was tested by comparing the degree of disease control obtained in crops sprayed according to forecast, and those sprayed according to normal practice. Sixteen fields of mainseason carrots representative of typical commercial crops in the main growing areas were selected for the first year of study. Weather data for each field or cluster of fields was collected using an Adcon Telemetry weather station with sensors for rain, temperature, humidity, windspeed and wind direction. At each site fields were paired. One of each pair was treated with a fungicide program designed to control the main foliar diseases of carrots in accordance with normal practice. The other member of the pair was treated in accordance with the advice generated by the PLANT-Plus system together with the interpretation of a DMA adviser. The results to date from the field observation trials showed that there was a light to moderate level of *Alternaria* foliage infection in the untreated plots. Little or no infection occurred in either the normal practice treatments or the PLANT-Plus treatments, and there was a reduction in treatment number using PLANT-Plus forecasts. *Sclerotinia* infections in carrot crops were widespread in 2000. There were no apparent differences between control obtained using normal practice fungicide programs compared to that obtained using PLANT-Plus. There was also no evidence of significant control with the fungicide programs used compared to untreated plots.

With the use of PLANT Plus the average number of fungicide treatments applied to the commercial crops in this study was reduced from 4.3 to 3.4, while retaining acceptable control of *Alternaria*. Though the severity of disease in the untreated control areas was greater than that in the treated crops, it did not reach epidemic levels as it has done in previous years.

2. Variety susceptibility

Varieties were inoculated with *Alternaria* spores on and the trial irrigated as necessary to promote infection. This produced a uniform and relatively high “infection pressure”. There were substantial differences in the levels of *Alternaria* developing on the varieties included in the trial, and these differences were maintained over the growing season, with little evidence of changes in variety ranking order as the season progressed. The lowest infection level was 7% foliage area infected on Indiana by 20th October. The highest level, 52%, occurred on NUN 6710. Varieties have been classified into four groups, based on the level of infection on 20th October, as described below.

Group A - evidence of good partial resistance, 20% or less foliage area infected
Group B – moderate resistance, from 21% up to 28 % foliage infected
Group C – poor resistance, from 29% to 35% foliage infected
Group D – very susceptible, from 36% to 52% foliage area infected

Group A	Group B	Group C	Group D
Gladiator	Narbonne	Nerac	Nairobi
Bolero	Narman	Senior	Navarre
Maestro	Nigel	Leonor	Victor
Riga	Nepal	Atlantis	Furore
Bristol	EX 942060	Redco	NUN 6710
Indiana	Kamaran	RX 4420046	NUN 6717
			Nantucket
			Primo
			PX 942114
			EX 962005

These results indicate that variety can have a major effect on disease development. All seed used in the trial tested negative for *Alternaria dauci*, confirming that the differences observed were due to the applied inoculum, and were not biased by seed-borne disease.

3. Fungicide efficacy

Four products were tested on the variety Nairobi for protectant and eradicant activity by applications made before 7 and 1 day before inoculation with Alternaria spores and 7 days afterwards. The products were Amistar (azoxystrobin, experimental approval) applied at 0.8l/ha, Folicur (tebuconazole), OLA, applied at 1l/ha, Corbel (fenpropimorph), OLA, applied at 1 l/ha, and Compass (iprodione and thiopanate methyl), OLA, applied at 2 l/ha. Apart from the pre- and post- inoculation sprays, all subsequent sprays were applied as indicated by a Plant Plus forecasting system. Two prophylactic treatment programmes coincided with forecast sprays in this season's work. A further treatment consisted of Amistar applied just after inoculation, followed by Folicur at all subsequent forecast sprays. Untreated control plots showed 30% foliage infection on 26th October. Amistar, Folicur and Corbel were all most effective when the first spray was applied before inoculation (ie before the infection event), whereas Compass had superior eradicant activity. Overall, regardless of the initial pre- or post-inoculation timing, Corbel was the least effective product, followed by Compass, Folicur and Amistar in order of increasing efficacy. The difference between Compass and Folicur was very small. The most effective treatment was the combination of Amistar applied 1 day before inoculation, with subsequent sprays of Folicur applied at forecast risk periods.

4. Effects of *Alternaria* on yield

Controlling *Alternaria* with fungicides produced yield benefits in terms of the weight of 100 marketable roots harvested on 13th November. The mean yield of untreated plots was 16.2 kg, and the best yield improvement (19.7 kg) was given by Amistar applied before infection, and then subsequently at forecast risk times. At harvest on 19th February after strawing over, the mean yield of untreated plots was 16.50, and the mean yield improvement over all treatments was 2.2 kg. The Amistar/Folicur programme which gave the best overall control of foliage infection gave one of the poorer yield benefits at both harvests. The reason for this is unclear, though two of the three replicate plots for this treatment gave very low yields, and further statistical investigation is under way to determine whether any unusual field factors may have occurred.

Action points for growers

- *Alternaria* can have substantial effects on the yield of marketable produce, and action should be taken to reduce infection
- Forecasting systems offer the potential to reduce prophylactic sprays while still retaining control of the disease
- Varieties appear to differ in levels of resistance to the disease, and though none is completely resistant, some may require fewer sprays than others to minimise the disease
- A comparison of available and potential new products indicated that Folicur and Compass were superior to Corbel. Applying a first spray 7 days before an introduced "infection event", with subsequent sprays applied at forecast risks, gave the best control. Amistar was the most effective single product tested.

Anticipated practical and financial benefits

The results illustrate the benefits which arise from controlling severe *Alternaria* infections, and also the savings which can be made by responding to forecast risks rather than prophylactic sprays. Findings from the first year indicate that failure to control Alternaria could result in losses of 10% worth about £3.8 million on the current UK acreage, but also that a forecasting system could reduce spray costs by approximately £30-40/ha, depending on product used. Varieties differed substantially in susceptibility to *Alternaria*, offering the opportunity to exploit partial resistance in ICM systems.

Science section

Introduction

Alternaria blight of carrots, caused by *Alternaria dauci*, has recently increased in importance in the UK crop with growers applying frequent sprays to maintain disease free foliage. Infections are tending to appear earlier in the season than has previously been experienced, and the disease is found in all of the major carrot growing regions of the country. Disease which develops earlier in the season is more likely to have an effect on yield, though late season disease may also be significant, both in terms of direct yield loss and harvesting dificulties caused by foliage breakdown. The disease is seed-borne, and can also survive on carrot debris. Once introduced on seed, the disease probably becomes established in intensive carrot growing areas.

Though growers apply fungicides to control Alternaria, there is very little information available on the losses which the disease can cause, and therefore on the cost effectiveness of sprays applied. Disease forecasting systems are increasingly being used in the field vegetable sector in order to satisfy the drive towards justification of inputs, and reduce costs of production to the grower. Though systems are available for prediction of *Alternaria* risks, there has been no independent evaluation of these in terms of their ability to reduce sprays compared to prophylactic approaches, and maintain disease control at acceptable levels. The use of resistant varieties has been advocated as part of integrated control systems for *Alternaria* elsewhere (Davis *et al*, 1993), but information on the relative susceptibilities of varieties used, or likely to be used, in the UK is extremely limited. This work was undertaken with four main objectives. Firstly, to evaluate and validate *Alternaria* blight forecasting systems; secondly, to investigate the range of susceptibility to *Alternaria* in varieties; thirdly to investigate the effectiveness of different fungicides for *Alternaria* control, and finally to establish the effects of the disease on carrot yield and quality.

Materials and Methods

Evaluation and validation of forecasting systems

Two systems, PLANT-Plus and DSV were appraised in an initial desk study. The PLANT-Plus *Alternaria* model is part of a family of disease models available from Dacom. The PLANT-Plus models use local weather data in combination with a local 5-day forecast. The disease models therefore analyse current and future conditions for disease infection events. PLANT-Plus models also take account of crop growth characteristics, variety tolerance and agrochemical degradation on treated foliage.

PLANT-Plus *Alternaria* model information is presented in graphical and tabular format and is delivered *via* Internet or local dial up software. As PLANT-Plus looks for future disease risk events it has the ability to optimise the use of protectant fungicides as well as indicating the appropriate timing for eradicant materials.

The DSV model is a generic model believed to have been originally developed by Campbell Soups. It is widely available and uses a physical leaf wetness sensor in combination with a temperature sensor. When conditions are suitable for infection the DSV model generates a daily index value. Once the accumulated daily values reach a user-defined threshold a treatment warning is generated. When a treatment has been applied the index re-sets to zero and the process starts again. DSV does not recognise variety sensitivity although a lower accumulated threshold can be set for susceptible material. It assumes the crop is totally protected once a treatment is applied, until the user-defined protection period has expired.

The desk study compared the functionality and output of the two systems described by using weather data from England and Portugal. Both models recognised infection periods, which were largely equivalent in their timing and severity indicating that either systems may be capable of providing infection warnings for *Alternaria* in carrots.

The advantage of the Plant Plus system over DSV is that crop data such as crop development, canopy density, leaf growth and presence of infection pressure can all be input into the system together with basic susceptibility information on variety grown. The individual performance of the fungicide chosen for crop protection is also modelled in relation to time and weather conditions. The combination of these features together with the integration of a 5-day local forecast gives Plant Plus a distinct advantage over the DSV system. Whilst Plant Plus was chosen as our comprehensive modelling system it was also decided to observe the output of DSV alongside for selected sites, during year 2000.

The validity of the system was tested from the degree of disease control obtained in crops sprayed according to forecast, and those sprayed according to normal practice. Sixteen fields of mainseason carrots representative of typical commercial crops in the main growing areas were selected for the first year of study. Weather data for each field or cluster of fields was collected using an Adcon Telemetry weather station with sensors for rain, temperature, humidity, windspeed and wind direction. Two stations were also equipped with a leaf wetness sensor. The data from each site was transmitted each 15 minutes to a receiver base station and each 6 hours was automatically deposited onto the Dacom Databank server via Internet. It was then integrated with a local 5-day weather forecast and made available for collection by accredited users.

Each day DMA advisers collected the site data *via* the Internet from the Dacom server and processed the data and the crop information together through the PLANT-Plus alternaria model. The resultant advice was interpreted and when a treatment was necessary the adviser communicated with the field manager who arranged to apply an appropriate treatment.

At each site fields were paired. One of each pair was treated with a fungicide program designed to control the main foliar diseases of carrots in accordance with normal practice. The other member of the pair was treated in accordance with the advice generated by the PLANT-Plus system together with the interpretation of a DMA adviser.

Each site was recorded for crop characteristics including growth, density, senescence and the presence of *Alternaria* and *Sclerotinia*. Each field also contained an area that was untreated with fungicides. This was located towards the centre of each field to avoid any edge effects. A typical example of this layout is shown at Appendix I. The interpretation of PLANT- Plus graphics is shown in Appendix III. All sites were recorded finally in October prior to the application of winter straw covering.

Evaluation of variety susceptibility

Varieties of carrot were drilled on 9th May 2000 on a gravelly clay site at NIAB, Cambridge. Plots were 4m long and 4 rows wide on 1.8 m beds. Fertiliser (60:60:60 N:P:K) was applied to beds on 2nd May. Treflan and Saprecon granules were applied on 8th May and Linuron on 9th May. Each variety was replicated three times in a randomised block design. Four pathogenic isolates of *Alternaria dauci*, obtained from seed samples submitted to the Official Seed Testing Station and UK culture collections, were increased on malt agar plates at 22 °C, under 12h nuv light and 12h dark. Spores were removed from the plates by soaking in distilled water, scraping, and filtering the resulting suspension through a kitchen plastic mesh sieve, and then a single layer of muslin. The plots were inoculated with 250ml of an aqueous suspension containing 1 x 10^4 spores per ml on 16th and 23rd August when foliage was meeting in the rows. The trial was irrigated just prior to inoculation and the suspension was directed downwards at the mid point of the foliage to ensure that the inoculum was protected by the upper leaf canopy. The trial was irrigated during rain-free periods to promote cycles of infection, and scored at approximately weekly intervals through the season. Scores were made of the % foliage and petiole area infected with *Alternaria* on a per plot basis (ie taking all the foliage area in a plot into account) using the area diagrams shown in Appendix II as a guide. Seed of all the varieties used was tested for the presence *of A. dauci* using a blotter method.

Evaluation of the effectiveness of fungicides

Fifty-one plots of the variety Nairobi were drilled at NIAB trial ground, Cambridge on 4th May in a sandy clay loam soil. Plots were 9m long and 4 rows wide on 1.8m beds. There were three replicates of seventeen treatments arranged in a randomised block design. Discard plots were included at each end of the trial. An Adcon weather station was erected on a grass strip approximately 30m from the trial area. Plots were irrigated to promote establishment, and also just prior to inoculation with *Alternaria* spores on 1st August but no further irrigation was used. Plots were inoculated using the same method and inoculum source as described for the variety susceptibility trial at a rate of 500ml of inoculum per plot. Fungicides were applied to the trial at various times as summarised in Tables 1, 2 and 3. Prophylactic spray timings were judged by monitoring disease progress through the leaf canopy, and spraying when small new lesions were seen developing. The plots were scored at intervals through the season using the same method and scoring scale as the variety trial.

Table 1. Treatment details for fungicide effectiveness trial.

Product	Active ingredient	Current status	Rate (l product/ha)	Application volume (l water/ha)
Folicur	Tebuconazole	OLA	1	400
Amistar	Azoxystrobin	experimental*	0.8	400
Compass	Iprodione/ thiophanate methyl	OLA	2	400
Corbel	Fenpropimorph	OLA	1	400

* used under Automatic Experimental Approval for the trial

Table 2. Treatment list for fungicide trial

Treatment	Timing*
Untreated 1	
Untreated 2	
Folicur	7 days before inoculation + forecast
Amistar	7 days before inoculation + forecast
Compass	7 days before inoculation + forecast
Corbel	7 days before inoculation + forecast
Folicur	1 day before inoculation + forecast
Amistar	1 day before inoculation + forecast
Compass	1 day before inoculation + forecast
Corbel	1 day before inoculation + forecast
Folicur	7 days after inoculation + forecast
Amistar	7 days after inoculation + forecast
Compass	7 days after inoculation + forecast
Corbel	7 days after inoculation + forecast
Folicur	1 day before inoculation, then prophylactically
Amistar	1 day before inoculation, then prophylactically
Amistar/Folicur	Amistar 1 day before inoculation, Folicur as forecast

* 7 days before applied 25th July, 1 day before applied 31st July, 7 days after applied 8th August

Table 3. Timings of forecast and prophylactic sprays

Forecast sprays	Prophylactic sprays*
31st August	31st August
18th September	18th September
3rd October	3rd October

* prophylactic coincided with forecast in this season

Effects of disease on yield

Plots in the fungicide trial were harvested on 13th November by taking a 1m section across 4 rows, and recording total weight, root number, unmarketable roots and then calculating weight per 100 marketable roots. The trial was covered with straw on 14th November and uncovered again on 19th February 2001 prior to taking a second harvest.

Results and Discussion

Evaluation and validation of forecasting systems

The results to date from the field observation trials showed that a light to moderate level of *Alternaria* infection occurred in the untreated areas, and that little or no infection occurred in either the normal practice areas, or the PLANT Plus prediction areas. Overall, treatment number was reduced using the PLANT Plus system. *Sclerotinia* infection was widespread in 2000, and the opportunity was taken to record differences between the areas receiving no spray, normal practice, or PLANT-Plus *Alternaria* forecast spray. There were no apparent differences between the latter two treatments, but also no evidence of significant control of *Sclerotinia* with the fungicide programmes used compared to the untreated plots.

With PLANT Plus *Alternaria* forecasts, the average number of fungicide treatments applied to the commercial crops in this study was reduced from 4.3 to 3.4. Control of *Alternaria* was similar in both cases and was of a commercially acceptable standard. *Alternaria* was present in untreated control plots at levels greater than in treated crops, though severity was not regarded as being at epidemic level in contrast to previous years A selection of PLANT Plus graphics is presented in Appendix IV. The summary data collected from all commercial sites is presented in Appendix VI.

The DSV model depends on the deployment of a physical leaf wetness sensor preferably in or near the crop. Weather stations in Suffolk and in Perthshire were equipped with such a device and it was therefore possible to run the DSV model on the appropriate fields near to these stations. Treatments were triggered at an accumulated DSV index value of 16.

Treatments which were recommended by the DSV model and those which were applied in accordance with the Plant-Plus recommendations were as follows:

Perthshire		Suffolk	
DSV	Plant-Plus	DSV	Plant-Plus
August 10th	August 10th	July 6th	
	August 21st	July 30th	July 28th
September 2nd	August 30th	August 14th	
	September 13th	August 27th	August 23rd
October 4th		September 12th	September 7th
		September 28th	September 21st

Although the main subject of this study is *Alternaria*, levels of other diseases are of interest to the project team following comments from growers in some regions. The most significant disease to affect the foliage of commercial crops in year 2000 was *Sclerotinia.* It was not possible to quantify the exact effects on yield, quality or storage life but observations on severity of infection tend to indicate that all may have been significantly affected. Disease was most prevalent in Norfolk, Yorkshire and Scotland.

In the autumn of 2000 Dacom introduced for evaluation a *Sclerotinia* model for carrots and the opportunity was taken to process the collected raw data through the new model and observe the output. This showed that there were many favourable infection opportunities for *Sclerotinia* throughout the growing period, and that significant infection opportunities occurred during the early stages of the carrot crop's life cycle when no fungicides were applied. A selection of graphics and tabled output for *Sclerotinia* is presented at Appendix V.

Evaluation of variety susceptibility

There were large and significant differences in the level of *Alternaria* developing on varieties, and in general the ranking order was maintained over the season (Table 4). None of the seed used for the trial showed infection with *A .dauci* in a 200 seed test, thus the differences observed are not confounded by the presence of seed-borne infection. The results illustrate that there is potential for exploiting resistance to *Alternaria*, albeit partial in nature, in commercial varieties undergoing trial in the UK. However, it should be noted that the current most popular varieties such as Nairobi and Nerac are relatively susceptible to the disease. The results confirm previous limited data available for some varieties (eg Victor susceptible, and Riga more resistant) which were included as putative controls.

Table 4 Severity of *Alternaria* infection (% foliage area infected) in 28 carrot varieties

	20th Sept	28th Sept	6th Oct	13th Oct	20th Oct	27th Oct
Nairobi	3.7	13.3	26.7	38.3	40.0	48.3
Narbonne	2.8	12.3	15.7	26.7	28.3	28.3
Narman	2.2	7.3	20.0	28.3	23.3	25.0
Navarre	3.7	18.3	35.0	46.7	38.3	43.3
Nerac	2.2	17.0	27.3	34.0	34.0	34.0
Gladiator	0.4	9.3	15.0	26.7	18.3	19.0
Bolero	0.2	4.3	8.0	9.3	12.3	15.7
Senior	2.0	12.3	23.3	30.0	31.7	30.0
Victor	1.9	8.3	20.0	25.0	38.3	41.7
Maestro	0.4	10.3	15.0	18.3	20.0	23.3
Leonor	0.4	6.7	16.7	25.0	31.7	36.7
Riga	0.4	3.7	7.3	9.0	12.0	10.7
Nigel	2.2	16.7	30.0	31.7	28.3	28.3
Atlantis	2.0	18.3	26.7	30.0	35.0	33.3
Furore	1.0	10.7	30.0	43.3	48.3	56.7
NUN 6710	7.0	18.3	31.7	46.7	51.7	56.7
Nepal	1.9	11.0	16.7	20.0	24.3	23.3
Bristol	0.2	5.3	6.3	12.3	15.7	17.3
NUN 6717	2.7	17.3	35.0	46.7	40.0	43.3
EX 942060	0.7	6.3	10.0	18.3	26.7	31.7
Nantucket	3.7	23.3	38.3	45.0	45.0	43.3
Primo	2.2	19.0	40.0	48.3	50.0	50.0
Kamaran	0.7	6.3	10.7	16.7	23.3	28.3
Redco	2.3	12.3	21.7	26.7	33.3	40.0
Indiana	0.1	1.3	4.0	6.3	7.7	10.0
PX 942114	4.2	14.3	26.7	33.3	46.7	40.0
EX 962005	2.8	21.7	41.7	48.3	46.7	46.7
RX 4420046	5.2	15.7	30.0	36.7	30.0	30.0
lsd (p=0.05)	3.70	10.96	15.66	18.57	18.59	21.21

Evaluation of the effectiveness of fungicides

Treatment differences were apparent at the first score on 14th September, and were generally maintained through the season. By 2nd November, the most effective treatments remained those where an early pre-inoculation spray had been applied. Of these, Folicur and Amistar were more effective than Compass and Corbel. The most effective treatment combination overall was Amistar applied 1 day before inoculation, followed by forecast sprays of Folicur. Table 5 shows all scores taken during the season.

Table 5 Progress of *Alternaria* (% foliage infected) under different fungicide regimes

Treatment	14th Sep	22nd Sep	2nd Oct	5th Oct	12th Oct	19th Oct	26th Oct	2nd Nov
Untreated (1)	3.0	4.0	11.7	19.0	21.7	24.7	30.0	38.0
Untreated (2)	3.0	4.0	11.7	15.7	20.7	23.3	32.0	39.3
- 7 days +forecast								
Folicur	2.3	2.0	5.5	7.7	6.0	8.7	10.7	16.0
Amistar	0.5	0.5	2.5	3.7	3.0	3.0	10.3	15.3
Compass	0.7	1.0	2.2	1.8	3.3	6.7	14.0	22.7
Corbel	1.7	1.5	10.3	13.0	12.3	12.0	16.7	26.0
-1 day + forecast								
Folicur	1.7	1.7	6.7	9.7	9.0	14.0	15.0	27.0
Amistar	1.0	0.7	3.0	4.3	5.3	8.3	17.3	27.0
Compass	0.8	0.7	2.0	1.5	3.7	5.3	14.3	25.0
Corbel	4.0	3.7	12.7	17.3	18.7	25.0	26.0	25.7
+7 days + forecast								
Folicur	2.3	1.2	10.0	11.7	10.7	15.0	23.3	22.7
Amistar	2.0	1.2	3.3	2.2	6.0	8.0	14.7	20.7
Compass	1.7	1.3	4.7	5.3	4.3	8.7	9.7	22.3
Corbel	1.3	1.7	8.7	10.0	11.7	14.0	20.0	26.3
- 1 day + prophylactic								
Folicur	0.4	1.3	5.0	8.0	10.3	17.3	17.0	25.3
Amistar	2.0	0.8	2.8	5.7	5.7	10.3	11.0	24.7
Amistar/Folicur*	0.5	0.8	1.5	3.0	3.0	4.3	9.0	14.0
Lsd p=0.05	1.28	1.12	6.12	4.61	5.13	4.82	5.09	7.29

*Amistar at –1 day, Folicur at forecast periods

Effects of disease on yield

Effects of *Alternaria* on yield were measured in the fungicide trial. At the first harvest, an estimate of leaf retention was made to indicate ease of harvesting by top lifting. Ten plants per plot (middle rows) were assessed for leaf retention on a 0-5 scale (5= high retention) and an index calculated. All treatments except Corbel improved the weight of 100 marketable roots, compared to untreated controls, but the effects were not statistically significant (Table 6). Nevertheless, the mean response of all treated plots compared to the untreated mean showed a yield improvement of 1.35 kg, or 8%. Nearly all treatments improved leaf retention, with Amistar programmes generally giving the highest scores (Table 6). At the second harvest after strawing over, the mean yield improvement of all treatments compared to untreated controls was 2.2 kg, or 13%. Pre-inoculation treatments with Amistar generally gave greater yield improvements than other treatments (Table 7), though Corbel applied post-inoculation gave an unexpectedly high yield improvement. Leaf retention after uncovering was assessed on a 1-5 scale for each plot, where 5 represented 5 leaves per plant. Treatment differences were small, and though all improved leaf retention compared to untreated, no consistent differences were seen (Table 7) in contrast to the first harvest.

Table 6. Effects of fungicide treatment on number of marketable roots, weight per 100 marketable roots and leaf retention (0-100 index) on 13th November

Treatment	No. marketable roots	Weight/100 (kg)	Leaf retention index
Untreated (1)	81.0	16.1	31.3
Untreated (2)	64.0	16.3	27.3
- 7 days +forecast			
Folicur	53.3	16.6	60.7
Amistar	49.7	19.7	92.7
Compass	52.7	17.9	81.3
Corbel	70.7	16.3	50.7
-1 day + forecast			
Folicur	75.0	17.2	70.7
Amistar	67.3	17.5	76.7
Compass	56.3	18.3	75.3
Corbel	82.0	15.2	32.7
+7 days + forecast			
Folicur	80.0	18.7	46.0
Amistar	74.7	17.2	77.3
Compass	83.0	17.1	75.3
Corbel	84.0	17.8	57.3
- 1 day + prophylactic			
Folicur	77.0	18.4	55.3
Amistar	70.0	18.1	72.0
Amistar/Folicur*	77.3	16.7	94.0
Lsd p=0.05	25.26	3.54	22.55

* Amistar at –1 day, Folicur at forecast periods

Table 7. Effects of fungicide treatment on number of marketable roots, weight per 100 marketable roots and leaf retention at harvest on 19th February.

Treatment	No. marketable roots	Weight/100 (kg)	Leaf retention 1-5
Untreated (1)	72.00	16.48	1.0
Untreated (2)	73.00	16.52	1.0
- 7 days +forecast			
Folicur	59.33	18.45	1.67
Amistar	64.00	19.56	2.00
Compass	56.00	19.00	1.67
Corbel	59.00	18.76	2.00
-1 day + forecast			
Folicur	68.00	18.93	1.67
Amistar	63.00	19.96	1.67
Compass	65.67	20.09	1.67
Corbel	72.33	18.04	2.00
+7 days + forecast			
Folicur	64.67	17.61	2.00
Amistar	70.33	16.35	2.00
Compass	52.33	19.57	2.00
Corbel	68.00	20.22	1.67
- 1 day + prophylactic			
Folicur	73.33	19.01	2.00
Amistar	53.33	17.79	2.00
Amistar/Folicur*	73.00	17.19	1.67
Lsd p=0.05	17.245	3.059	0.599

* Amistar at –1 day, Folicur at forecast periods

The coefficient of variation for yield at the first and second harvest was relatively high at 12.3%. and 10 % respectively. Further statistical investigation is in progress to determine whether any corrections can be made for field effects. It is thought that the epidemic created by inoculation, though severe, may not have coincided with the major period of yield accumulation in the 2000 season, thus effects on yield may be underestimated. Categories of unmarketable roots are being analysed further to determine any specific effects of treatment on different categories.

Conclusions

Based on the first year's results, the following conclusions can be made:

- PLANT Plus forecasting systems can reduce the number of sprays applied for *Alternaria* while retaining acceptable levels of control, offering growers the opportunity to reduce production costs
- Varieties differ substantially in resistance to *Alternaria*, and in future, this information could be incorporated into forecasting systems enabling further reductions in spray frequency
- The most effective disease control was achieved when sprays were applied well before an infection event. Over the season, Amistar and Folicur gave better control than Compass, and all of these were more effective than Corbel. A programme of Amistar (just before infection) and Folicur (at forecast risk periods) was the most effective treatment overall. Such combination treatments, subject to future availability of Amistar, provide potential anti-resistance strategies.
- Fungicide treatments increased the yield of marketable roots by 10% on average over both harvests, though further data are needed to substantiate this figure.

Technology transfer

This work has been described in principle at NIAB-HDC Carrot Open Days. Results from the first year were presented to an HDC Carrot Workshop on 11th April 2001. Subject to agreement, the results presented in this report should be made available on the HDC website, or through an article in HDC News for the forthcoming growing season.

References

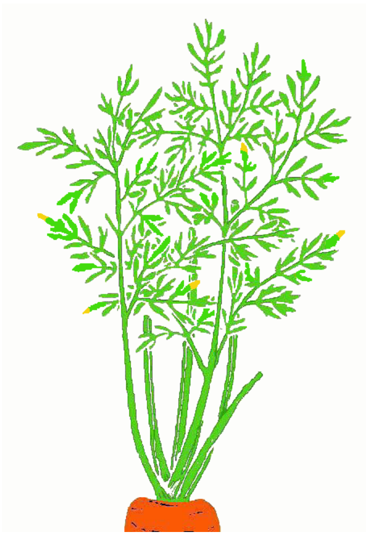
Davis M; Gilbertson B; Nunez J; Pryor B; Strandberg J. 1993 *Alternaria* disease of carrots. Bulletin of the University of California-Davis, December 1993

APPENDIX I

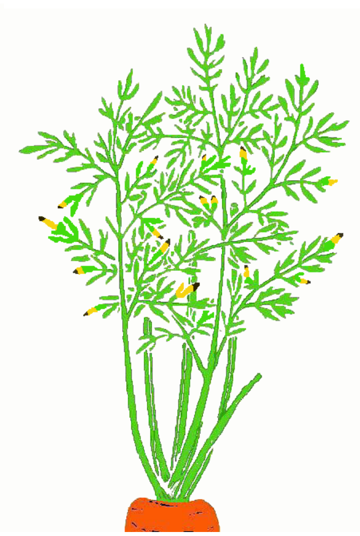
Control plot in commercial crop – Norfolk Rotac 2000

APPENDIX II

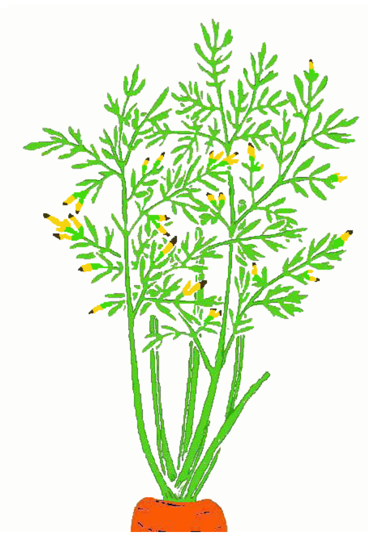
Scale for Alternaria assessment



1%

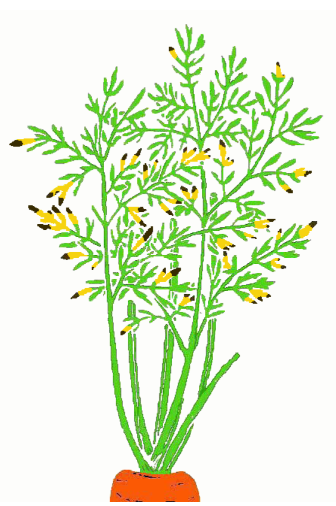


5%

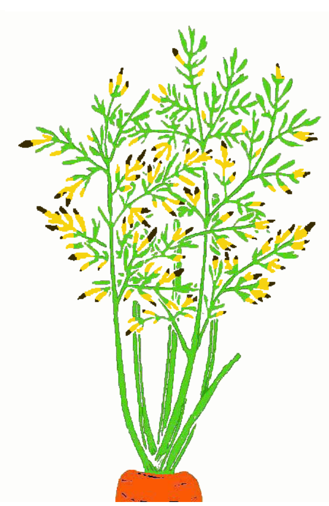


10%

15%



20%



40%

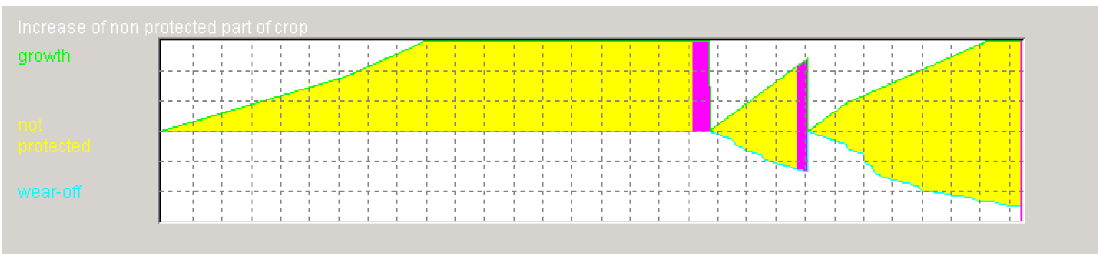
- Interpolate between % points
- Score all yellowing and blackening confirmed as *Alternaria*
- Include petiole area
- Examine the whole of the plot, and assign mean score

APPENDIX III

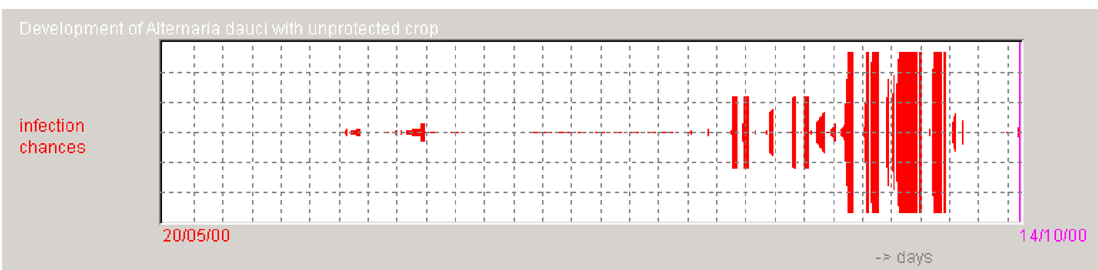
Interpretation of PP Advice Graphics

PP graphics are presented in pairs and represent changes in crop status and in disease risk over a specific time period. The graphics presented in this report are season reviews which cover the time period between early June and mid October.

The top graphic of the pair illustrates the rate of growth of the crop foliage together with the wear off of the fungicide treatments applied to control disease.



The bottom graphic illustrates the infection events, which have been identified by the PP system assuming the crop is unprotected.

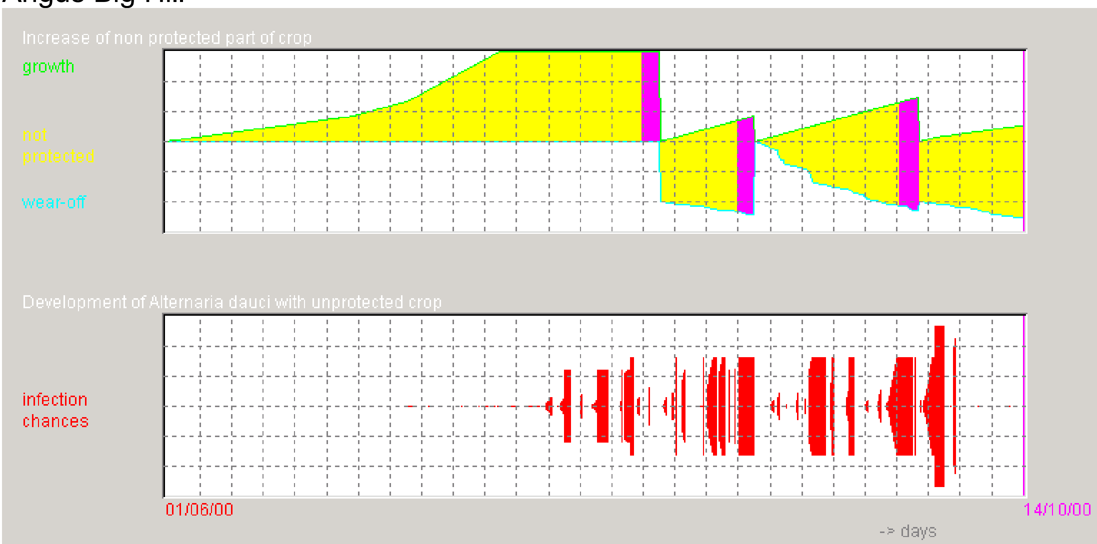


Optimum crop protection is achieved when the treatments (top graphic, vertical bars) are timed just in advance of or to coincide with the most significant infection events.

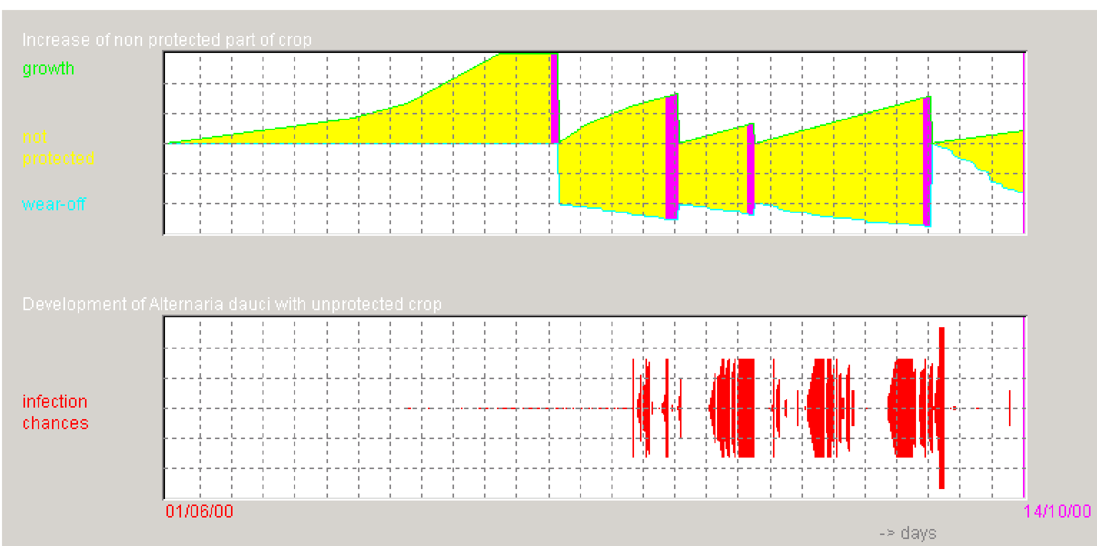
APPENDIX IV

PLANT Plus Season Review – Alternaria advice graphics

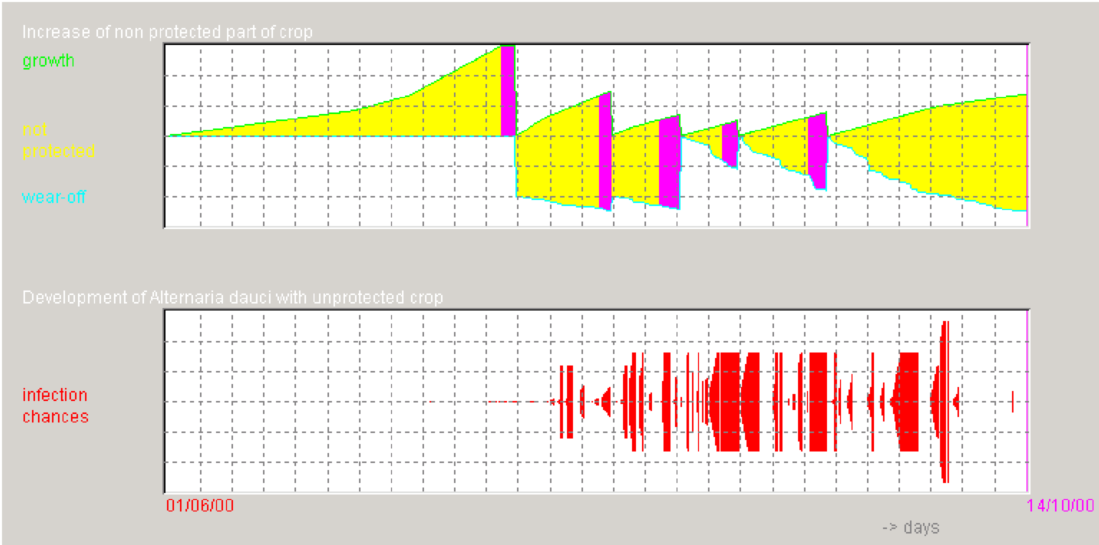
Angus Big Hill



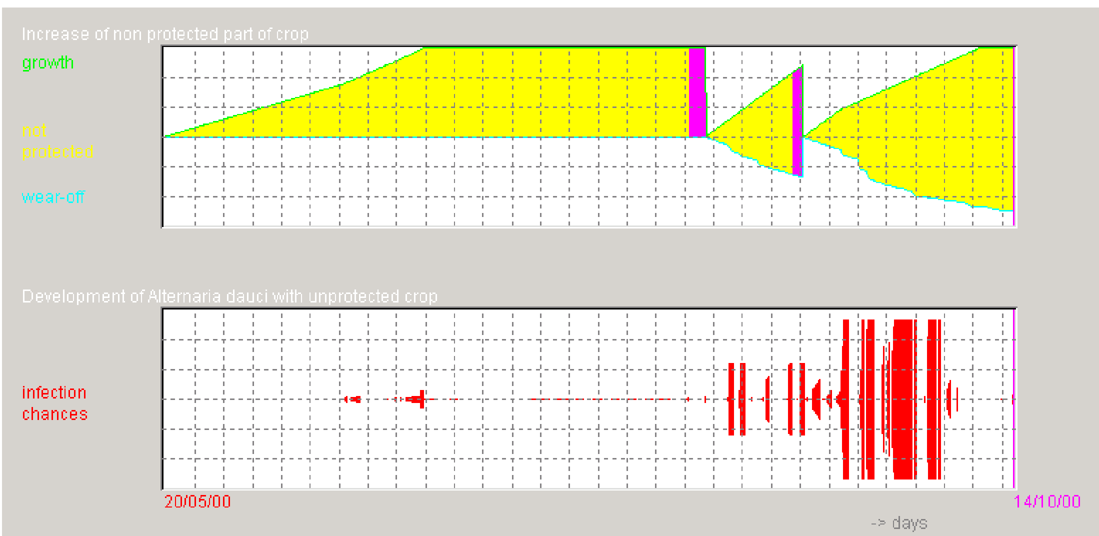
Fife Top Strip



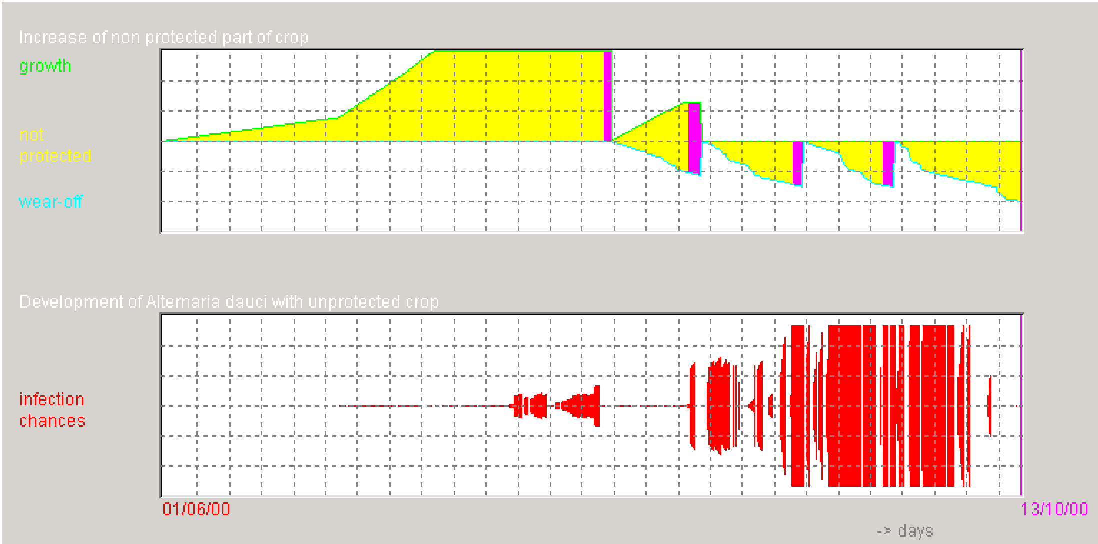
Perthshire Marlefield



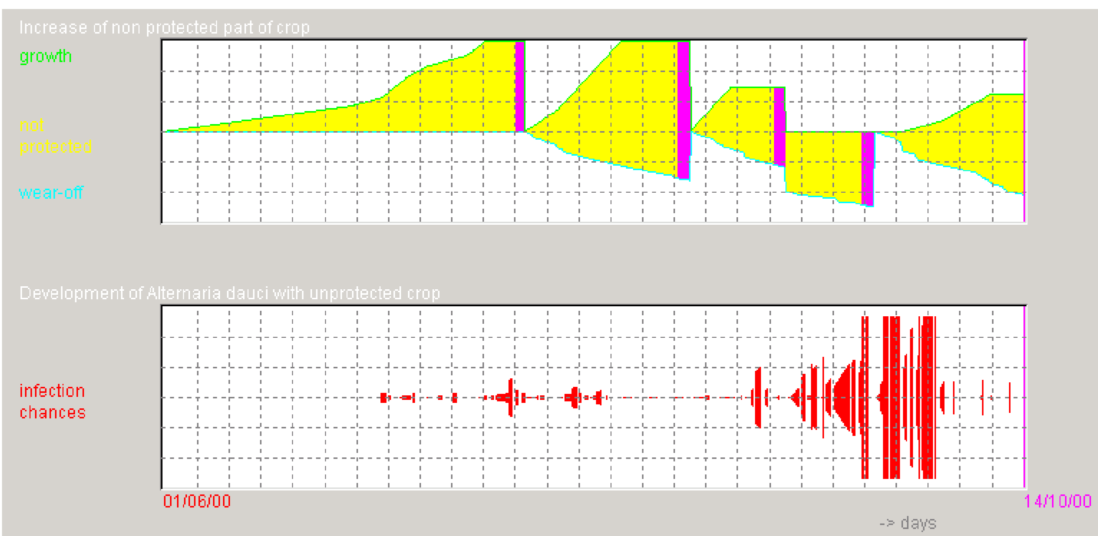
Yorks Ricall Mine



Norfolk Rotac 933



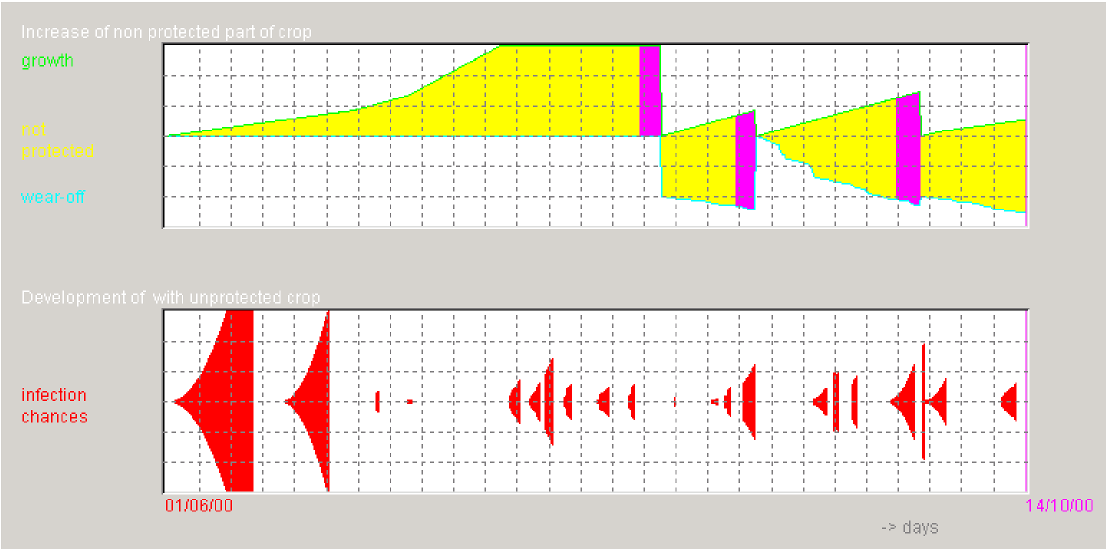
Suffolk Sutton Hoo SHP 122A/B



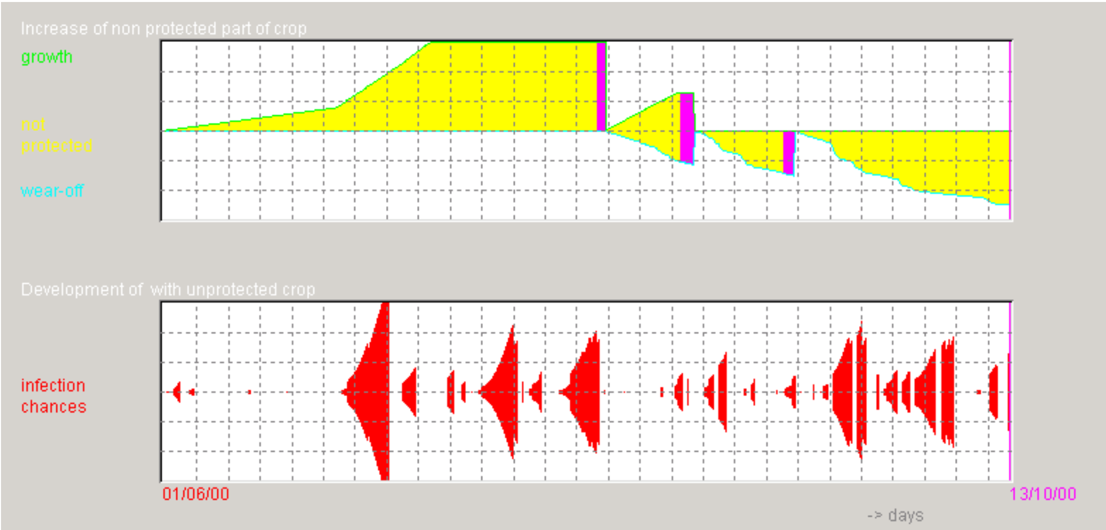
APPENDIX V

PLANT Plus Season Review – Sclerotinia advice graphics

Angus Big Hill



Norfolk Rotac 933



APPENDIX VI

Summary of PLANT Plus and normal practice sprays

1. All sites
2. Scotland
3. Yorkshire
4. Norfolk
5. Suffolk

Summary of all Commercial Sites

Number of Sites	**Summary of Averages**	Presence of Alternaria	Number of Treatments	Presence of Sclerotinia
8	NORMAL PRACTICE	6.3	4.3	5.1
8	Untreated	8.3	0.0	5.1
8	PLANT PLUS ADVICE	5.8	3.4	7.6
8	Untreated	7.8	0.0	7.8

PLANT-Plus Infection Rating Presence of Alternaria dauci	PLANT-Plus Infection Rating
First sign of disease in the area - within 25km radius	1
No infection in the crop but a few infected fields in the area	2
No infection in the crop but several infected fields in the area	3
No infection in the crop but many infected fields in the area	4
No infection in the crop but conditions favourable for disease spread	5
Disease found in the crop, less than 1% infected foliage	6
Disease found in the crop, 5-10% infected foliage	8
Disease found in the crop, >10% infected foliage	10

PLANT-Plus Infection Rating Presence of Sclerotinia
First sign of disease in crop
Disease found in the crop, widespread infection
Disease found in the crop, limited foliar damage
Disease found in the crop, extensive foliar damage
Disease found in the crop, extensive foliar damage, core rot present

Scotland

NORMAL PRACTICE

Location	Site	Field	Treatment				
Fife	Carriston	Tin Shed	Date	8/10/00	8/22/00	9/5/00	9/21/00
			Product	Folicur	Folicur	Folicur	Corbel
			Rate	0.5 ltr/ha	0.5 ltr/ha	0.5 ltr/ha	1.0 ltr/ha
			Untreated	nil	nil	nil	nil
Angus	Balmirmer	Bothy Park	Date	8/3/00	8/16/00	8/29/00	9/10/00
			Product	Folicur	Folicur	Folicur	Folicur
			Rate	0.5 ltr/ha	0.5 ltr/ha	0.5 ltr/ha	0.5 ltr/ha
			Untreated	nil	nil	nil	nil
Perthshire	Loanleven	Kinon Park	Date	8/10/00	8/21/00	8/30/00	9/13/00
			Product	Folicur	Folicur	Folicur	Corbel
			Rate	0.5 ltr/ha	1.0 ltr/ha	1.0 ltr/ha	1.0 ltr/ha
			Untreated	nil	nil	nil	nil

PLANT PLUS ADVICE

Fife	Balbirnie	Top Strip	Date	8/2/00	8/21/00	9/2/00	9/30/00
			Product	Folicur	Folicur	Folicur	Corbel
			Rate	0.5 ltr/ha	0.5 ltr/ha	0.5 ltr/ha	1.0 ltr/ha
			Untreated	nil	nil	nil	nil
Angus	Ardestie	Big Hill	Date		8/18/00	9/2/00	9/28/00
			Product		Folicur	Folicur	Folicur
			Rate		0.5 ltr/ha	1.0 ltr/ha	0.5 ltr/ha
			Untreated	nil	nil	nil	nil
Perthshire	Loanleven	Marlefield	Date	8/10/00	8/21/00	8/30/00	9/13/00
			Product	Folicur	Folicur	Folicur	Corbel

			Rate	0.5 ltr/ha	1.0 ltr/ha	1.0 ltr/ha	1.0 ltr/ha
			Untreated	nil	nil	nil	nil

Summary of Averages	sites	treatments
NORMAL PRACTICE	3	4
Untreated	3	0
PLANT PLUS ADVICE	3	3.66
Untreated	3	0

Yorkshire

NORMAL PRACTICE

Location	Site	Field	Treatment			
Yorkshire		Providence	Date	8/10/00	8/22/00	9/8/00
			Product	Folicur	Folicur	Folicur
			Rate	0.5 ltr/ha	1.0 ltr/ha	1.0 ltr/ha
			Untreated	nil	nil	nil

PLANT PLUS ADVICE

Yorkshire		Ricall Mine	Date		8/22/00	9/8/00
			Product		Folicur	Folicur
			Rate		1.0 ltr/ha	1.0 ltr/ha
			Untreated		nil	nil

Summary of Averages	sites	treatments
NORMAL PRACTICE	1	3
Untreated	1	0
PLANT PLUS ADVICE	1	2
Untreated	1	0

Norfolk

NORMAL PRACTICE

Location	Site	Field	Treatment					
Norfolk	Wroxham	936	Date	7/28/00	8/10/00	8/24/00	9/9/00	9/23/00
			Product	Folicur	Folicur	Folicur	Folicur	Corbel
			Rate	0.5 ltr/ha	0.5 ltr/ha	0.5 ltr/ha	0.5 ltr/ha	1.0 ltr/ha
			Untreated	nil	nil	nil	nil	nil
	Wroxham	934	Date	7/28/00	8/10/00	8/24/00	9/9/00	9/23/00
			Product	Folicur	Folicur	Folicur	Folicur	Corbel
			Rate	0.5 ltr/ha	0.5 ltr/ha	0.5 ltr/ha	0.5 ltr/ha	1.0 ltr/ha
			Untreated	nil	nil	nil	nil	nil
	Wroxham	935	Date	7/28/00	8/10/00	8/24/00	9/9/00	9/23/00
			Product	Folicur	Folicur	Folicur	Folicur	Corbel
			Rate	0.5 ltr/ha	0.5 ltr/ha	0.5 ltr/ha	0.5 ltr/ha	1.0 ltr/ha
			Untreated	nil	nil	nil	nil	nil

<u>PLANT PLUS ADVICE</u>							
Norfolk	Rotac	933 (106)	Date	8/10/00	8/24/00	9/9/00	9/23/00
			Product	Compass	Compass	Folicur	Corbel
			Rate	2.0 ltr/ha	2.0 ltr/ha	1.0 ltr/ha	1.0 ltr/ha
			Untreated	nil	nil	nil	nil
	Rotac	931 (94)	Date	8/10/00	8/24/00	9/9/00	9/23/00
			Product	Compass	Compass	Folicur	Corbel
			Rate	2.0 ltr/ha	2.0 ltr/ha	1.0 ltr/ha	1.0 ltr/ha
			Untreated	nil	nil	nil	nil
	Rotac	932 (95)	Date	8/10/00	8/24/00	9/9/00	9/23/00
			Product	Compass	Compass	Folicur	Corbel
			Rate	2.0 ltr/ha	2.0 ltr/ha	1.0 ltr/ha	1.0 ltr/ha
			Untreated	nil	nil	nil	nil

Summary of Averages	sites	treatments
<u>NORMAL PRACTICE</u>	3	5
Untreated	3	0
<u>PLANT PLUS ADVICE</u>	3	4
Untreated	3	0

Suffolk

NORMAL PRACTICE

Location	Site	Field	Treatment					
Suffolk			Date	7/28/00	8/10/00	8/24/00	9/9/00	9/23/00
			Product	Folicur	Folicur	Folicur	Folicur	Corbel
			Rate	0.5 ltr/ha	0.5 ltr/ha	0.5 ltr/ha	0.5 ltr/ha	1.0 ltr/ha
			Untreated	nil	nil	nil	nil	nil

PLANT PLUS ADVICE

Suffolk	Sutton Hoo	SHP 122A/B	Date		7/28/00	8/23/00	9/7/00	9/21/00
			Product		Compass	Folicur	Folicur	Folicur
			Rate		2 ltr/ha	0.5 ltr/ha	0.5 ltr/ha	1.0 ltr/ha
			Untreated		nil	nil	nil	nil

Summary of Averages	sites	treatments
NORMAL PRACTICE	1	5
Untreated	1	0
PLANT PLUS ADVICE	1	4
Untreated	1	0