Project Report No. 357 Part 2

**Development of a decision support system for phoma and light leaf spot in winter oilseed rape ('PASSWORD' Project)**

December 2004

**Chapter 8**

**Evaluation of cultivar resistance and fungicide strategies**

## 8.1 Introduction

The overall aim of this component of project was to quantify the contribution of cultivar resistance and fungicides for disease control and to establish guiding principles to optimise disease management. Data from field experiments have been also been used in the development of new disease models so that PASSWORD can provide information on the risk of yield loss in current cultivars.

There were five main objectives in this part of the study:

1. To monitor the development of light leaf spot and phoma stem canker epidemics.
2. To appraise the contribution and value of genetic resistance for the control of light leaf spot and phoma stem canker.
3. To examine disease development in relation to weather factors.
4. To determine the optimum strategy for disease control using cultivar resistance and fungicides.
5. To test disease forecasts.

## 8.2 Materials and methods

The work was done at three locations, each with a specific disease target:
1. ADAS Boxworth, Cambridge – high risk site for phoma leaf spot and stem canker.
Cultivar x fungicide experiments, 2000-2003

1. 2. SAC Aberdeen, Aberdeen, Scotland – high risk site for light leaf spot.
Cultivar x fungicide experiments, 2000-2003

3. Rothamsted Research, Harpenden, Herts – high risk site for light leaf spot, moderate risk of stem canker.
Fungicide dose and timing experiments, 2000-2003

### 8.2.1 Cultivar x fungicide experiments

Single replicated field experiments with three cultivars and four fungicide treatments were done at both ADAS Boxworth and SAC Aberdeen in harvest years 2001, 2002 and 2003. Disease development and control were monitored throughout the year and related to seed yield.

<u>Boxworth</u>

The experiment was laid out as a randomised block design with four replicate blocks. Three cultivars with differing resistance to stem canker (Pronto, Apex and Escort) (Table 12) were drilled in late August or early September each year (Table 13). Target plant populations were 40 plants/$m^2$ for the hybrid cultivar Pronto and 80 plants/$m^2$ for Apex and Escort. Plot size was 48 $m^2$. Fungicide programmes were applied to manipulate the disease epidemics and were first applied to all cultivars when phoma leaf spot threshold (c.10% plants affected) was reached in at least one cultivar (Table 13). Fungicide treatment rates used at Boxworth were:

flusilazole + carbendazim (as Punch C) at 0.4 litres product/ha, difenoconazole (as Plover) at 0.25 l/ha + carbendazim (as Bavistin DF) 0.5 kg/ha and tebuconazole (as Folicur) at 0.75 l/ha for pgr activity (Appendix Tables 1 & 2).

Table 12. Cultivars and UK disease resistance ratings (1-9 scale), Boxworth 2000-2003.

| Cultivar | Resistance rating Phoma stem canker | Resistance rating Light leaf spot | Reference code |
|---|---|---|---|
| Pronto | 5 | 6 | 1 |
| Apex | 5 | 5 | 2 |
| Escort | 7 | 7 | 3 |

The incidence and severity of all diseases were assessed. Foliar and pod disease severities were recorded as the % leaf or pod area affected. Stem diseases were assessed on individual plants using a 0-4 Index (0 = healthy, 4 = dead) that was converted to a 0-100 index for pre-harvest and multisite comparisons. After an initial field sample of 10 plants from each control plot to monitor disease development, all plots were sampled (10 plants/plot) at the second spray date and close to each spray application date and then made at approximately 6 weekly intervals until crop maturity (see Appendix Table 3). The plants were generally assessed on the same day as they were sampled in autumn but were incubated in winter/spring for a short period to encourage sporulation of light leaf spot. The final assessment for stem and pod diseases was made in the field on 25 plants/plot. Plant numbers/$m^2$ were assessed after harvest in all plots in 0.25$m^2$ quadrats (5 quadrats/plot).

Table 13. Fungicide programmes applied to experiments at Boxworth, 2000-2003.

| Programme | Treatment | **2000 – 2001** | | | |
|---|---|---|---|---|---|
| Timing | | First disease mid October<br><br>10 Oct 2000 | T1 + 6 weeks December<br><br>18 Dec 2000 | Early Feb Early stem extension<br><br>7 March 2001 | Stem extension for pgr activity<br><br>9 April 2001 |
| GS | | 1,07-1,08 | 1,10-1,12 | 2,1, 3,1 | 2,6, 3,3 (30cm) |
| 1 | Untreated | - | - | - | - |
| 2 | Full | Punch C | Plover + Bavistin | Punch C | - |
| 3 | Autumn | Punch C | Plover + Bavistin | - | - |
| 4 | Managed | Punch C | - | - | Folicur |
| | | | | | |
| | | **2001 - 2002** | | | |
| Timing | | First disease mid October<br><br>17 Oct 2001 | T1 + 6 weeks December<br><br>26 Nov 01 | Early Feb Early stem extension<br><br>15 Feb 2002 | Stem extension for pgr activity<br><br>20 March 02 |
| GS | | 1,5-1,7 | 1,10-1,12 | 1,16, 2,3, 3,1 | 2,3, 3,3 |
| 1 | Untreated | - | - | - | - |
| 2 | Full | Punch C | Plover + Bavistin | Punch C | - |
| 3 | Autumn | Punch C | Plover + Bavistin | - | - |
| 4 | Managed | Punch C | - | - | Folicur |
| | | | | | |
| | | **2002 - 2003** | | | |
| Timing | | First disease mid October<br><br>18 Nov 2002 | T1 + 6 weeks December<br><br>05 Dec 2002 | Early Feb Early stem extension<br><br>10 Feb 2003 | Stem extension for pgr activity<br><br>08 April 2003 |
| GS | | 1,06 | 1,08 | 3,1 | 3,5-3,6 |
| 1 | Untreated | - | - | - | - |
| 2 | Full | Punch C | Plover + Bavistin | Punch C | - |
| 3 | Autumn | Punch C | Plover + Bavistin | - | - |
| 4 | Managed | Punch C | - | - | Folicur |

Plots were harvested using a Sampo 2025 plot combine and harvested plot lengths were recorded individually. Moisture content was assessed by a Dickey-John GS2000 and final yield expressed at 90% dry matter.

Data were analysed by analysis of variance using GENSTAT, with use of appropriate transformations of data when data showed a skewed distribution.

A Delta T data logger with sensors for temperature, relative humidity, surface wetness (3 heights after stem extension) and rainfall was operated in the field within an oilseed rape crop. An automatic weather station was also operated at Boxworth.

SAC Aberdeen

Three field experiments were done in Aberdeenshire, during the seasons 2000/2001, 2001/2002 and 2002/2003. Three winter oilseed rape cultivars with differing resistance to light leaf spot were used throughout (Table 14). Trials were sown at standard timings (late August/early September) and seed rates for Aberdeenshire (6 kg/ha Apex and Escort, 3.6 kg/ha Synergy). The fungicides used were Punch C (carbendazim + flusilazole, 125:250 g a.i/l., standard full dose application rate of 0.8 l/ha) and Folicur (tebuconazole, 250 g a.i./l, standard full dose application rate of 1.0 l/ha) (Table 15).

Table 14. Winter oilseed rape cultivars and UK disease resistance ratings (1-9) for Aberdeen.

| Cultivar | Resistance rating Phoma stem canker | Resistance rating Light leaf spot | Reference code |
|---|---|---|---|
| Apex | 5 | 5 | 2 |
| Escort | 7 | 7 | 3 |
| Synergy | 4 | 6 | 4 |

Four fungicide programmes were used to manipulate disease epidemics, the actual timings of these programmes depending on the disease levels and season (Table 15). All programmes were designed to start at first signs of disease as follows:

1. Full and autumn only programmes - start in mid-October to early November, at the standard commercial timings for the area (for Aberdeenshire early to mid-November), when ground cover was good, if no light leaf spot had appeared before this time. Second sprays to be applied in early December, dependent on weather and ground conditions. Spring spray to be applied at stem extension (GS 3.3).

2. Managed programme – crops to be monitored fortnightly and fungicide sprays applied at first signs of light leaf spot on monitored plants, when weather and ground conditions allow. Spray timings may differ for different cultivars. Repeat if necessary in spring and if plant growth regulator (pgr) effect required (not required for these sites). First spray to consist of 0.4 l/ha Punch C, second and subsequent sprays to consist of Folicur (rates variable).

In the 2000/2001 season, autumn flooding and severe winter weather (6 weeks of snow and very hard frosts post-Christmas) followed by the Foot & Mouth outbreak severely disrupted the fungicide application timings.

Experiments were done as a split plot design, with cultivar as main plots and fungicides as sub-plot treatments, with four replicates. Plots were sown using an Oyjord plot drill, with plot size 40 m$^2$. Fungicides were applied using an AZO hand held sprayer. Fertiliser and other crop protection applications were applied according to local practices (see Appendix Table 7 for site details).

Disease assessments were carried out at regular intervals during the season. Prior to stem extension, 10 plants/plot were incubated in a damp chamber at room temperature for 24 – 48 hours before assessing light leaf spot and other diseases. Plants were assessed for % leaves, % plants and % leaf area affected with light leaf spot, phoma leaf spot and stem canker (and alternaria and downy mildew). At the end of the season, disease assessments were done on stems and pods. Plant counts were done before Christmas and after harvest.

Plots were harvested using a Sampo plot combine. Moisture content of seeds was calculated by drying 100g of freshly harvested seed in an oven at 80°C for 48 hours then weighing. Final yields were adjusted to 90% dry matter.

Data were analysed by Analysis of Variance using the general linear model of the GENSTAT for Windows package. Selected data are shown in the results. Full details can be found in the Appendix section.

Table 15. Fungicide programmes applied to experiments at Aberdeen, 2000-2003.

| Programme | Name | 2000 – 2001 | | | |
|---|---|---|---|---|---|
| | | 02 Nov 00 | Dec 00 | 11 April 01 | 15 May 01 |
| | | GS 1.08 – 1.11 | | GS 3.1 | GS 3.5 |
| 1 | Untreated | - | - | - | - |
| 2 | Full | 0.4 l/ha Punch C | - | 0.75 l/ha Folicur | 0.5 l/ha Folicur |
| 3 | Autumn | 0.4 l/ha Punch C | | 0.75 l/ha Folicur | - |
| 4 | Managed | - | - | 0.6 l/ha Punch C | 0.75 l/ha Folicur |
| | | | | | |
| | | 2001 - 2002 | | | |
| | | 02 Nov 01 | 10 Dec 01 | 05 Feb 02 | 18 April 02 |
| | | GS 1.06-1.08 | GS 1.08-1.11 | GS 1.10-1.12 | GS 3.5 |
| 1 | Untreated | - | - | - | - |
| 2 | Full | 0.4 l/ha Punch C | 0.5 l/ha Folicur | - | 0.5 l/ha Folicur |
| 3 | Autumn | 0.4 l/ha Punch C | 0.5 l/ha Folicur | - | - |
| 4 | Managed | - | 0.4 l/ha Punch C (Apex only) | 0.4 l/ha Punch C (Escort & Synergy) | 0.5 l/ha Folicur |
| | | | | | |
| | | 2002 - 2003 | | | |
| | | 12 Nov 02 | 12 Dec 02 | 16 Jan 03 | 21 March 03 |
| | | GS 1.08 | GS 1.10-1.11 | GS 1.11-1.12 | GS 3.3 |
| 1 | Untreated | - | - | - | - |
| 2 | Full | 0.4 l/ha Punch C | 0.5 l/ha Folicur | - | 0.5 l/ha Folicur |
| 3 | Autumn | 0.4 l/ha Punch C | 0.5 l/ha Folicur | - | - |
| 4 | Managed | - | - | 0.4 l/ha Punch C | 0.5 l/ha Folicur |

8.2.2 Fungicide spray timing experiments at Rothamsted

Field experiments were done at Rothamsted in 2000/01, 2001/02 and 2002/03. All were randomised block experiments with 20 x 3m plots and three replicates of each treatment (six replicates of untreated treatment, except in 2002/03 when there were three replicates of untreated). In all experiments, cv Apex was sown at 80 – 90 seeds/$m^2$ and flusilazole + carbendazim was applied as flusialzole + carbendazim 200 + 100 g a.i./ha (as Punch C at 0.8 l/ha product) on three occasions in the autumn: F1, when approximately 10% plants had phoma leaf spot, and F2 and F3 at approximately monthly intervals thereafter (Table 16). One treatment, R (routine), received four or five applications at monthly intervals and others received combinations of spray timings as two half-rate applications.

Table 16. Time of sowing, harvest and application of flusilazole + carbendazim fungicide in relation to leaf numbers present on 30 untreated, marked plants on winter oilseed rape (cv. Apex) experiments at Rothamsted in 2000/01, 2001/02 and 2002/03.

| | | 2000/01 | 2001/02 | 2002/03 | |
|---|---|---|---|---|---|
| | | | | Large plants | Small plants |
| Approx. date of emergence | | 4 September | 24 August | 1 Sept | 17 Sept |
| Sowing date | | 23 August | 14 August | 20 August | |
| Date of flusilazole + carbendazim application | F1 | 9 October (47 days > sowing) | 22 October (68 days > sowing) | 4 November (76 days > sowing) | |
| | F2 | 6 November (75 days > sowing) | 19 November (97 days > sowing) | 18 December (120 days > sowing) | |
| | F3 | 14 December (113 days > sowing) | 8 January (147 days > sowing) | 16 January (149 days > sowing) | |
| Leaf numbers present on >50% of 30 marked plants at time of flusilazole + carbendazim application | F1 | 2 - 6 | 3 -9 | 4 - 11 | 2 – 4 |
| | F2 | 4 - 10 | 6 - 12 | 8 - 17 | 4 - 10 |
| | F3 | 7 – 13+ | 9 - 15 | 10 - 20 | 7 - 13 |
| Date of tebuconazole application | T | 3 April | 5 April | 18 March | |
| Harvest date | | 23 July (334 days > sowing) | 18 July (338 days > sowing) | 14 July (328 days > sowing) | |

Ten plants/plot were sampled monthly throughout the season, and assessed for disease. In addition, five plants at 2 m intervals along each long side of each of three untreated plots (i.e. 10 plants/plot; 1 plot/block), were marked at the beginning of the season and individual leaves monitored at 7-14 day intervals as they developed, became infected with phoma leaf spot and abscissed. Leaves were numbered in sequence on the underside with a permanent marker pen, and at each assessment the number of phoma lesions was recorded for each leaf. Once branching began, only leaves on the main stem were monitored.

In 2000/01, leaf assessments ceased in late January because of frost damage. In 2002/03, a dry period after sowing caused emergence to occur in two distinct periods, resulting in a mixture of early-germinating, large plants and late-germinating, small plants. The fungicide experiment was therefore moved to another part of the field where germination was more uniform, but 30 large and 30 small plants from the original experimental site were marked and monitored. Five large and five small plants were arranged alternately down each side of three plots (i.e. 10 large and 10 small plants/plot; 1 plot/block). Marked plants were also assessed for stem canker at 2-4 week intervals from stem extension to harvest using a 0-4 scale. At the final, destructive assessment an internal examination was made of the stem to ascertain whether the canker was confined to the cortex or whether the pith was also affected. On one or two occasions in the autumn of each season, the length of the longest leaf on each plant was measured and in the summer of 2002 and 2003 the diameter of stem bases was measured. In each season, the number of pods/plant was estimated at harvest. A Burkard spore sampler, located approximately 1 km from the field experiment and surrounded by stems collected after harvest from the previous season's untreated plots, was operated each season to monitor *L. maculans* ascospore release. A light leaf spot epidemic developed in each season and tebuconazole (Folicur) was applied in the spring to the whole experiment except those plots containing marked plants.

## 8.3 Results

### 8.3.1 Cultivar x Fungicide experiments

<u>ADAS Boxworth 2000-2001</u>

*Disease development on untreated plots (Figure 23; Appendix Tables 4a, 4b, 4c).*

Early growth was slow in dry conditions. Downy mildew was most active during the period from mid October to December and showed particularly rapid development at the 2-4 leaf stage between 9 and 17 October. The severity of downy mildew was low in autumn and rarely exceeded 0.3% leaf area.

Phoma leaf spot was first seen on 9 October and the increase in incidence was slower than in previous years. The largest increase was between 6 and 14 November when incidence approximately doubled on all three cultivars, averaging 93 to 100% plants affected. The severity of phoma leaf spot flu ctuated in the autumn and the overall trend was for severity to increase up to 9 February and then to decline. Apex showed the highest incidence and most severe phoma leaf spot infection, whilst Escort had the lowest incidence and severity (Table 17). However, the basic pattern of phoma leaf spot development was similar on all cultivars.

The first phoma stem lesions were found in late March when 9% of stems had lesions. There was further lesion development during flowering, but the main increase in stem lesions took place after the end of flowering. In late March, stem canker lesions (23% plants affected) were slightly more common than upper stem lesions (9% plants affected). The incidence of basal canker on untreated plots increased to 91% of plants affected at the end of flowering and 93-98% canker by 27 June (Fig. 23). Final canker severity was moderate with indices (0-100 scale) in untreated controls in the range 30-44 (Table 20).

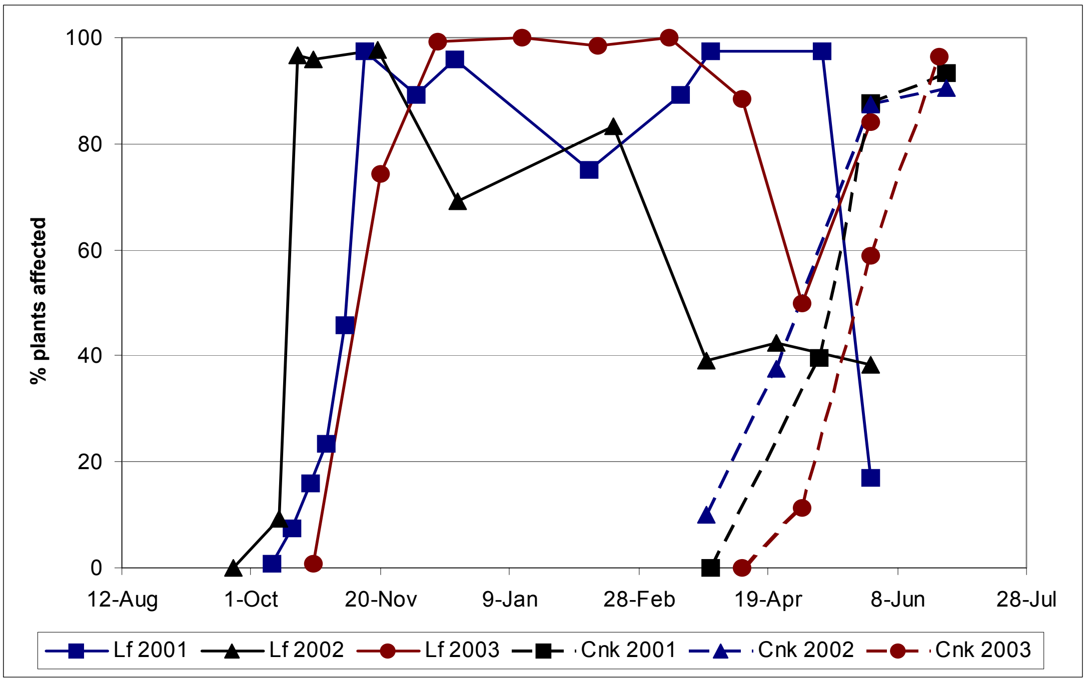


Figure 23. Development of phoma leaf spot and stem canker on cv. Apex in harvest years 2001, 2002 and 2003 at Boxworth.

Light leaf spot was first seen on 28 March and it increased sharply during April to affect 48-58% plants in untreated plots in early May. Leaf infection was more severe on Apex than the other two cultivars.

Light leaf spot was present mainly on untreated Apex in late May and fungicides had prevented disease development in most plots (Tables 21& 22). Even on untreated Apex leaves, severity was only 0.7% area affected. Rather low levels of light leaf spot were recorded on stems where severity remained low (1.2% area affected) up to harvest. There were low levels of sclerotinia stem rot at crop maturity and low levels of light leaf spot, powdery mildew and downy mildew on pods. Petals stuck to leaves in the unsettled weather during flowering and this led to a high incidence of botrytis on leaves, though there was little stem infection (Appendix Table 4).

*Disease control*

*Phoma leaf spot (Tables 17 & 18)*: The first full assessment on 19 December showed that the first fungicide treatment applied on 10 November 2000 had given good control of phoma leaf spot. Phoma incidence was reduced from 96% in the untreated to 18-28% in the three treatment regimes. The leaf spot severity data showed very effective control (c.95%) had been achieved. Escort showed a significantly lower incidence and severity of phoma leaf spot than the other cultivars. Assessments on 9 February – approximately 7 weeks after the second fungicide (Plover + mbc on 18 December) showed rather weaker control of phoma leaf spot and no significant differences in severity between the Managed treatment (a single autumn spray) and the two spray programmes in Full and Autumn treatments. There was, however, a significantly higher incidence of phoma leaf spot in the single spray treatment compared with the two-spray treatments. These effects were more readily identifiable on the 16 March assessment because control of phoma was achieved only where two autumn sprays had been applied. These treatments halved incidence of phoma leaf spot and reduced its severity by 87%. Control was slightly less effective on 29 March, but still significant for the Full and Autumn regimes. At this stage the severity of phoma leaf spot on Escort was only half that on Pronto and about 35% of that on Apex (Table 17).

*Basal cankers and upper stem lesions (Tables 19, 20, 25 & 26)*: stem canker lesions affected 39% of untreated plants in early May and this increased to 93% plants affected by harvest. In early May, there were signs that cultivar resistance, but not fungicides, were providing some control of canker. The canker index was lowest on cv. Apex, but there was no difference between Pronto and Escort. Fungicide effects were also weak. On 29 May, phoma stem lesions were apparent but were predominantly found on Pronto (24% plants affected) and were not controlled by fungicides (Table 20). Pre-harvest phoma stem lesions were all slight lesions and are unlikely to have affected yield. All the fungicide treatments reduced the incidence and severity of stem canker at harvest, with the Full programmes giving slightly better control than the Managed treatment, but neither differed from the Autumn programme (Table 19).

*Light leaf spot (Tables 21 & 22)*: there was light leaf spot in this experiment from early March onwards and it was consistently more prevalent in the untreated control of Apex than in any other treatment. All the programmes gave good reductions in disease incidence on leaves in late March and controlled stem infection.

*Yield (Tables 23 and 34)*

This was a moderately yielding site, which averaged 2.81 t/ha. There were significant differences in yield between cultivars and a significant cultivar x fungicide interaction. There was no response to fungicides, but the interaction revealed a response of 0.36-0.59 t/ha on Apex and a small negative response on Escort (-0.07 to –0.16 t/ha). Yield was reduced by sulphur deficiency problems in two of the four blocks and this may have contributed to the negative yield effects recorded in four treatments. Covariate correction for the sulphur deficiency symptoms was done and gave a marginal improvement in the coefficient of variation for yield, which improved from 7.0% to 6.7%. Escort gave the highest mean yield and this was significantly higher than Apex, but not Pronto;  Pronto also gave a better yield than Apex.

Overall, all fungicide treatments averaged small positive yield trends (0.14-0.20 t/ha), but these would have not have covered the costs of a two spray treatment (0.14 t/ha yield response = £20/ha with rapeseed at £150/t given fungicide costs of £25/ha for 2 x half dose of fungicide), unless there was an economic benefit from an improvement in oil content.

Table 17. Incidence and severity of phoma leaf spot at each full assessment, Boxworth 2000/2001; cultivar and fungicide treatment means.

| | % plants with phoma | | | | | | % leaf area affected by phoma leaf spot | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatment | 19/12 | 09/02 | 16/03 | 29/03 | 09/05 | 29/05 | 19/12 | 09/02 | 16/03 | 29/03 | 09/05 | 29/05 |
| Variety | | | | | | | | | | | | |
| Pronto | 41.9 | 55.6 | 67.5 | 88.7 | 86.9 | 8.8 | 0.20 | 0.81 | 0.44 | 0.44 | 0.60 | 0.05 |
| Apex | 51.2 | 61.2 | 83.7 | 91.9 | 88.7 | 8.1 | 0.37 | 0.99 | 0.62 | 0.63 | 0.64 | 0.06 |
| Escort | 29.4 | 44.4 | 41.9 | 71.9 | 70.6 | 3.8 | 0.09 | 0.56 | 0.15 | 0.22 | 0.30 | 0.02 |
| SED 33df | 4.94 | 4.76 | 7.75 | 4.02 | 5.77 | 3.43 | 0.074 | 0.189 | 0.111 | 0.066 | 0.075 | 0.017 |
| F test | <0.1% | 1% | <0.1% | <0.1% | 1% skew | ns skew | 1% skew | ns skew | <0.1% skew | <0.1% | <0.1% | ns skew |
| | | | | | | | | | | | | |
| Fungicide | | | | | | | | | | | | |
| Nil | 95.8 | 75.0 | 89.2 | 97.5 | 97.5 | 16.7 | 0.78 | 1.75 | 0.64 | 0.78 | 0.75 | 0.13 |
| Full | 22.5 | 44.2 | 43.3 | 63.3 | 64.2 | 3.3 | 0.03 | 0.37 | 0.07 | 0.14 | 0.24 | 0.01 |
| Autumn | 27.5 | 40.0 | 46.7 | 83.3 | 80.8 | 5.0 | 0.06 | 0.35 | 0.08 | 0.29 | 0.46 | 0.02 |
| Managed | 17.5 | 55.8 | 78.3 | 92.5 | 85.8 | 2.5 | 0.02 | 0.67 | 0.83 | 0.53 | 0.61 | 0.01 |
| SED 33df | 5.71 | 5.50 | 8.95 | 4.64 | 6.66 | 3.96 | 0.085 | 0.218 | 0.129 | 0.132 | 0.0869 | 0.019 |
| F test | <0.1% | <0.1% | <0.1% | <0.1% | <0.1% skew | 1% skew | <0.1% skew | <0.1% skew | <0.1% skew | <0.1% | <0.1% | <0.1 skew |
| | | | | | | | | | | | | |
| Interaction | ns | ns | ns | 5% | ns | ns | ns | ns | 5% | <0.1% | ns | ns |

Table 18. Effect of spray timing on phoma leaf spot incidence (I) (% plants affected) and severity (S) (% leaf area affected), Boxworth 2000/2001.

| Cultivar | Fungicide | Assessment dates | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 19.12.00 | | 09.02.01 | | 16.03.01 | | 29.03.01 | | 09.05.01 | | 29.05.01 | |
| | | I | %area | I | S | I* | S* | I | S | I | S | I | S |
| Apex | Untreated | 100.0 | 1.25 | 80.0 | 2.04 | 100.0 | 0.92 | 100.0 | 1.15 | 100.0 | 0.98 | 17.5 | 0.16 |
| Apex | Full | 32.5 | 0.05 | 50.0 | 0.36 | 62.5 | 0.12 | 67.5 | 0.14 | 67.5 | 0.21 | 2.5 | 0.01 |
| Apex | Autumn | 45.0 | 0.12 | 50.0 | 0.57 | 72.5 | 0.12 | 100.0 | 0.37 | 90.0 | 0.58 | 7.5 | 0.05 |
| Apex | Managed | 27.5 | 0.04 | 65.0 | 1.00 | 100.0 | 1.32 | 100.0 | 0.88 | 97.5 | 0.78 | 5.0 | 0.02 |
| Pronto | Untreated | 100.0 | 0.74 | 80.0 | 1.93 | 97.5 | 0.65 | 100.0 | 0.80 | 97.5 | 0.76 | 20.0 | 0.16 |
| Pronto | Full | 20.0 | 0.02 | 35.0 | 0.26 | 40.0 | 0.05 | 62.5 | 0.09 | 70.0 | 0.35 | 7.5 | 0.01 |
| Pronto | Autumn | 27.5 | 0.03 | 42.5 | 0.29 | 52.5 | 0.11 | 92.5 | 0.31 | 85.0 | 0.59 | 5.0 | 0.01 |
| Pronto | Managed | 20.0 | 0.02 | 65.0 | 0.75 | 80.0 | 0.94 | 100.0 | 0.57 | 95.0 | 0.73 | 2.5 | 0.01 |
| Escort | Untreated | 87.5 | 0.34 | 65.0 | 1.28 | 70.0 | 0.35 | 92.5 | 0.38 | 95.0 | 0.51 | 12.5 | 0.08 |
| Escort | Full | 15.0 | 0.02 | 47.5 | 0.51 | 27.5 | 0.03 | 60.0 | 0.20 | 55.0 | 0.17 | 0.0 | 0.00 |
| Escort | Autumn | 10.0 | 0.02 | 27.5 | 0.19 | 15.0 | 0.02 | 57.5 | 0.19 | 67.5 | 0.20 | 2.5 | 0.01 |
| Escort | Managed | 5.0 | 0.01 | 37.5 | 0.26 | 55.0 | 0.22 | 77.5 | 0.15 | 65.0 | 0.33 | 0.0 | 0.00 |
| Grand mean | | 40.8 | 0.22 | 53.7 | 0.79 | 64.4 | 0.40 | 84.2 | 0.44 | 82.1 | 0.515 | 6.9 | 0.04 |
| SED (61df)<br>F test | | 9.89<br>ns | 0.147<br>skew | 9.53<br>ns | 0.377<br>ns | 15.50<br>ns | 0.223<br>5%<br>skew | 8.04<br>5% | 0.132<br><0.1% | 11.54<br>ns<br>skew | 0.1506<br>ns | 6.86<br>skew<br>ns | 0.047<br>skew<br>ns |

* Logit transformed data analysed

Table 19. Effect of spray timing on stem canker and stem lesion incidence (I) (% plants affected) and severity (S) (0 – 4 score), Boxworth 2001; cultivar and fungicide treatment means.

| Treatment | | | | Assessment dates | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 09.05.01 | | | | 29.05.01 | | | | 27.6.01 | |
| | | | | | canker | | stem lesions | | canker | |
| Treatment | Ckr I | Ckr Ind | Stem I | Stem Ind | I | S | I* | S* | I | S[1] |
| Variety | | | | | | | | | | |
| Pronto | 47.7 | 0.56 | 6.3 | 0.06 | 89.4 | 1.43 | 24.4 | 0.26 | 82.5 | 29.4 |
| Apex | 16.3 | 0.16 | 0.0 | 0.00 | 63.7 | 0.87 | 3.7 | 0.04 | 55.5 | 16.6 |
| Escort | 36.2 | 0.39 | 1.3 | 0.01 | 73.7 | 1.17 | 5.6 | 0.06 | 58.5 | 17.9 |
| SED 33df | 6.74 | 0.081 | 1.41 | 0.014 | 5.30 | 0.127 | 4.70 | 0.036 | 4.32 | 1.695 |
| F test | <0.1% | <0.1% | <0.1% skew | <0.1% skew | <0.1% | <0.1% | <0.1% skew | <0.1% skew | 0.1% | <0.1% |
| | | | | | | | | | | |
| Fungicide | | | | | | | | | | |
| Nil | 39.4 | 0.44 | 2.6 | 0.03 | 87.5 | 1.41 | 10.8 | 0.125 | 93.3 | 36.1 |
| Full | 40.0 | 0.44 | 2.5 | 0.03 | 77.5 | 1.18 | 11.7 | 0.117 | 45.3 | 12.9 |
| Autumn | 27.5 | 0.29 | 0.8 | 0.01 | 74.2 | 1.04 | 8.3 | 0.092 | 56.7 | 16.6 |
| Managed | 26.7 | 0.33 | 4.2 | 0.04 | 63.3 | 0.99 | 14.2 | 0.142 | 66.7 | 19.5 |
| SED 33df | 7.78 | 0.94 | 1.63 | 0.016 | 6.11 | 0.146 | 5.42 | 0.0585 | 4.99 | 1.957 |
| F test | ns | ns | ns skew | ns skew | 1% | 5% | ns skew | ns skew | <0.1% | <0.1% |

* Logit transformed data analysed
[1] Index is 0-100 scale

Table 20. Effect of spray timing on stem canker and stem lesion incidence (I) (% plants affected) and severity (S) (0 – 4 score), Boxworth 2001.

| Cultivar | Fungicide | Assessment dates | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 09.05.01 | | | | 29.05.01 | | | | 27.6.01 | |
| | | canker | | stem lesions | | canker | | stem lesions | | canker | |
| | | I | S | I | S | I | S | I* | S* | I | S[1] |
| Apex | Untreated | 12.5 | 0.13 | 0.0 | 0.00 | 85 | 1.38 | 5 | 0.05 | 97.0 | 34.8 |
| Apex | Full | 27.5 | 0.28 | 0.0 | 0.00 | 65 | 0.75 | 3 | 0.03 | 19.0 | 4.8 |
| Apex | Autumn | 10.0 | 0.10 | 0.0 | 0.00 | 53 | 0.63 | 3 | 0.03 | 44.0 | 11.0 |
| Apex | Managed | 15.0 | 0.15 | 0.0 | 0.00 | 53 | 0.73 | 5 | 0.05 | 62.0 | 15.8 |
| Pronto | Untreated | 60.8 | 0.68 | 7.8 | 0.08 | 95 | 1.55 | 20 | 0.23 | 98.0 | 43.5 |
| Pronto | Full | 45.0 | 0.58 | 5.0 | 0.05 | 85 | 1.43 | 30 | 0.30 | 70.0 | 21.3 |
| Pronto | Autumn | 40.0 | 0.43 | 2.5 | 0.03 | 93 | 1.33 | 15 | 0.18 | 78.0 | 25.5 |
| Pronto | Managed | 45.0 | 0.58 | 10.0 | 0.10 | 85 | 1.40 | 33 | 0.33 | 84.0 | 27.3 |
| Escort | Untreated | 45.0 | 0.50 | 0.0 | 0.00 | 83 | 1.30 | 8 | 0.10 | 85.0 | 30.0 |
| Escort | Full | 47.5 | 0.48 | 2.5 | 0.03 | 83 | 1.35 | 3 | 0.03 | 47.0 | 12.8 |
| Escort | Autumn | 32.5 | 0.35 | 0.0 | 0.00 | 78 | 1.18 | 8 | 0.08 | 48.0 | 13.3 |
| Escort | Managed | 20.0 | 0.25 | 2.5 | 0.03 | 53 | 0.85 | 5 | 0.05 | 54.0 | 15.5 |
| Grand mean | | 33.4 | 0.374 | 2.52 | 0.025 | 75.6 | 1.154 | 11.3 | 0.119 | 65.5 | 21.3 |
| SED (33df) | | 13.48 | 0.162 | 2.822 | 0.0282 | 10.59 | 0.253 | 9.39 | 0.1014 | 8.64 | 3.39 |
| F test | | ns | ns | ns | ns | ns | ns | ns | ns | 1% | ns |
| | | skew | skew | | | | | skew | skew | | |

*Logit transformed data analysed

[1] **Index is 0-100 scale**

Table 21. Incidence and severity of light leaf spot in relation to cultivar and fungicide treatment, Boxworth 2001; cultivar and fungicide treatment means.

| | % plants with light leaf spot | | | | | % leaf area affected by light leaf spot | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Treatment | 29/03 | 16/05 | 29/05 | 9/05 stem | 29/05 stem | 29/03 | 16/05 | 29/05 | 9/05 stem | 29/05 stem |
| Cultivar | | | | | | | | | | |
| Pronto | 1.3 | 32.0 | 0.6 | 0.6 | 2.5 | 0.012 | 0.25 | 0.012 | 0.003 | 0.04 |
| Apex | 0.6 | 31.9 | 7.5 | 0.6 | 12.5 | 0.012 | 0.54 | 0.191 | 0.075 | 0.93 |
| Escort | 5.6 | 25.0 | 0.6 | 0.6 | 0.0 | 0.081 | 0.45 | 0.001 | 0.003 | 0.00 |
| SED 33df | 2.45 | 6.96 | 1.39 | 0.80 | 1.89 | 0.0423 | 0.305 | 0.0648 | 0.0430 | 0.248 |
| F test | ns skew | ns | 0.1% skew | ns skew | <0.1% skew | ns skew | ns skew | ns skew | ns Skew | <0.1% skew |
| Fungicide | | | | | | | | | | |
| Nil | 5.0 | 54.3 | 10.8 | 2.5 | 19.2 | 0.058 | 1.35 | 0.026 | 0.108 | 1.27 |
| Full | 1.7 | 20.8 | 0.0 | 0.0 | 0.0 | 0.017 | 0.10 | 0.000 | 0.000 | 0.00 |
| Autumn | 2.5 | 24.2 | 0.8 | 0.0 | 0.0 | 0.058 | 0.11 | 0.012 | 0.000 | 0.00 |
| Managed | 0.8 | 19.2 | 0.0 | 0.0 | 0.8 | 0.008 | 0.09 | 0.000 | 0.000 | 0.02 |
| SED 33df | 2.83 | 8.04 | 2.28 | 0.923 | 3.08 | 0.0488 | 0.353 | 0.1058 | 0.0703 | 0.287 |
| F test | ns skew | <0.1% | <0.1 skew | 5% skew | <0.1% skew | ns skew | 1% skew | 5% skew | ns skew | <0.1% skew |
| Interaction | ns skew | ns | ns skew | ns skew | <0.1% skew | ns skew | ns skew | ns skew | ns skew | ns skew |

Table 22. Effect of spray timing on light leaf spot incidence (I) (% plants affected) and severity (S)(% stem area affected), Boxworth 2001.

| Cultivar | Fungicide | Light leaf spot assessment dates | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 09.03.01 | | 29.05.01 | | 09.0501 | | 29.05.01 | |
| | | leaf | | leaf | | Stem lesions | | stem lesions | |
| | | 1 | S | I | S | I | S | I* | S* |
| Apex | Untreated | 57.5 | 1.87 | 27.5 | 0.725 | 2.5 | 0.30 | 50.0 | 3.71 |
| Apex | Full | 27.5 | 0.14 | 0.0 | 0.000 | 0.0 | 0.00 | 0.0 | 0.00 |
| Apex | Autumn | 17.5 | 0.05 | 2.5 | 0.037 | 0.0 | 0.00 | 0.0 | 0.00 |
| Apex | Managed | 25.0 | 0.08 | 0.0 | 0.000 | 0.0 | 0.00 | 0.0 | 0.00 |
| Pronto | Untreated | 58.0 | 0.62 | 2.5 | 0.050 | 2.5 | 0.01 | 7.5 | 0.10 |
| Pronto | Full | 22.5 | 0.11 | 0.0 | 0.000 | 0.0 | 0.00 | 0.0 | 0.00 |
| Pronto | Autumn | 32.5 | 0.18 | 0.0 | 0.000 | 0.0 | 0.00 | 0.0 | 0.00 |
| Pronto | Managed | 15.0 | 0.08 | 0.0 | 0.000 | 0.0 | 0.00 | 0.0 | 0.00 |
| Escort | Untreated | 47.5 | 1.55 | 2.5 | 0.005 | 2.5 | 0.01 | 0.0 | 0.00 |
| Escort | Full | 12.5 | 0.04 | 0.0 | 0.000 | 0.0 | 0.00 | 0.0 | 0.00 |
| Escort | Autumn | 22.5 | 0.09 | 0.0 | 0.000 | 0.0 | 0.00 | 0.0 | 0.00 |
| Escort | Managed | 17.5 | 0.10 | 0.0 | 0.000 | 0.0 | 0.00 | 0.0 | 0.00 |
| Grand mean | | 29.6 | 0.41 | 2.92 | 0.068 | 0.63 | 0.027 | 5.0 | 0.32 |
| SED (33df)<br>F test | | 13.93<br>ns<br>skew | 0.611<br>ns | 3.94<br><0.1%<br>skew | 0.1296<br>ns<br>5.4% | 0.16<br>ns<br>skew | 0.1217<br>ns<br>skew | 5.34<br><0.1%<br>skew | 0.496<br><0.1%<br>skew |

* Logit transformed data analysed

Table 23. Mean yield in relation to cultivar and fungicide treatment, Boxworth, 2001-2003; cultivar and fungicide treatment means.

| Treatment | Yield at 90% dry matter (t/ha) | | | |
|---|---|---|---|---|
| | 2001 | 2002 | 2003 | Mean |
| Cultivar | | | | |
| Pronto | 2.87 | 4.06 | 3.24 | 3.39 |
| Apex | 2.65 | 3.71 | 3.33 | 3.22 |
| Escort | 2.92 | 3.70 | 2.97 | 3.20 |
| SED(33df;mean 104df) | 0.070 | 0.130 | 0.175 | 0.119 |
| F test | 0.1% | 5% | ns | ns |
| | | | | |
| Fungicide | | | | |
| Untreated | 2.69 | 3.35 | 2.70 | 2.91 |
| Full | 2.85 | 3.98 | 3.45 | 3.43 |
| Autumn | 2.83 | 3.96 | 3.23 | 3.34 |
| Managed | 2.89 | 4.00 | 3.34 | 3.41 |
| SED(33df;mean 104df) | 0.081 | 0.106 | 0.202 | 0.138 |
| F test | ns | <0.1% | 1% | <0.1% |
| CV(%) | 7.0 | 9.6 | 15.5 | 17.8 |
| Interaction | 1% | ns | 5% | ns |

Table 24. Yield and mean yield of cultivars and fungicides, Boxworth, 2001-2003.

| Treatment | | Yield (t/ha) | | | |
|---|---|---|---|---|---|
| Cultivar | Fungicide | | | | |
| | | 2001 | 2002 | 2003 | Mean |
| Pronto | Untreated | 2.73 | 3.44 | 2.83 | 3.00 |
| Pronto | Full | 2.92 | 4.16 | 3.40 | 3.49 |
| Pronto | Autumn | 2.79 | 4.49 | 3.12 | 3.47 |
| Pronto | Managed | 3.05 | 4.15 | 3.60 | 3.60 |
| Apex | Untreated | 2.30 | 3.29 | 2.90 | 2.83 |
| Apex | Full | 2.72 | 3.87 | 4.06 | 3.55 |
| Apex | Autumn | 2.90 | 3.78 | 3.47 | 3.39 |
| Apex | Managed | 2.67 | 3.87 | 2.89 | 3.14 |
| Escort | Untreated | 3.04 | 3.30 | 2.36 | 2.90 |
| Escort | Full | 2.89 | 3.92 | 2.89 | 3.23 |
| Escort | Autumn | 2.81 | 3.61 | 3.09 | 3.17 |
| Escort | Managed | 2.95 | 3.98 | 3.52 | 3.48 |
| SED (33df; mean 104 df) | | 0.140 | 0.260 | 0.349 | 0.238 |
| F test | | 1% | ns | 5% | ns |
| CV (%) | | 7.0 | 9.6 | 15.5 | 17.8 |
| Interactions by year | | | | | ns |

Table 25. Mean stem canker in relation to cultivar and fungicide treatment, Boxworth 2001-2003.

| Treatment | Mean stem canker index (0-100 scale) | | | |
|---|---|---|---|---|
| | 2001 | 2002 | 2003 | Mean |
| Cultivar | | | | |
| Pronto | 29.4 | 41.8 | 34.1 | 35.1 |
| Apex | 16.6 | 26.9 | 28.8 | 24.1 |
| Escort | 17.9 | 24.5 | 25.5 | 22.6 |
| SED(33df;mean 105df) | 1.70 | 2.60 | 2.14 | 1.31 |
| F test | <0.1% | <0.1% | 0.1% | <0.1% |
| | | | | |
| Fungicide | | | | |
| Untreated | 36.1 | 58.8 | 50.6 | 48.5 |
| Full | 12.9 | 12.1 | 4.5 | 9.8 |
| Autumn | 16.6 | 16.9 | 20.8 | 18.1 |
| Managed | 19.5 | 36.4 | 42.1 | 32.7 |
| SED(33df;mean 105df) | 1.96 | 5.20 | 1.74 | 1.52 |
| F test | <0.1% | <0.1% | <0.1% | <0.1% |
| CV(%) | 22.5 | 23.7 | 20.5 | 23.6 |
| Interaction C x F | ns | ns | ns | 5% |

Table 26. Annual and mean stem canker indices by cultivar and fungicide treatment, Boxworth 2001-2003.

| Treatment | Mean stem canker index (0-100 scale) | | | | |
|---|---|---|---|---|---|
| | | | | | |
| Cultivar | Fungicide | | | | |
| | | 2001 | 2002 | 2003 | Mean |
| Pronto | Untreated | 43.5 | 70.0 | 51.3 | 54.9 |
| Pronto | Full | 21.3 | 17.3 | 5.3 | 14.6 |
| Pronto | Autumn | 25.5 | 27.8 | 30.3 | 27.8 |
| Pronto | Managed | 27.3 | 52.3 | 49.8 | 43.1 |
| Apex | Untreated | 34.8 | 53.0 | 49.3 | 45.7 |
| Apex | Full | 4.8 | 8.8 | 5.3 | 6.3 |
| Apex | Autumn | 11.0 | 14.0 | 19.0 | 14.7 |
| Apex | Managed | 15.8 | 31.8 | 41.8 | 29.8 |
| Escort | Untreated | 30.0 | 53.5 | 51.3 | 44.9 |
| Escort | Full | 12.8 | 10.3 | 3.0 | 8.7 |
| Escort | Autumn | 13.3 | 9.0 | 13.0 | 11.8 |
| Escort | Managed | 15.5 | 25.3 | 34.8 | 25.2 |
| SED (33df; mean 104 df) | | 3.39 | 5.20 | 4.27 | 2.63 |
| F test | | ns | ns | ns | 5% |
| CV (%) | | 22.5 | 23.7 | 20.5 | 23.6 |
| Interactions by year | | | | | ns |

ADAS Boxworth 2001-2002

*Disease development on untreated plots (Appendix Tables 5a, 5b, 5c)*

Early growth was slow in dry conditions and downy mildew was most active during October and then declined to a low incidence until late March. The severity of downy mildew was low in autumn and rarely exceeded 0.2% leaf area.

Phoma leaf spot was first seen on 12 October and the increase in its incidence was more rapid than in previous years, with 95-100% plants affected only a week later (Figure 23). The severity of phoma leaf spot fluctuated in the autumn and the peak severity occurred on 29 November. Phoma leaf spot remained moderately severe up to 20 March. Apex showed the most severe phoma leaf spot infection and Escort had the lowest severity.

The first phoma stem canker lesions were found in late March on all three cultivars, when 7.5-15% of stems had lesions. There was further lesion development during flowering, and the main increase in canker lesions took place before the end of flowering. The incidence of basal canker on untreated plots increased to 88-93% by 27 June. Canker severity was moderately severe with indices (0-100 scale) in untreated controls in the range 53-70. In late April, the first phoma stem lesions started to appear but final incidence was very low (8-13% plants affected).

Light leaf spot was first seen on 20 February and it increased steadily during stem extension and flowering, affecting leaves on 48-78% of plants by the end of May. Light leaf spot was most severe on Apex. Stem symptoms were apparent from April onwards and there was some pod infection, notably on Apex.where untreated plants showed 10% pod area affected. There were low levels of powdery mildew on stems and pods at crop maturity (range 2-6% pod area affected) and traces of alternaria on pods (0.1% area).

***Phoma leaf spot** control **(Tables 27 & 28)***

The first full assessment on 28 November showed that the first fungicide treatment applied on 17 October 2001 had given good control of phoma leaf spot by reducing severity from 3.2% to 0.5%. Phoma incidence was only slightly reduced from 98% in the untreated to 80-88% in the three treatment regimes. Escort showed a significantly lower incidence and severity of phoma leaf spot than the other cultivars. Assessments on 18 February – approximately 12 weeks after the second fungicide (Plover + mbc on 26 November) showed rather weaker control of phoma leaf spot and a significant difference in incidence and severity between the single autumn spray (Managed treatment) and the two spray programmes. These effects were less readily identifiable in the 25 March assessment, because phoma control (reduced disease severity) was achieved only with the Full spray treatments. The Full and Autumn treatments still reduced phoma incidence by more than 50%. Thereafter, control of phoma leaf spot was no longer apparent (Table 27), though the lowest severity persisted on Escort (Table 28).

*Control of basal cankers and stem lesions (Tables 29, 30 & 31)*

At the end of April, there were encouraging signs that fungicides in the Full and Autumn programmes were providing some control of canker. Canker index data indicated that canker was being controlled rather more effectively on Escort than on the other two cultivars, particularly with the Managed programme (51% plants with canker on Escort, 82% plants with canker on Apex and 84% plants with canker on Pronto) (Table 31). Pre-harvest, canker indices were reduced to less than 20 (i.e. >60% control) by full and autumn programmes on Apex and Escort, but only by the Full programme on Pronto. On 27 June, phoma stem lesions were apparent on 9% plants overall, but they were not controlled by fungicides.

Fungicides delayed the appearance of cankers, particularly between 22 April and 29 May, when untreated incidence increased by 51% and treated incidence by only 6-8% in full and autumn programmes (Table 30). There were smaller increases in incidence of basal cankers during June. Differences between untreated and treated plots were significant by the end of May, when canker incidence was reduced from 90% to as little as 17% with the full programme. The Full and Autumn programmes reduced canker severity pre-harvest from 59 to 12-17 (Table 30) and were significantly more effective than the Managed programme (index 36). Fungicides reduced the incidence of moderate and severe lesions and increased the percentage of healthy or slightly infected stems. Pronto had more moderate and severe cankers than the other two cultivars. There was a significant cultivar x fungicide interaction for canker incidence, but not for canker severity index.

*Light leaf spot control (Tables 32, 33 & 34)*

Light leaf spot was recorded in this experiment from February onwards and it was consistently more prevalent in the untreated control than in any of the fungicide treatments. All the programmes gave good reductions in light leaf spot incidence on leaves from March onwards. The advantage of Full and Autumn programmes over single autumn spray in the Managed treatment was apparent in March, but this effect tended to disappear by the April assessments following the spring application of Folicur in the Managed treatment. Later assessments of light leaf spot on stems and pods also showed that autumn and full regimes remained effective.

*Yield (Tables 23 and 24)*

This was a fairly high yielding site which averaged 3.82 t/ha (1 t/ha more than in 2001). There were significant differences in yield between Pronto and the other two cultivars, but no cultivar x fungicide interaction. The response to fungicides revealed a response of 0.49-0.58 t/ha on Apex, 0.31-0.68 t/ha on Escort and 0.71-1.05 t/ha on Pronto. Pronto was the highest yielding cultivar overall, though cultivars differed by only 0.15 t/ha in their untreated yield. Overall, all fungicide treatments were cost-effective if each fungicide spray application equates to 0.1 t/ha of yield. The best margin was achieved with the Autumn programme on Pronto (1.05 t/ha minus a 0.2 t/ha treatment cost = 0.85 t/ha with rapeseed at £150/t = £127.5/ha. All three fungicide treatments gave rather similar yields, margins were therefore higher in Autumn and Managed treatments where only two sprays were used compared with three applications in the Full programme.

Table 27. Incidence and severity of phoma leaf spot at each full assessment, Boxworth 2001/2002.

| Treatment | % plants with phoma | | | | | | % leaf area affected by phoma leaf spot | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cultivar | 19/10 | 28/11 | 18/02 | 25/03 | 22/4 | 29/05 | 19/10 | 28/11 | 18/02 | 25/03 | 22/4 | 29/05 |
| Pronto | | 94.4 | 85.6 | 36.2 | 45.6 | 5.6 | | 1.36 | 0.42 | 0.15 | 0.39 | 0.17 |
| Apex | | 95.6 | 83.7 | 26.9 | 33.1 | 9.4 | | 1.63 | 0.43 | 0.11 | 0.25 | 0.26 |
| Escort | | 72.5 | 55.0 | 13.1 | 20.6 | 6.9 | | 0.51 | 0.18 | 0.04 | 0.15 | 0.09 |
| SED 33df | | 2.37 | 4.56 | 5.26 | 7.20 | 3.34 | | 0.172 | 0.039 | 0.030 | 0.104 | 0.148 |
| F test | | <0.1% | <0.1% | <0.1% | 1% | ns | | <0.1% | <0.1% | <0.1%* | ns | ns |
| | | | | | | | | | | | | |
| Fungicide | | | | | | | | | | | | |
| Nil | | 97.5 | 83.3 | 39.2 | 42.5 | 8.3 | | 3.22 | 0.51 | 0.13 | 0.44 | 0.31 |
| Full | | 87.5 | 66.7 | 11.7 | 39.2 | 7.5 | | 0.50 | 0.21 | 0.03 | 0.29 | 0.08 |
| Autumn | | 80.0 | 67.5 | 17.5 | 40.0 | 5.8 | | 0.47 | 0.23 | 0.10 | 0.28 | 0.20 |
| Managed | | 85.0 | 81.7 | 33.3 | 10.8 | 7.5 | | 0.48 | 0.42 | 0.13 | 0.05 | 0.11 |
| SED 33df | | 2.74 | 5.26 | 6.08 | 8.31 | 3.86 | | 0.198 | 0.045 | 0.025 | 0.120 | 0.171 |
| F test | | <0.1% | 1% | <0.1% | 0.1% | ns | | <0.1% | <0.1% | <0.1%* | 5% | ns |
| | | | | | | skew | | skew | | skew | skew | skew |
| Interaction | | ns | ns | 5% | ns | ns | | <0.1% | ns | ns | ns | ns |

* Angular transformed data analysed, actual data presented

Table 28. Effect of spray timing on phoma leaf spot incidence (I) (% plants affected) and severity (S) (% leaf area affected), Boxworth 2001/2002.

| Cultivar | Fungicide | Phoma leaf spot | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 28.11.01 | | 18.02.02 | | 25.03.02 | | 22.04.02 | | 29.05.02 | |
| | | I | %area | I | S | I | S* | I | S | I | S |
| Apex | Untreated | 100 | 4.53 | 85 | 0.60 | 33 | 0.12 | 40 | 0.34 | 3 | 0.53 |
| Apex | Full | 100 | 0.78 | 83 | 0.27 | 25 | 0.09 | 33 | 0.28 | 10 | 0.06 |
| Apex | Autumn | 85. | 0.61 | 78 | 0.27 | 13 | 0.09 | 48 | 0.31 | 8 | 0.13 |
| Apex | Managed | 98 | 0.59 | 90 | 0.58 | 38 | 0.16 | 13 | 0.08 | 18 | 0.32 |
| Pronto | Untreated | 100 | 3.69 | 93 | 0.65 | 53 | 0.20 | 58 | 0.83 | 10 | 0.21 |
| Pronto | Full | 93 | 0.52 | 78 | 0.27 | 5 | 0.01 | 58 | 0.45 | 5 | 0.03 |
| Pronto | Autumn | 95 | 0.60 | 83 | 0.30 | 35 | 0.18 | 55 | 0.22 | 8 | 0.45 |
| Pronto | Managed | 90 | 0.65 | 90 | 0.49 | 53 | 0.21 | 13 | 0.08 | 0 | 0.00 |
| Escort | Untreated | 93 | 1.46 | 73 | 0.30 | 33 | 0.09 | 30 | 0.16 | 13 | 0.19 |
| Escort | Full | 70 | 0.20 | 40 | 0.09 | 5 | 0.01 | 28 | 0.15 | 8 | 0.16 |
| Escort | Autumn | 60 | 0.19 | 43 | 0.12 | 5 | 0.03 | 18 | 0.30 | 3 | 0.01 |
| Escort | Managed | 68 | 0.19 | 65 | 0.21 | 10 | 0.03 | 8 | 0.01 | 5 | 0.01 |
| Grand mean | | 87.5 | 1.165 | 74.8 | 0.35 | 25.4 | 0.099 | 33.1 | 0.266 | 7.3 | 0.17 |
| SED 33 df | | 6.70 | 0.343 | 9.12 | 0.078 | 10.52 | 0.061 | 14.39 | 0.207 | 6.69 | 0.30 |
| F Test | | ns | 5%* | ns | ns | 5% | ns | ns | ns skew | ns skew | ns skew |

* Angular transformed data analysed, but actual data presented

Table 29. Effect of spray timing on stem canker and stem lesion incidence (I) (% plants affected) and severity (S) (0 – 4 score), Boxworth 2002.

| Treatment | Assessment date | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 22.04.02 | | | | 29.05.02 | | | |
| Cultivar | canker | | stem lesions | | canker | | stem lesions | |
| | I | S | I | S | I | S | I | S |
| Pronto | 25.6 | 7.7 | 2.5 | 0.03 | 54.4 | 24.7 | 3.7 | 0.04 |
| Apex | 23.8 | 6.7 | 0.6 | 0.01 | 43.1 | 15.9 | 5.6 | 0.08 |
| Escort | 18.1 | 5.0 | 0.0 | 0.00 | 34.4 | 13.8 | 5.6 | 0.09 |
| SED 33df | 5.29 | 1.66 | 1.36 | 0.014 | 4.99 | 2.35 | 2.50 | 0.033 |
| F test | Ns | Ns | Ns | Ns | 0.1% | <0.1% | Ns | Ns |
| | | | | | | | | |
| Fungicide | | | | | | | | |
| Nil | 39.2 | 11.5 | 1.7 | 0.02 | 90.0 | 42.5 | 11.7 | 0.18 |
| Full | 10.8 | 2.9 | 0.0 | 0.00 | 16.7 | 6.0 | 1.7 | 0.03 |
| Autumn | 12.5 | 3.3 | 1.7 | 0.02 | 20.8 | 6.9 | 4.2 | 0.04 |
| Managed | 27.5 | 8.1 | 0.8 | 0.01 | 48.3 | 17.1 | 2.5 | 0.03 |
| SED 33df | 6.11 | 1.91 | 1.57 | 0.016 | 5.77 | 2.71 | 2.89 | 0.038 |
| F test | <0.1% | <0.1% | Ns skew | Ns skew | <0.1% | <0.1% | 1% skew | <0.1% skew |
| Grand mean | 22.5 | 6.46 | 1.04 | 0.01 | 44.0 | 18.12 | 5.0 | 0.07 |
| Interaction | ns | ns | ns | ns | 5% | 5% | ns | ns |

Table 30. Canker incidence and severity pre-harvest, Boxworth 2002.

| Treatment Cultivar | Canker index (0-100) | % Nil canker stems | % Index 1 | % Index 2 | % Index 3 | % Index 4 | % moderate/ severe canker | Phoma stem lesion index (0-100) |
|---|---|---|---|---|---|---|---|---|
| Pronto | 41.8 | 31.8 | 18.0 | 16.0 | 19.8 | 14.5 | 50.2 | 2.62 |
| Apex | 26.9 | 40.5 | 30.8 | 11.5 | 15.3 | 2.0 | 28.8 | 2.50 |
| Escort | 24.5 | 53.7 | 18.5 | 10.5 | 10.5 | 6.8 | 27.8 | 1.75 |
| SED(47df) | 3.65 | 3.65 | 3.61 | 2.77 | 3.01 | 1.58 | 4.28 | 0.544 |
| F test | <0.001 | <0.001 | 0.001 | 0.122 | 0.016 | <0.001 | <0.001 | 0.235 |
| | | | | | | | | |
| Fungicide | | | | | | | | |
| Nil | 58.8 | 8.7 | 18.3 | 19.7 | 35.7 | 17.7 | 73.0 | 3.08 |
| Full | 12.1 | 71.7 | 16.7 | 5.3 | 4.3 | 2.0 | 11.7 | 2.67 |
| Autumn | 16.9 | 60.0 | 23.7 | 7.0 | 7.3 | 2.0 | 16.3 | 2.00 |
| Managed | 36.4 | 27.7 | 31.0 | 18.7 | 13.3 | 9.3 | 41.3 | 1.42 |
| SED(47df) | 4.21 | 4.21 | 4.17 | 3.20 | 3.48 | 1.82 | 4.94 | 0.628 |
| F test | <0.001 | <0.001 | 0.007 | <0.001 | <0.001 | <0.001 | <0.001 | 0.059 |
| | | | | | | skew | | |
| Interaction | ns | 5% | 5% | ns | ns | <0.1% | ns | ns |

Table 31. Incidence and severity (0-100 index) of canker and phoma stem lesions pre-harvest, Boxworth 2002.

| Cultivar | Fungicide | Assessed 27.06.02 | | | |
|---|---|---|---|---|---|
| | | Canker | | Stem lesions | |
| | | **I** | **S** | **I** | **S** |
| Apex | Untreated | 93 | 53.0 | 13 | 3.8 |
| Apex | Full | 24 | 8.8 | 13 | 3.3 |
| Apex | Autumn | 39 | 14.0 | 9 | 2.3 |
| Apex | Managed | 82 | 31.8 | 3 | 0.8 |
| Pronto | Untreated | 93 | 70.0 | 12 | 3.5 |
| Pronto | Full | 40 | 17.2 | 10 | 2.5 |
| Pronto | Autumn | 56 | 27.7 | 8 | 2.0 |
| Pronto | Managed | 84 | 52.2 | 10 | 2.5 |
| Escort | Untreated | 88 | 53.5 | 8 | 2.0 |
| Escort | Full | 21 | 10.3 | 9 | 2.3 |
| Escort | Autumn | 25 | 9.0 | 7 | 1.8 |
| Escort | Managed | 51 | 25.3 | 4 | 1.0 |
| Grand mean | | 91.3 | 31.1 | 8.83 | 2.29 |
| SED (33 df) | | 7.30 | 5.20 | 4.37 | 1.09 |
| F test | | 5% | ns | ns | ns |

Table 32. Incidence and severity of light leaf spot on leaves, Boxworth 2001/2002.

| Treatment | % plants with light leaf spot | | | | % leaf area affected by light leaf spot | | | |
|---|---|---|---|---|---|---|---|---|
| | 18/02 | 25/03 | 22/4 | 29/05 | 18/02 | 25/03 | 22/4 | 29/05 |
| Cultivar | | | | | | | | |
| Pronto | 0.6 | 14.4 | 31.3 | 30.0 | 0.014 | 0.093 | 0.70 | 1.06 |
| Apex | 1.3 | 15.0 | 32.5 | 30.0 | 0.021 | 0.234 | 1.46 | 2.66 |
| Escort | 0.6 | 6.2 | 19.4 | 18.8 | 0.012 | 0.044 | 0.26 | 1.08 |
| SED 33df | 0.87 | 3.84 | 7.45 | 4.49 | 0.0170 | 0.0901 | 0.549 | 0.484 |
| F test | ns | ns | ns | 5% | ns | ns | ns | 1% |
| | | | | | | | | |
| Fungicide | | | | | | | | |
| Nil | 2.5 | 25.8 | 53.3 | 63.3 | 0.047 | 0.320 | 2.31 | 5.47 |
| Full | 0.0 | 0.8 | 15.0 | 8.3 | 0.000 | 0.008 | 0.11 | 0.32 |
| Autumn | 0.0 | 7.5 | 23.3 | 21.7 | 0.000 | 0.059 | 0.39 | 0.43 |
| Managed | 0.8 | 13.3 | 19.2 | 11.7 | 0.016 | 0.107 | 0.41 | 0.18 |
| SED 33df | 1.01 | 4.44 | 8.61 | 5.19 | 0.0196 | 0.104 | 0.633 | 0.559 |
| F test | ns | ns | <0.1% | <0.1% | <0.1% | 5% | 1% | <0.1% |
| | skew | skew | skew | | skew | skew | skew | skew |
| Interaction | ns | ns | ns | ns | ns | ns | 5% | <0.1% |

Table 33. Effect of spray timing on light leaf spot incidence (I) (% plants affected) and severity (S) (% leaf or stem area affected), Boxworth 2002.

| Cultivar | Fungicide | Light leaf spot | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 19.02.02 | | 25.03.02 | | 22.04.02 | | 22.04.02 | | 29.05.02 | | 29.05.02 | |
| | | leaf | | leaf | | leaf | | stem lesions | | leaf | | stem lesions | |
| | | 1 | S | I | S | I | S | I* | S* | I | S | I | S |
| Apex | Untreated | 5 | 0.08 | 30 | 0.59 | 75 | 5.00 | 23 | 0.64 | 78 | 9.48 | 68 | 3.75 |
| Apex | Full | 0 | 0.00 | 3 | 0.03 | 15 | 0.08 | 3 | 0.01 | 8 | 0.44 | 3 | 0.03 |
| Apex | Autumn | 0 | 0.00 | 13 | 0.13 | 15 | 0.17 | 3 | 0.01 | 20 | 0.47 | 15 | 0.25 |
| Apex | Managed | 0 | 0.00 | 15 | 0.19 | 25 | 0.59 | 10 | 0.12 | 15 | 0.28 | 30 | 0.51 |
| Pronto | Untreated | 3 | 0.06 | 33 | 0.25 | 45 | 1.48 | 8 | 0.25 | 65 | 3.19 | 35 | 0.75 |
| Pronto | Full | 0 | 0.00 | 0 | 0.00 | 20 | 0.14 | 0 | 0.00 | 10 | 0.38 | 8 | 1.92 |
| Pronto | Autumn | 0 | 0.00 | 5 | 0.01 | 33 | 0.58 | 0 | 0.00 | 33 | 0.55 | 13 | 0.11 |
| Pronto | Managed | 0 | 0.00 | 20 | 0.11 | 28 | 0.59 | 8 | 0.24 | 13 | 0.13 | 18 | 0.36 |
| Escort | Untreated | 0 | 0.00 | 15 | 0.13 | 40 | 0.44 | 8 | 0.08 | 48 | 3.6 | 33 | 0.65 |
| Escort | Full | 0 | 0.00 | 0 | 0.00 | 10 | 0.10 | 3 | 0.01 | 8 | 0.14 | 8 | 0.08 |
| Escort | Autumn | 0 | 0.00 | 5 | 0.04 | 23 | 0.42 | 3 | 0.10 | 13 | 0.28 | 5 | 0.11 |
| Escort | Managed | 3 | 0.05 | 5 | 0.02 | 5 | 0.05 | 0 | 0.00 | 8 | 0.14 | 23 | 0.35 |
| Grand mean | | 0.8 | 0.02 | 11.9 | 0.12 | 27.7 | 0.81 | 5.4 | 0.122 | 26.3 | 1.60 | 21.3 | 0.74 |
| SED | | 0.078 | 0.034 | 7.69 | 0.18 | 14.91 | 1.10 | 5.45 | 0.256 | 8.98 | 0.97 | 9.66 | 0.812 |
| F test | | ns skew | ns skew | ns skew | ns skew | ns | 5% skew | ns skew | ns skew | ns | <0.1% | ns skew | 1% skew |

* Logit transformed data analysed

Table 34. Effect of spray timing on stem light leaf spot (I) (% plants affected) and severity (S) (% area affected), Boxworth 2002

| **Cultivar** | Fungicide | Light leaf spot assessments | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 22.04.02 | | 29.05.02 | | 27.06.02 | | |
| | | stem lesions | | stem lesions | | stem lesions | | % pod area |
| | | I | S | I* | S* | I | S | S |
| Apex | Untreated | 23 | 0.65 | 68 | 3.75 | 66 | 1.40 | 10.0 |
| Apex | Full | 3 | 0.01 | 3 | 0.03 | 3 | 0.05 | 12.8 |
| Apex | Autumn | 3 | 0.01 | 15 | 0.25 | 18 | 0.20 | 6.0 |
| Apex | Managed | 10 | 0.12 | 30 | 0.51 | 35 | 1.62 | 3.5 |
| Pronto | Untreated | 8 | 0.25 | 35 | 0.75 | 41 | 4.20 | 1.7 |
| Pronto | Full | 0 | 0.00 | 8 | 1.92 | 0 | 0.00 | 1.3 |
| Pronto | Autumn | 0 | 0.00 | 13 | 0.11 | 5 | 0.08 | 0.0 |
| Pronto | Managed | 8 | 0.24 | 18 | 0.36 | 3 | 0.03 | 0.0 |
| Escort | Untreated | 8 | 0.08 | 33 | 0.65 | 3 | 0.03 | 0.3 |
| Escort | Full | 3 | 0.01 | 8 | 0.08 | 0 | 0.00 | 2.5 |
| Escort | Autumn | 3 | 0.10 | 5 | 0.11 | 2 | 0.02 | 0.0 |
| Escort | Managed | 0 | 0.00 | 23 | 0.35 | 2 | 0.02 | 0.0 |
| Grand mean | | 5.4 | 0.12 | 21.3 | 0.74 | 14.8 | 0.64 | 3.2 |
| SED (33 df) | | 5.45 | 0.26 | 9.66 | 0.81 | 13.32 | 1.25 | 5.61 |
| F test | | ns skew | ns skew | ns* | 1% skew | ns skew | ns skew | ns skew |

* Angular transformed data analysed, actual percentage data shown

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*Disease development on untreated plots (Appendix Tables 6a, 6b, 6c)*

Early growth was slow in dry conditions during September and downy mildew was active in October and then showed exceptionally low activity for the rest of the season (Appendix Tables 5a-c)..

Phoma leaf spot was first seen on 25 October, at least 3 weeks later than usual and the increase in incidence was slower than in previous years, taking 6 weeks instead of 2 weeks to reach maximum incidence (Figure 23). Weekly monitoring in adjacent plots indicated a large increase in phoma leaf occurred between 11 and 20 November. Most plants had phoma spotting by 12 December and this was maintained up to early April. There was still a high incidence of phoma leaf spot in late May, a feature which follows from delayed autumn epidemics. Phoma leaf spot severity was highest in January and March and rather less severe on Escort than on the other two cultivars.

The first phoma stem lesions were found in early April when 2.5% of stems of Pronto and Apex had lesions. There was further lesion development during flowering, but the main increase in stem lesions took place after the end of flowering to affect 85-94% of untreated plants. In early May at the late flowering stage, the first basal canker lesions appeared and, unusually, were less prevalent than phoma stem lesions. The incidence of basal canker on untreated plots increased to 95-99% of plants affected by 24 June. However, canker severity was moderate with indices (0-100 scale) in untreated controls in the range 49-51.

Light leaf spot was first seen on 12 March and it showed very weak activity thereafter, presumably checked by dry weather in April.

*Disease control*

Phoma leaf spot (Tables 35 & 36): the first full assessment on 12 December showed that the first fungicide treatment applied on 18 November 2002 had reduced the severity of phoma leaf spot,but not its incidence. Escort showed a significantly lower incidence of phoma leaf spot than the other cultivars. Assessments on 13 January – approximately 5 weeks after the second fungicide (Plover + mbc on 5 December) and 8 weeks after the first spray in the Managed regime - showed better control of phoma leaf spot (>90%). On 12 February, the single November spray was no longer providing control, but Full and Autumn programmes maintained control. In March, phoma incidence and severity were lowest in the Full programme, showing the benefits of a spring fungicide (applied on 10 February). The

November spray provided good control for 8 weeks and the February spray for about 12 weeks. Escort had lower incidence of phoma leaf spot infection than the other cultivars and this was consistent in all the assessments.

There were significant differences in severity between the single autumn spray (managed treatment) and the two spray programmes. There was, however, a significantly higher incidence of phoma leaf spot in the single spray managed treatment compared with the two spray schedule. These effects were more readily identifiable on the 16 March assessment, when the two autumn spray treatments halved the incidence of phoma leaf spot and reduced its severity by 87%. Control was slightly less effective on 29 March, but still significant for the full and autumn regimes. At this stage the severity of phoma leaf spot on Escort was only half that recorded on Pronto and about 35% of that on Apex.

*Control of basal cankers and stem lesions (Tables 39, 40 & 41)*

In early April, phoma stem lesions were found only in untreated plots of Pronto and Apex. Unusually they appeared earlier than basal cankers. During May, the same trend continued with more phoma stem lesions in control plots and the highest incidence on Pronto. Differences between fungicide treatments were emerging by the end of May, with the Full regime giving very good control of stem lesions. The Managed programme was least effective. Before harvest, there was a very high incidence (mean 87% untreated plants affected) of stem lesions, some which were moderate or severe and causing premature ripening. The Full programme gave 74% control compared with 24% for the autumn programme. Most control was therefore achieved with the February spray.

Cankers appeared in early May as anticipated from the late phoma leaf spot epidemic.
Early control of canker was apparent during May, particularly for the Full and Autumn programmes. Canker index data indicated that canker was being well controlled on all cultivars by the Full programme (c.90%), moderately well by the Autumn programme(c.60%) and poorly by the Managed treatment (c.16%). There was virtually no difference in the untreated canker index between cultivars, but stem lesion severity was higher on Pronto than Apex or Escort. The Full programme gave 83% plants with no canker compared with 38% in the Autumn treatment, 6% in the Managed programme and 3% in control plots. The Full programme controlled almost all the cankers in severity classes 2-4 and left 16% plants with index 1 cankers. The Autumn programme left 19% plants with moderate or severe cankers (compared with 59% in untreated) and 43% plants with Index 1 (Table 40). This difference in efficacy is reflected in yield responses.

*Light leaf spot control(Tables 37 & 3)*

Tthere was very little light leaf spot in this experiment and it had a negligible impact on the experiment.

*Yield (Tables 23 & 24)*

This was a moderately yielding site which averaged 3.18 t/ha. Crop growth was restricted by the dry spring so plants were very short. High temperatures in June and July resulted in premature ripening where canker was not controlled and a relatively early harvest (16 July 2003). There were significant differences in yield between fungicides (but not between cultivars) and a cultivar x fungicide interaction. There was a response to fungicides of –0.01 1.16 t/ha on Apex, 0.29-0.77 t/ha on Pronto and 0.53-1.16 t/ha on Escort. Untreated Escort was the lowest yielding of the three cultivars at 2.35 t/ha. The Managed programme gave the highest yield on Escort and Pronto but had no effect on Apex (-0.01 t/ha). Overall, the Full programme gave a response of 0.75 t/ha, Autumn 0.53 t/ha and Managed 0.64 t/ha.

Overall, there was a net benefit for Full, Autumn and Managed programmes of 0.45, 0.33 and 0.44 t/ha or £67.50, £49.50 and £66.00/ha with rapeseed at £150/t.

This experiment provides new information on the effect of late phoma epidemics on small plants in moderately resistant cultivars. Important messages for the industry can be formulated to manage different epidemics with fungicide sprays.

Table 35. Incidence and severity of phoma leaf spot, Boxworth 2002/2003.

| Treatment | % plants with phoma leaf spot | | | | | | | % leaf area affected by phoma leaf spot | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 12/12 | 13/01 | 12/02 | 11/03 | 07/04 | 01/05 | 29/05 | 12/12 | 13/01 | 12/02 | 11/03 | 07/04 | 01/05 | 29/05 |
| Cultivar | | | | | | | | | | | | | | |
| Pronto | 95.6 | 56.9 | 70.0 | 96.9 | 75.0 | 38.1 | 60.0 | 0.83 | 1.00 | 0.99 | 2.41 | 0.66 | 0.27 | 1.36 |
| Apex | 89.4 | 74.4 | 81.9 | 96.2 | 80.0 | 46.9 | 71.2 | 0.89 | 1.04 | 1.12 | 2.03 | 0.89 | 0.41 | 1.90 |
| Escort | 81.9 | 53.1 | 63.1 | 86.2 | 57.5 | 21.9 | 39.4 | 0.70 | 0.76 | 0.63 | 1.65 | 0.38 | 0.23 | 0.65 |
| SED 33df | 3.69 | 4.75 | 4.05 | 4.79 | 4.69 | 6.70 | 6.37 | 0.104 | 0.113 | 0.19 | 0.256 | 0.089 | 0.097 | 0.413 |
| F test | 1% | <0.1% | <0.1% | ns | <0.1% | 1% | <0.1% | ns | 5% | 5% | 5% | <0.1% | ns | 1%* |
| | | | | | | | | | | | | | | |
| Fungicide | | | | | | | | | | | | | | |
| Nil | 99.2 | 100.0 | 98.3 | 100.0 | 88.3 | 50.0 | 84.2 | 1.71 | 3.11 | 1.90 | 3.29 | 1.07 | 0.56 | 2.27 |
| Full | 85.0 | 36.7 | 60.8 | 80.8 | 36.7 | 23.3 | 40.0 | 0.47 | 0.12 | 0.31 | 0.54 | 0.10 | 0.21 | 0.52 |
| Autumn | 85.0 | 43.3 | 34.2 | 92.5 | 77.5 | 40.8 | 57.5 | 0.56 | 0.15 | 0.14 | 2.28 | 0.73 | 0.32 | 1.52 |
| Managed | 86.7 | 65.8 | 93.3 | 99.2 | 80.8 | 28.3 | 45.8 | 0.49 | 0.35 | 1.31 | 2.01 | 0.68 | 0.12 | 0.90 |
| SED 33df | 4.27 | 5.49 | 4.68 | 5.53 | 5.42 | 7.73 | 7.35 | 0.121 | 0.130 | 0.222 | 0.296 | 0.103 | 0.112 | 0.476 |
| F test | 1% | <0.1% | <0.1% | 1% | <0.1% | 1% | <0.1% | <0.1% | <0.1% | <0.1% | <0.1% | <0.1% | 1% | <0.1%* |
| | | | | | | | | | skew | | | | skew | skew |
| Interaction | ns | ns | 5% | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns |

* Significance on angular transformed data, actual data presented

Table 36. Effect of spray timing on phoma leaf spot incidence (I) (% plants affected) and severity (S) (% leaf area affected), Boxworth 2002/2003.

| Cultivar | Fungicide | Assessment date | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 12.12.02 | | 13.01.03 | | 12.02.03 | | 11.03.03 | | 07.04.03 | |
| | | I | % area | I | S | I | S* | I | S | I | S |
| Apex | Untreated | 98 | 1.83 | 100 | 3.09 | 100 | 2.41 | 100 | 3.13 | 93 | 1.38 |
| Apex | Full | 88 | 0.53 | 58 | 0.21 | 85 | 0.44 | 88 | 0.61 | 48 | 0.17 |
| Apex | Autumn | 88 | 0.63 | 63 | 0.27 | 48 | 0.20 | 100 | 2.64 | 90 | 1.10 |
| Apex | Managed | 85 | 0.57 | 78 | 0.58 | 95 | 1.45 | 98 | 1.76 | 90 | 0.93 |
| Pronto | Untreated | 100 | 1.69 | 100 | 3.58 | 98 | 1.82 | 100 | 3.84 | 98 | 1.19 |
| Pronto | Full | 95 | 0.49 | 23 | 0.06 | 55 | 0.28 | 88 | 0.69 | 30 | 0.07 |
| Pronto | Autumn | 95 | 0.66 | 35 | 0.08 | 28 | 0.09 | 100 | 2.57 | 83 | 0.68 |
| Pronto | Managed | 93 | 0.47 | 70 | 0.28 | 100 | 1.76 | 100 | 2.56 | 90 | 0.71 |
| Escort | Untreated | 100 | 1.61 | 100 | 2.68 | 98 | 1.46 | 100 | 2.90 | 75 | 0.65 |
| Escort | Full | 73 | 0.39 | 30 | 0.09 | 43 | 0.19 | 68 | 0.33 | 33 | 0.07 |
| Escort | Autumn | 73 | 0.39 | 33 | 0.10 | 28 | 0.12 | 78 | 1.64 | 60 | 0.41 |
| Escort | Managed | 83 | 0.42 | 50 | 0.20 | 85 | 0.74 | 100 | 1.72 | 63 | 0.40 |
| Grand mean | | 89 | 0.81 | 61.5 | 0.93 | 71.7 | 0.91 | 93.1 | 2.03 | 70.8 | 0.64 |
| SED | | 7.39 | 0.209 | 9.51 | 0.225 | 8.10 | 0.385 | 9.58 | 0.0.513 | 9.39 | 0.179 |
| F TEST | | ns | ns | ns | ns | 5% | ns | ns | ns | ns | ns |

* Angular transformed data analysed but actual data presented

Table 37. Incidence and severity of light leaf spot on leaves, Boxworth 2002/2003.

| Treatment | % plants with light leaf spot | | | | % leaf area affected by light leaf spot | | | |
|---|---|---|---|---|---|---|---|---|
| | 11/03 | 07/04 | 01/05 | 29/05 | 11/03 | 07/04 | 01/05 | 29/05 |
| Cultivar | | | | | | | | |
| Pronto | 0.6 | 3.7 | 0.6 | 0.0 | 0.01 | 0.09 | 0.001 | 0.000 |
| Apex | 0.0 | 1.3 | 3.1 | 0.6 | 0.00 | 0.01 | 0.128 | 0.003 |
| Escort | 0.0 | 1.3 | 0.0 | 0.0 | 0.00 | 0.01 | 0.000 | 0.000 |
| SED 33df | 0.51 | 3.25 | 1.60 | 0.51 | 0.005 | 0.073 | 0.079 | 0.0025 |
| F test | ns | ns | ns | ns | ns | ns | ns | ns |
| | | | | | | | | |
| Fungicide | | | | | | | | |
| Nil | 0.83 | 7.5 | 3.3 | 0.0 | 0.01 | 0.13 | 0.155 | 0.000 |
| Full | 0.00 | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 | 0.000 | 0.000 |
| Autumn | 0.00 | 0.0 | 0.8 | 0.0 | 0.00 | 0.00 | 0.001 | 0.000 |
| Managed | 0.00 | 0.8 | 0.8 | 0.8 | 0.00 | 0.01 | 0.017 | 0.004 |
| SED 33df | 0.589 | 3.75 | 1.85 | 0.59 | 0.006 | 0.085 | 0.0915 | 0.0030 |
| F test | ns | ns | ns | ns | ns | ns | ns | ns |
| | skew | skew | skew | skew | skew | skew | skew | skew |
| Interaction | ns | ns | ns | ns | ns | ns | ns | ns |

Table 38. Effect of spray timing on phoma and light leaf spot (Lls) incidence (I) (% plants affected) and severity (S) (% leaf area affected) Boxworth 2003.

| Cultivar | Fungicide | Assessment dates | | | | | |
|---|---|---|---|---|---|---|---|
| | | 01.05.03 | | 29.05.03 | | 01.05.03 | |
| | | Phoma leaf | | Phoma leaf | | Lls leaf | |
| | | 1 | S | I | S | I | S |
| Apex | Untreated | 78 | 0.81 | 90 | 2.62 | 10 | 0.460 |
| Apex | Full | 35 | 0.23 | 55 | 0.92 | 0 | 0.000 |
| Apex | Autumn | 48 | 0.47 | 75 | 2.66 | 0 | 0.000 |
| Apex | Managed | 28 | 0.12 | 65 | 1.38 | 3 | 0.050 |
| Pronto | Untreated | 33 | 0.41 | 85 | 2.31 | 0 | 0.000 |
| Pronto | Full | 28 | 0.19 | 48 | 0.48 | 0 | 0.000 |
| Pronto | Autumn | 55 | 0.35 | 63 | 1.67 | 3 | 0.003 |
| Pronto | Managed | 38 | 0.13 | 45 | 1.00 | 0 | 0.000 |
| Escort | Untreated | 40 | 0.46 | 78 | 1.88 | 0 | 0.000 |
| Escort | Full | 8 | 0.20 | 18 | 0.17 | 0 | 0.000 |
| Escort | Autumn | 20 | 0.14 | 35 | 0.25 | 0 | 0.000 |
| Escort | Managed | 20 | 0.12 | 28 | 0.32 | 0 | 0.000 |
| Grand mean | | 35.6 | 0.30 294 | 56.9 | 1.30 | 1.25 | 0.043 |
| SED | (33df) | 13.39 | 0.194 | 12.73 | 0.825 | 3.20 | 0.159 |
| F test | | ns | ns skew | ns | ns skew | ns skew | ns skew |

* Logit transformed data analysed

Table 39. Effect of spray timing on stem canker and stem lesion incidence (I) (% plants affected) and severity (S) (0 – 100 score) Boxworth 2003.

| Treatment | Assessment date | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 07.04.03 | | | | 01.05.03 | | | | 29.05.03 | | | |
| | canker | | stem lesions | | canker | | stem lesions | | canker | | Stem lesions | |
| | 1 | S | I | S | I | S | I | S | I | S | I | S |
| Cultivar | | | | | | | | | | | | |
| Pronto | 0 | 0 | 0.6 | 0.60 | 5.6 | 1.4 | 12 | 3.6 | 28.1 | 10.2 | 26.9 | 9.7 |
| Apex | 0 | 0 | 0.6 | 0.13 | 3.1 | 0.9 | 5 | 1.4 | 25.0 | 8.0 | 17.5 | 5.4 |
| Escort | 0 | 0 | 0.0 | 0.00 | 2.5 | 0.6 | 6 | 1.6 | 24.4 | 9.1 | 18.1 | 5.3 |
| SED 33df | | | 0.73 | 0.116 | 2.15 | 0.61 | 3.1 | 0.98 | 5.96 | 2.41 | 4.03 | 1.45 |
| F test | | | Ns | Ns | Ns | Ns | Ns | Ns | Ns | Ns | 5% | 1% |
| | | | | | | | | | | | | |
| Fungicide | | | | | | | | | | | | |
| Nil | 0 | 0 | 1.7 | 0.25 | 10.0 | 2.5 | 17 | 5.2 | 55.0 | 20.8 | 35.0 | 12.7 |
| Full | 0 | 0 | 0.0 | 0.00 | 0.0 | 0.0 | 3 | 0.8 | 5.8 | 1.7 | 5.0 | 1.3 |
| Autumn | 0 | 0 | 0.0 | 0.00 | 0.8 | 0.2 | 3 | 0.8 | 9.2 | 2.5 | 18.3 | 5.8 |
| Managed | 0 | 0 | 0.0 | 0.00 | 4.2 | 1.3 | 7 | 1.9 | 33.3 | 11.3 | 25.0 | 7.5 |
| SED 33df | | | 0.85 | 0.133 | 2.49 | 0.70 | 3.6 | 1.13 | 6.88 | 2.78 | 4.65 | 1.67 |
| F test | | | Ns | Ns | 0.1% skew | 1% skew | 1% skew | 0.1% skew | <0.1% | <0.1% | <0.1% | <0.1% skew |
| Grand mean | | | 0.42 | 0.06 | 3.8 | 0.99 | 7.5 | 2.19 | 25.8 | 9.06 | 20.8 | 6.82 |
| Interaction | | | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns |

Table 40. Canker incidence and severity pre-harvest, Boxworth 2003.

| Treatment | % plants with canker | Canker index (0-100) | % healthy stems | % Index 1 | % Index 2 | % Index 3 | % Index 4 | Phoma stem lesions % plants | Phoma stem Index (0-100) |
|---|---|---|---|---|---|---|---|---|---|
| Cultivar | | | | | | | | | |
| Pronto | 75.0 | 34.1 | 25.0 | 27.8 | 37.5 | 5.3 | 4.5 | 71.7 | 26.2 |
| Apex | 69.5 | 28.8 | 30.5 | 32.5 | 29.3 | 6.8 | 1.0 | 60.2 | 18.6 |
| Escort | 58.0 | 25.5 | 42.0 | 26.5 | 22.7 | 5.0 | 3.8 | 47.0 | 16.5 |
| SED(47df) | 3.10 | 2.14 | 3.10 | 5.21 | 5.29 | 2.16 | 1.81 | 3.59 | 1.88 |
| F test | <0.1% | 0.1% | <0.1% | ns | 5% | ns | ns | <0.1% | <0.1% |
| | | | | | | | | | |
| Fungicide | | | | | | | | | |
| Nil | 97.3 | 50.6 | 2.7 | 25.0 | 48.7 | 14.7 | 9.0 | 87.0 | 33.8 |
| Full | 17.0 | 4.5 | 83.0 | 16.0 | 1.0 | 0.0 | 0.0 | 24.3 | 6.5 |
| Autumn | 61.7 | 20.8 | 38.3 | 43.0 | 16.7 | 1.3 | 0.7 | 65.7 | 19.1 |
| Managed | 94.0 | 42.1 | 6.0 | 31.7 | 53.0 | 6.7 | 2.7 | 61.7 | 22.4 |
| SED(47df) | 3.58 | 2.47 | 3.58 | 6.02 | 6.11 | 2.49 | 2.09 | 4.15 | 2.17 |
| F test | <0.1% | <0.1% | <0.1% | <0.1% | <0.1% | <0.1% | <0.1% | <0.1% | <0.1% |
| | | | | | | skew | skew | | |
| Interaction | 0.004 | 0.068 | 0.004 | 0.101 | 0.314 | 0.913 | 0.677 | 0.006 | 0.134 |

Table 41. Incidence and severity of canker and phoma stem lesions (0-100 index), pre-harvest, Boxworth 2003.

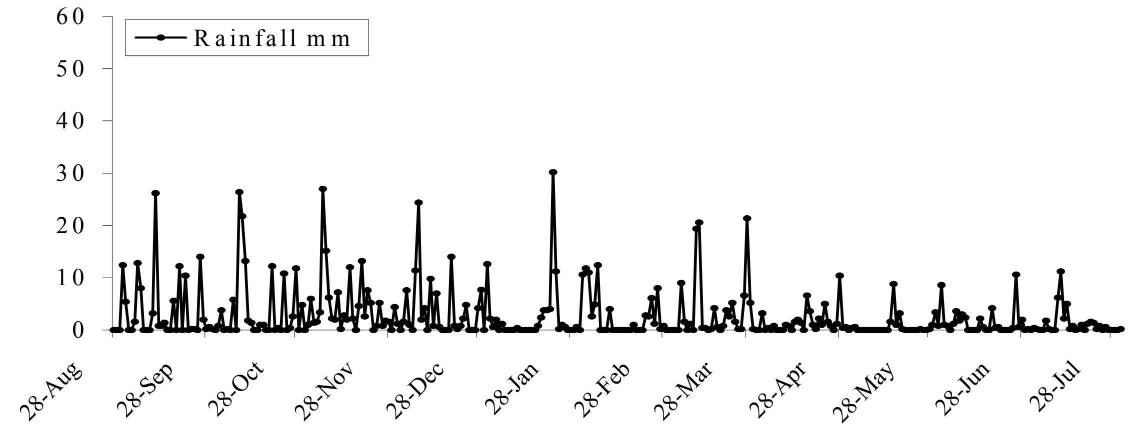
| Cultivar | Fungicide | Assessment date | | | |
|---|---|---|---|---|---|
| | | 24.06.03 | | | |
| | | Canker | | Stem lesions | |
| | | I | S | I | S |
| Apex | Untreated | 99 | 49.3 | 85 | 30.0 |
| Apex | Full | 21 | 5.3 | 28 | 7.5 |
| Apex | Autumn | 61 | 19.0 | 71 | 18.8 |
| Apex | Managed | 97 | 41.8 | 57 | 18.3 |
| Pronto | Untreated | 98 | 51.3 | 94 | 40.5 |
| Pronto | Full | 20 | 5.3 | 26 | 7.0 |
| Pronto | Autumn | 83 | 30.3 | 84 | 25.3 |
| Pronto | Managed | 99 | 49.8 | 83 | 32.0 |
| Escort | Untreated | 95 | 51.3 | 82 | 30.8 |
| Escort | Full | 10 | 3.0 | 19 | 5.0 |
| Escort | Autumn | 41 | 13.0 | 42 | 13.3 |
| Escort | Managed | 86 | 34.8 | 45 | 17.0 |
| Grand mean | | 67.5 | 29.48 | 59.7 | 20.44 |
| SED (33 df) | | 6.19 | 4.27 | 7.18 | 3.76 |
| F test | | 1% | ns | 1% | ns |

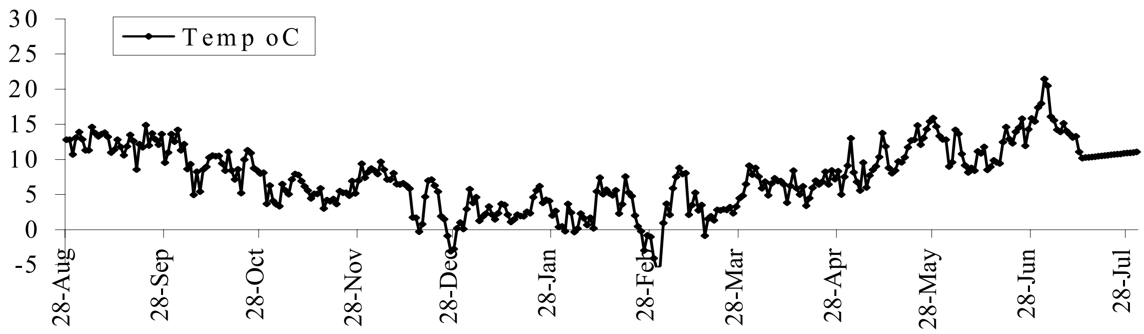
SAC Aberdeen 200-2001

*Weather, 2000 – 2001*

It was continuously wet from the time of sowing through to the end of March, with numerous periods of heavy rainfall (Figure 24). Temperatures at the end of December fell below zero and heavy snowfalls during the first six weeks of 2001 failed to thaw (the trial was in shade). As a result plants within the trial site remained frozen or covered with snow for a period of six weeks. Conditions were drier and warmer from the end of April until harvest.

Figure 24. Rainfall and temperature in Aberdeen, 2000-2001.




*Development of light leaf spot in untreated plots, 2000 - 2001*

The first light leaf spot was found in untreated plots of all cultivars in early December (Figure 25). Disease levels in untreated plots increased during the winter and spring months, reaching a maximum in early April. After this time the % leaves affected and the severity (% leaf area infected) decreased rapidly but the incidence (% plants affected) remained relatively high. The disease development curves for all three cultivars were similar. The levels of light leaf spot in Apex and Synergy were similar. The incidence of light leaf spot in Escort was only slightly lower than for Apex and Synergy, but the severity in Escort was lower than that for Apex and Synergy.

*Efficacy of fungicide programmes against l****ight leaf spot*** *2000 – 2001*

Due to the severe weather conditions and F&M outbreak during 2000/01, only one fungicide application was applied in the autumn of 2000. The second 'autumn' fungicide could not be applied until the F&M restrictions were lifted and weather/ground conditions were suitable, which was 11 Apr 2001 (GS 3.1). Because of the delay in application, the application dose was increased from 0.5 l/ha Folicur to 0.75 l/ha Folicur. The spring fungicide was applied to the Full programme five weeks later on 15 May 2001. At the time of applying the first autumn fungicide no light leaf spot was found in the managed plots so no spray was applied. Subsequent to light leaf spot appearing in the managed plots in December 2000, the first opportunity to apply a fungicide spray was 11 Apr 2001. At this time the dose of Punch C was increased from 0.4 l/ha to 0.6 l/ha. Because of this delayed first fungicide application the spring application was increased to 0.75 l/ha, applied on 15 May.

By 5 Apr 2001, six days prior to applying the second fungicide spray (first spray to Managed plots), the incidence of light leaf spot in untreated plots was similar for all cultivars (93.8% - 98.8%: mean of untreated and managed plots, the latter were untreated on this date; Figure 26; Appendix Table 8). Application of a single fungicide spray of 0.4 l/ha Punch C in the autumn had no effect on the incidence of light leaf spot in Apex. Fungicide application significantly reduced the incidence of light leaf spot in Synergy but the incidence was still high (>84%). An autumn fungicide significantly reduced disease incidence in Escort from 94% to 59%. On 05 Apr 2001, light leaf spot severity in Escort was significantly lower than in Synergy and Apex, Apex showing the most severe infection (Figure 26). An autumn fungicide significantly reduced light leaf spot severity in all three cultivars.

Four weeks after applying the 'second' autumn fungicide (first application to Managed plots), fungicide slightly reduced the incidence of light leaf spot but this was not significant: there were no differences between any of the treatments on all three cultivars (Figure 27). Light leaf spot severity was significantly less on Escort than on Synergy or Apex. Fungicide application significantly reduced levels of light leaf spot on Synergy and Apex but not on Escort. There were no differences between the fungicide programmes.

Seven weeks after applying the spring fungicides, there were little, if any, differences in light leaf spot incidence (Figure 28), but, in general, all fungicide programmes reduced disease severity. Application of a spring fungicide in May reduced disease severity in Synergy and Escort compared with an autumn only spray treatment, but this was not significant.

Fungicide had no effect on the incidence of stems affected (% stems affected) with light leaf spot in the cultivar Apex (Figure 28) but significantly reduced the severity (% stem area affected) of stem infection: there were no differences between any of the fungicide programmes. An autumn fungicide significantly reduced incidence of affected stems of Synergy and Escort, but application of a spring fungicide, or delaying the autumn fungicide until early spring, had no effect on stems incidence. All fungicide programmes, however, reduced the severity of stem diseaae, with no differences between any of the programmes. Fungicide did not reduce severity of light leaf spot on stems of Escort. Fungicide application had no effect on light leaf spot on pods of any cultivar (Figure 29).

*Phoma control*

**Phoma** leaf spot was found mainly on the cultivars Synergy and Apex (Appendix Table 9). The disease was already present by 31 Oct 2000 and reached a peak by 13 Nov 2000, when the incidence was 76 – 80% and severity 1.84 – 2.36% leaf area affected. By late January 2001 the disease had all but disappeared. Phoma leaf spotting on the cultivar Escort reached a peak in late November, when 8% of plants were affected at a severity of 0.16%. No phoma stem canker developed within the trial.

The application of 0.4 l/ha Punch C in the autumn significantly reduced the incidence and severity of phoma leaf spot in Synergy and Apex, reducing its incidence from 27.5-37.5% to 6.2-7.5% (Appendix Table 10).

*Plant counts, 2000 - 2001*

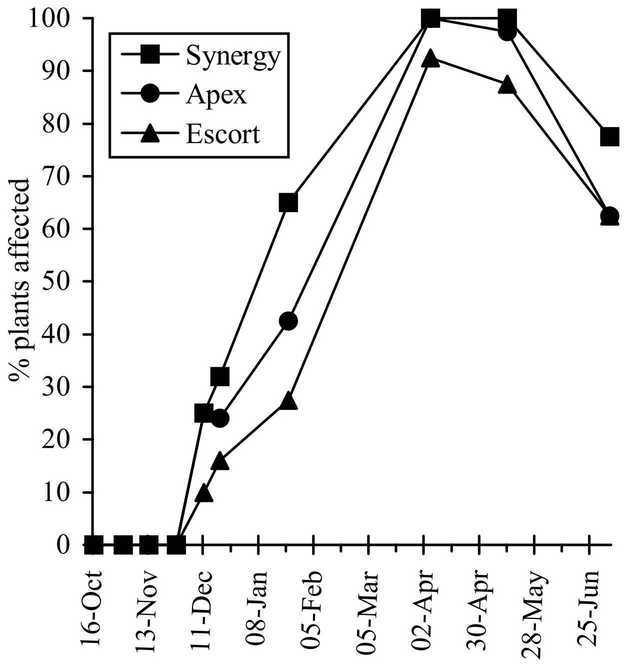
Cultivars were sown at rates of 6 kg/ha (Apex & Escort) and 3.6 kg/ha (Synergy), rates typical of Aberdeenshire, to give plant establishments of 60 – 70 plants/m2 and 40 plants/m2. The actual plant establishment in untreated plots in November 2000 was 92 plants/$m^2$ (Apex), 85 plants/$m^2$ (Escort) and 54 plants/$m^2$ (Synergy) (Appendix Table 11). Plant losses over-winter ranged from 9-10% in Synergy and Escort to 26% in Apex. All fungicide treatments reduced plant losses during the season, but these differences were not significant.

*Yield & yield components, 2000 – 2001*

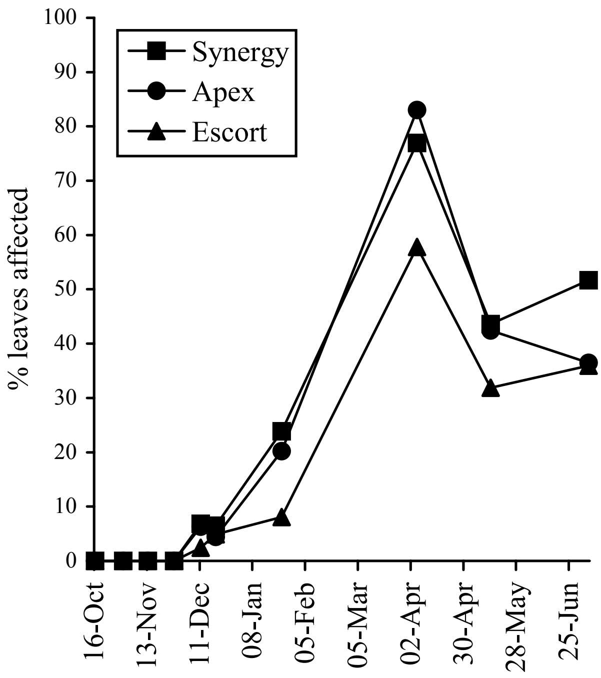
Escort gave the highest untreated yield, 3.87 t/ha, followed by Synergy (3.47 t/ha) and Apex (2.89 t/ha) (Figure 30). Despite this, Apex gave the highest yield response to Full and Autumn fungicide programmes, 23.5 – 25.7% increase in yield (Appendix Table 12). In general, the highest yield response was achieved with the Full fungicide programme, followed by the Autumn programmes, with the Managed programme giving the lowest, or a negative, response. The Full and Autumn programmes significantly increased yield of Apex and Escort, but did not significantly increase yield of Synergy. When the margins over fungicide costs were calculated, these were negative for Synergy; that is, for the 2000/2001 season growers would have earned more from this crop by leaving it untreated (£528/ha). Both the Full and Autumn programmes gave economic returns of £73–78/ha for Apex and £25–32/ha for Escort compared with the untreated. In all three cultivars, delaying fungicide application until early spring, as in the Managed programme, lost approximately £7 - £51/ha.

Figure 25. Development of light leaf spot in untreated plots, Aberdeen, 2000 – 2001.

**(a) Incidence on Plants**




**(b). Incidence on leaves**




**(c). Severity**

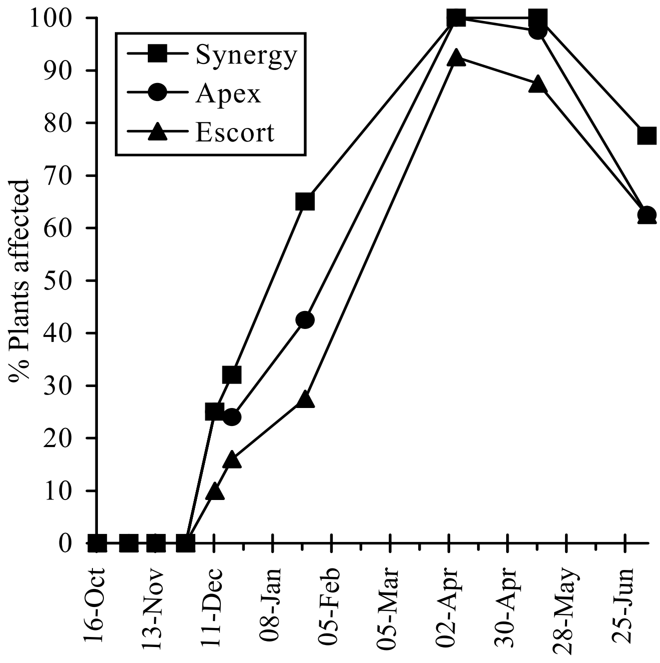


Figure 26. Effect of fungicide on incidence and severity of light leaf spot, Aberdeen, 5 Apr 2000, pre second 'autumn' fungicide application.

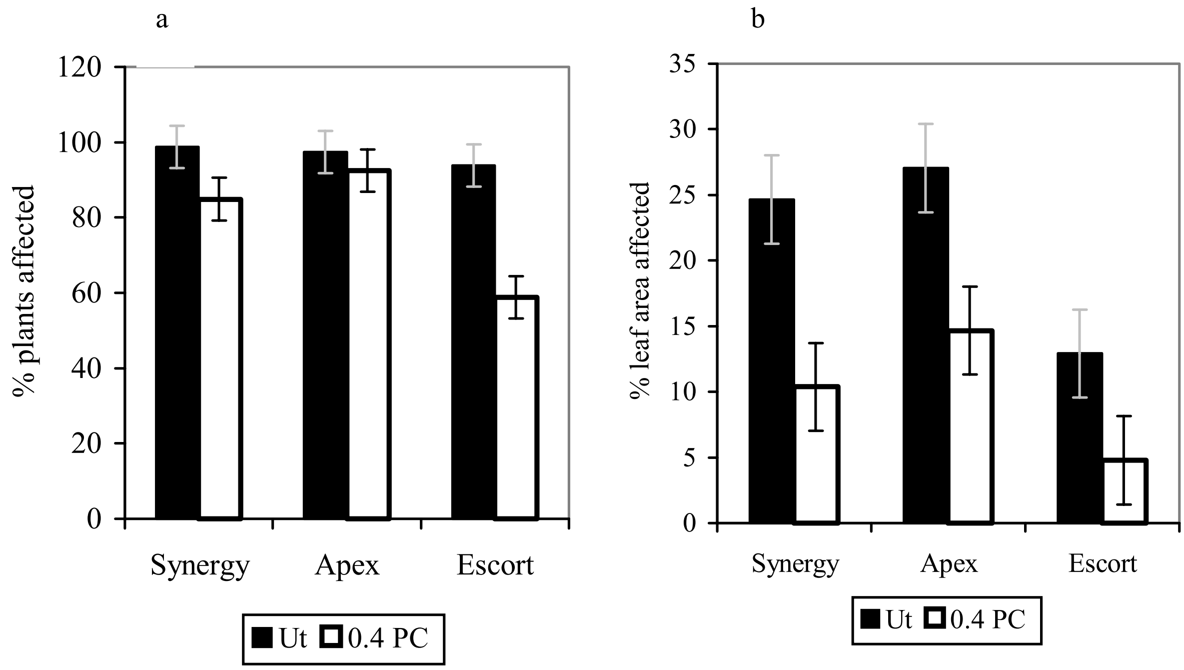



Figure 27. Effect of fungicide on incidence and severity of light leaf spot, Aberdeen 11 May 2000, pre-spring fungicide application.

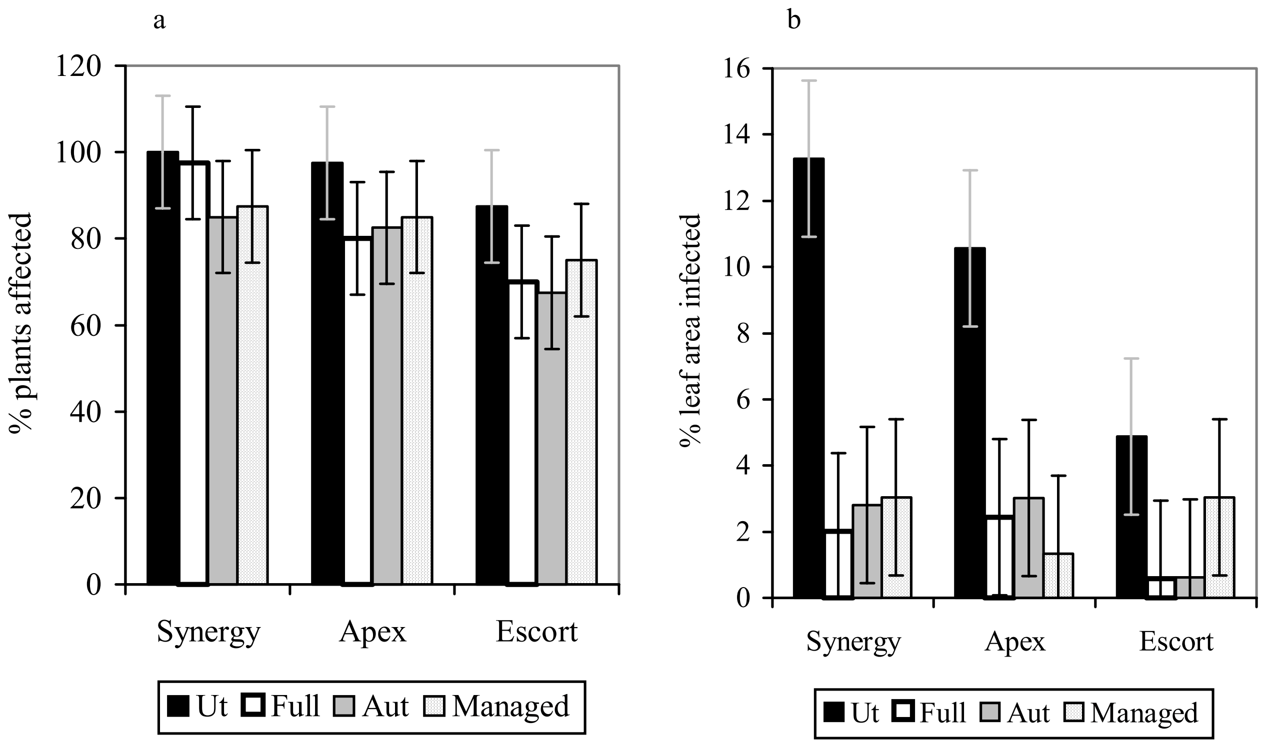


Figure 28. Effect of fungicide on incidence and severity of light leaf spot on leaves and stems, Aberdeen 5 Jul 2000, post-spring fungicide application.

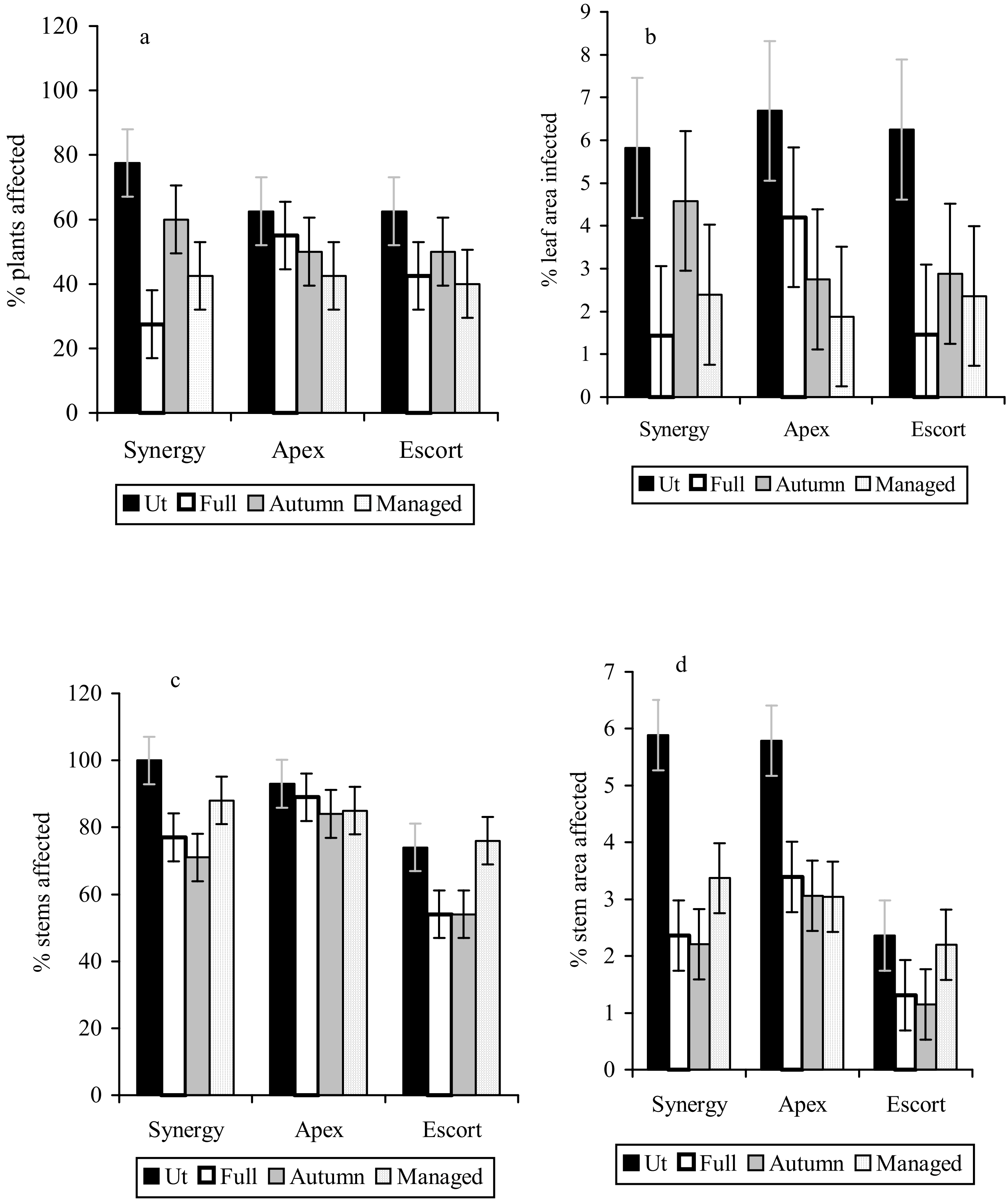


Figure 29. Effect of fungicide on severity of light leaf spot on pods, Aberdeen, August 2001.

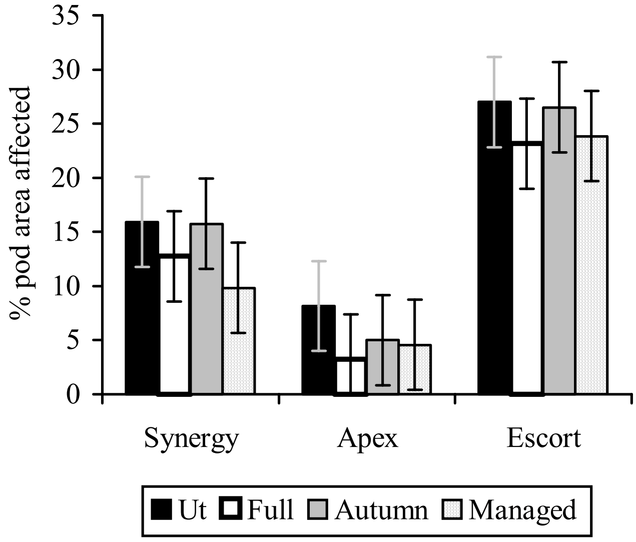
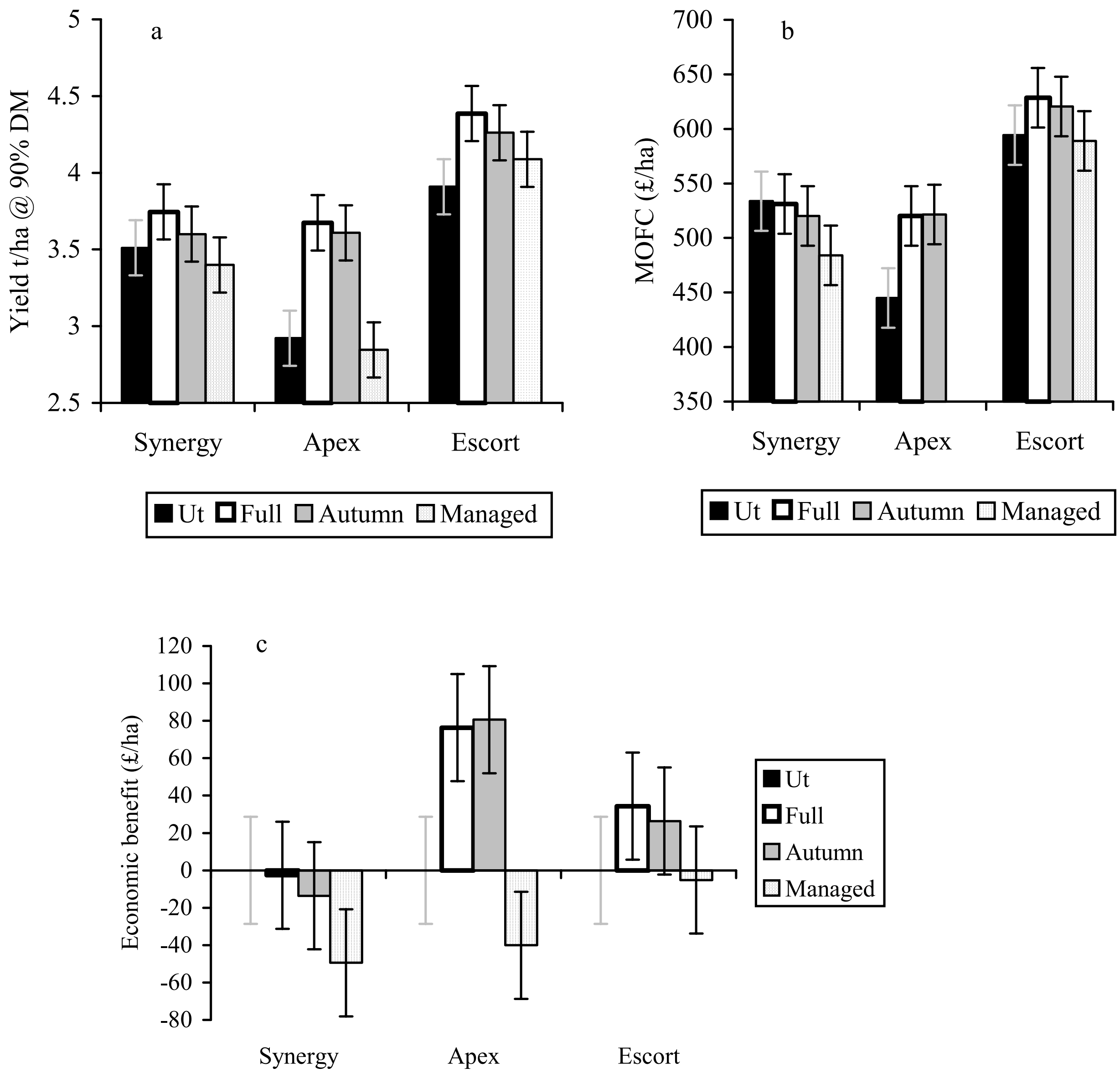


Figure 30. Effect of fungicide on Yield and Margins, 2000 – 2001.

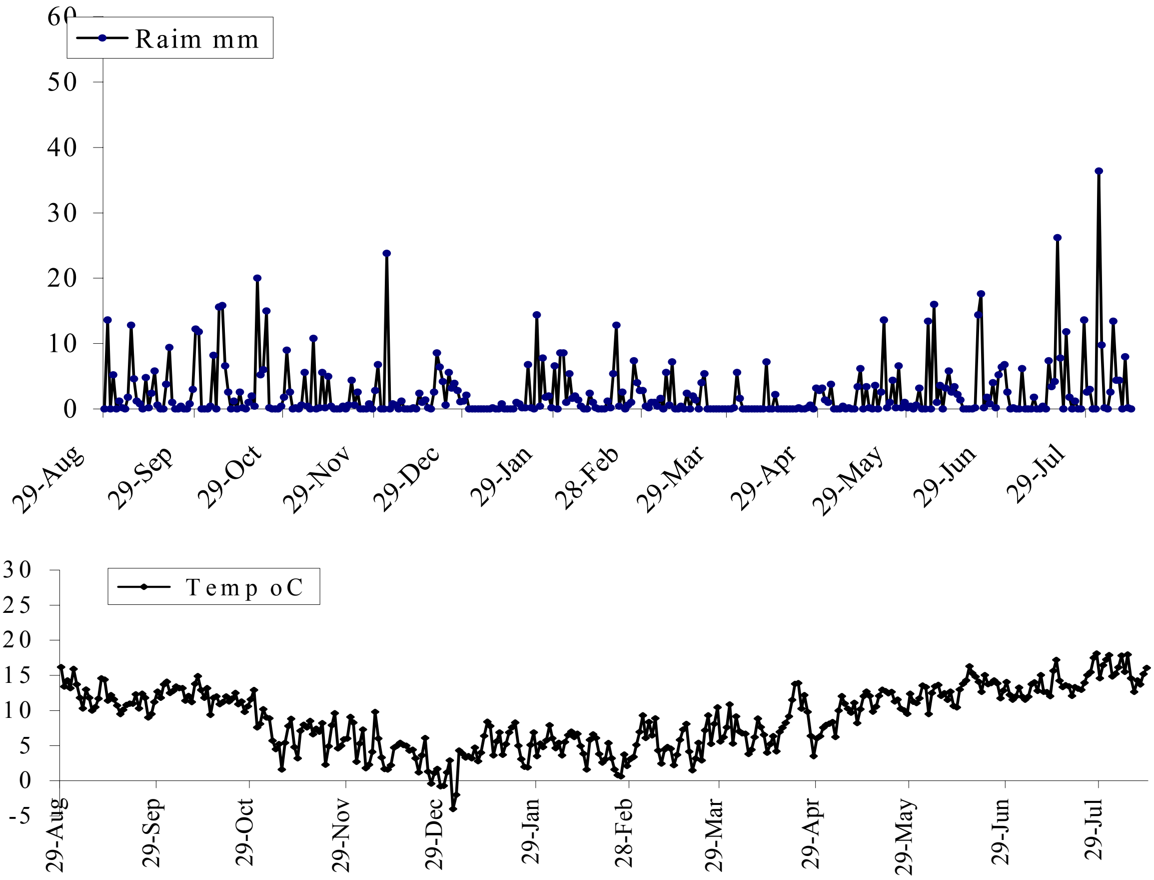


SAC Aberdeen 2001 – 2002

*Weather, 2001 - 2002*

During the autumn and spring of 2001-2002, there were a number of days when there were peaks of heavy rainfall that would aid in the spread of light leaf spot spore, but in general the autumn was much drier than in 2000 (Figure 31). Winter temperatures rarely dropped below freezing and although there were periods of snow cover the location of the trial meant snow quickly disappeared and there was no prolonged freezing of the crop. Rainfall during May – July 2002 was much heavier than in the same period of 2001.

Figure 31. Rainfall and mean daily temperature, Aberdeen 2001-2002.




*Development of light leaf spot in untreated plots, 2001-2002*

Light leaf spot first appeared in the cultivar Apex in mid-November, some four weeks earlier than the previous season, and in mid-December on Synergy and Escort (Figure 32). Disease increased to a maximum in mid-April, when 87% - 97% of plants were affected at 7 – 14% leaf area affected. The disease progress curves for all three cultivars were similar, with levels of disease on the resistant cultivar Escort only slightly lower, or on some dates higher, than in Synergy and Apex.

*Efficacy of fungicide programmes against l**ight leaf spot,** 2001 – 2002*

The application of two autumn fungicide sprays significantly reduced the severity of light leaf spot in all cultivars by mid-April (stem-extension), particularly in the susceptible cultivars Synergy and Apex (Figure 33, Appendix Table 13). Delaying fungicide application until December or February, as in the Managed programmes, significantly reduced the severity of light leaf spot infection on Apex and Synergy compared with the untreated, but was not as effective as the two autumn sprays. Delaying fungicide application until February did not significantly reduce light leaf spot severity in the resistant cultivar Escort.

Application of two fungicide sprays in the autumn (Full and Autumn programmes) significantly reduced the incidence of light leaf spot infection (% plants affected) in all cultivars by stem extension, but incidences were still >40% (Figure 33). The Managed programme had little or no effect on disease incidence at this time.

Application of a spring spray to the Full programme tended to reduce light leaf spot incidence and severity compared with the Autumn only programme, but this was not significant, with the exception of incidence on Escort (Figure 34). The Full programme gave significantly lower incidence of disease compared with the Managed programme, that also included a spring spray, but there were no differences between the Autumn programme and the Managed programme.

Fungicides did not reduce light leaf spot severity on stems (Figure 35). Fungicides tended to reduce incidence of light leaf spot on stems. Application of a Full three spray programmes to Synergy or a Full and Autumn only programmes to Escort, significantly reduced incidence of light leaf spot on stems compared with the untreated, but in general there were no differences between any of the fungicide programmes. Pod infection was negligible.

*Phoma control*

Phoma leaf spotting first appeared in all cultivars on 29 Oct 2001 (Appendix Table 14). Levels of infection were negligible in the cultivar Escort (maximum of <8% plants affected at 0.32% leaf area infected). Phoma leaf spotting in Apex peaked in mid-January, with 28% plants affected at 0.12% leaf area infected. Infection on Synergy peaked in late January 2002, with 37.5% plants affected at 0.12% leaf area infected. By mid-April, the incidence of phoma leaf spot infection was very low. No phoma stem canker developed.

Two autumn fungicide sprays significantly reduced the incidence of phoma leaf spotting on Synergy and Apex (Appendix Table 15). The single late fungicide applied to Managed plots also significantly reduced phoma leaf spot by late March/April.

*Plant counts, 2001 – 2002*

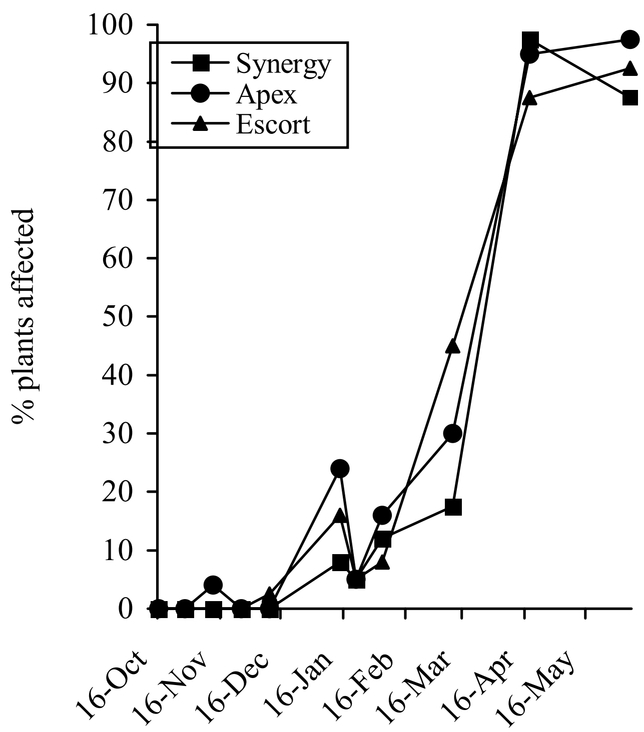
Despite sowing at seed rates of 6 kg/ha (Apex and Escort) and 3.6 kg/ha (Synergy) and aiming for plant establishment of 70 plants/$m^2$ and 50 plants/$m^2$ respectively, plant counts in late December 2001 were very low in untreated plots, 58-67 plants/$m^2$ for Escort and Apex and 37 plants/$m^2$ for Synergy (Appendix Table 16). These counts were much lower than for the same period in 2000. Plant losses of 20 – 23% occurred during the season. Fungicide application did not improve survival of plants over-winter.

*Yield and yield components, 2001 –2002*

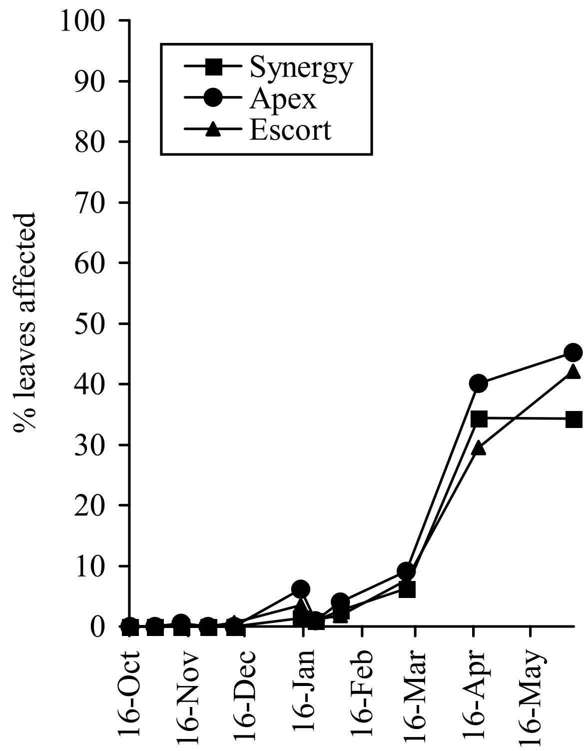
Untreated yields of all three cultivars were similar this season, 3.35 – 3.51 t/ha (Figure 36, Appendix Table 17). Fungicide had no effect on yields of Synergy. All fungicide programmes improved yield of Apex, but only the Full programme was significantly higher than the untreated: there were no differences between any of the fungicide programmes. The light leaf spot resistant cultivar Escort showed the greatest response to fungicide, with the Full and Autumn programmes increasing yield by 1.25 & 0.96 t/ha respectively (Appendix Table 17). The Managed programme increased yield of Escort, but this was not significant.

Calculating the margins over fungicide costs and economic benefits showed that fungicide applications to Synergy and Apex this season were not cost effective (Figure 36, Appendix Table 17). Application of a Full three-spray programme or two spray Autumn programme to the cultivar Escort gave returns of £158/ha and £124/ha respectively, but there were no significant differences between these two programmes. Environmentally, therefore, the two spray Autumn fungicide programme was more beneficial. Delaying fungicide application until first signs of light leaf spot (Managed programme) did not give significant economic returns from Escort.

Figure 32. Development of light leaf spot in untreated plots, Aberdeen, 2001 – 2002.




**(a) Incidence on Plants**




**(b) Incidence on Leaves**

**c) Severity**

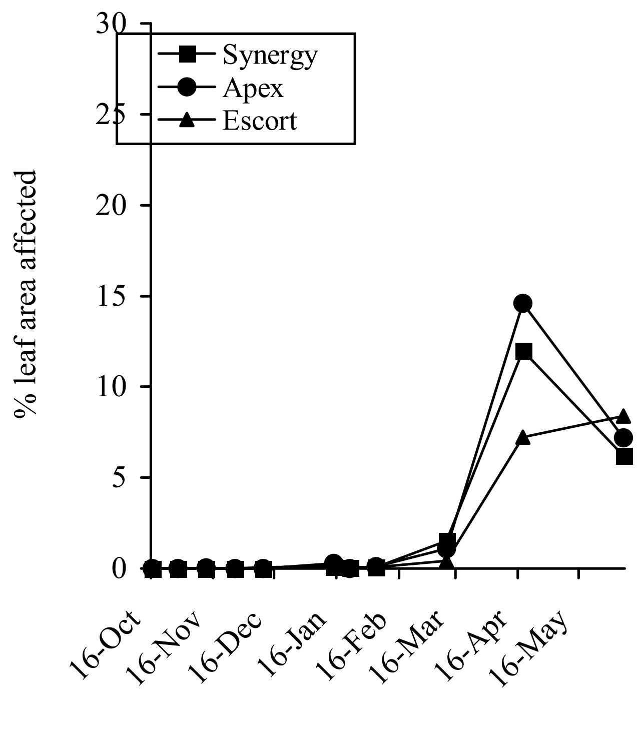


Figure 33. Effect of fungicide on incidence and severity of light leaf spot, Aberdeen, 11 Apr 2002, pre-spring fungicide.

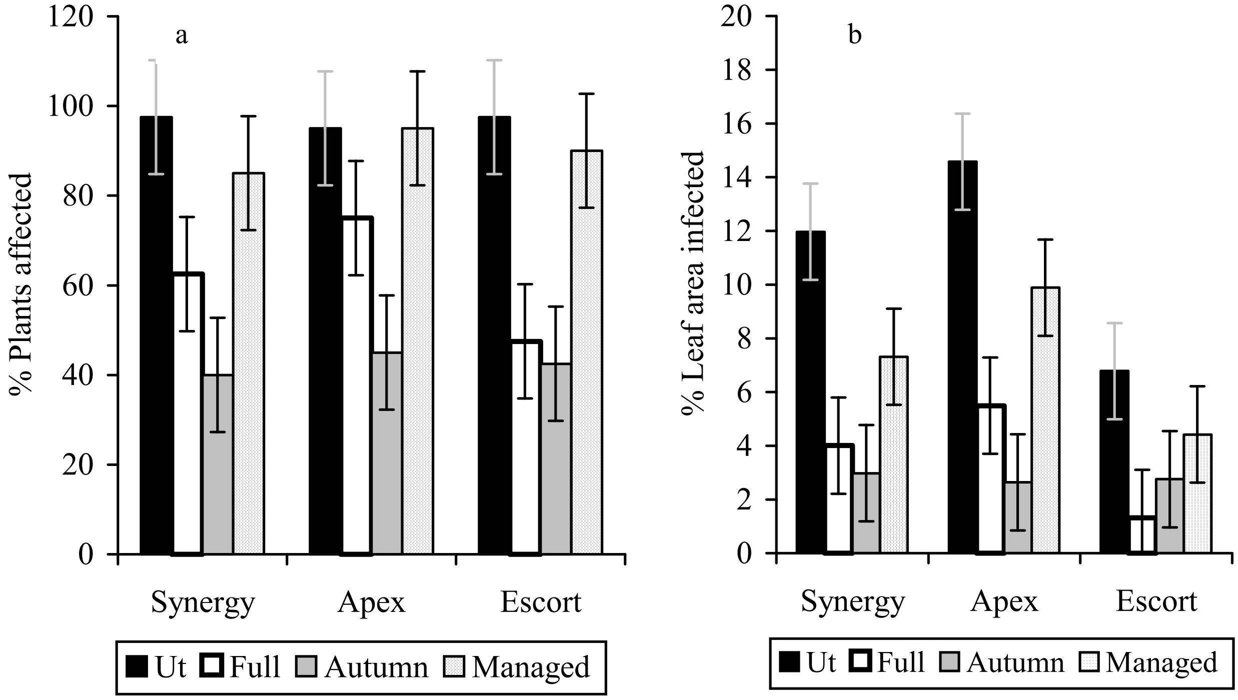



Figure 34. Effect of fungicide on incidence and severity of light leaf spot, Aberdeen, 7 Jun 2002, post-spring fungicide.

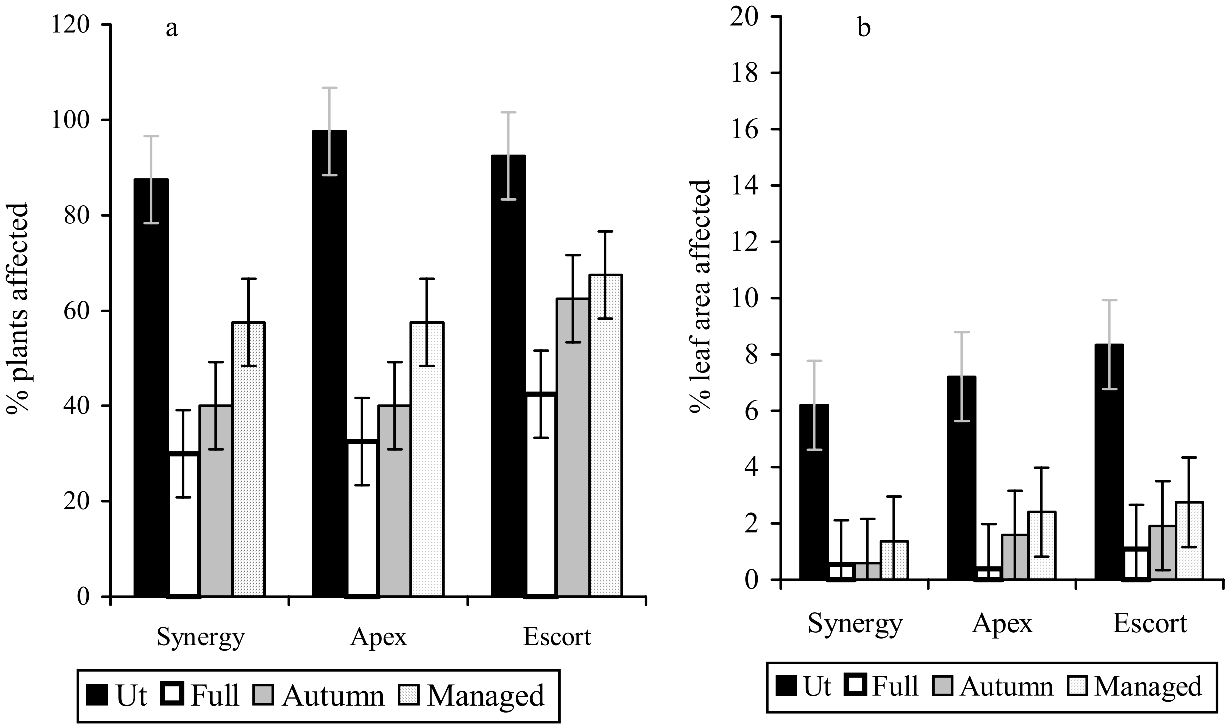


Figure 35. Effect of fungicide on incidence and severity of light leaf spot on stems and pods, Aberdeen, 7 June 2002.

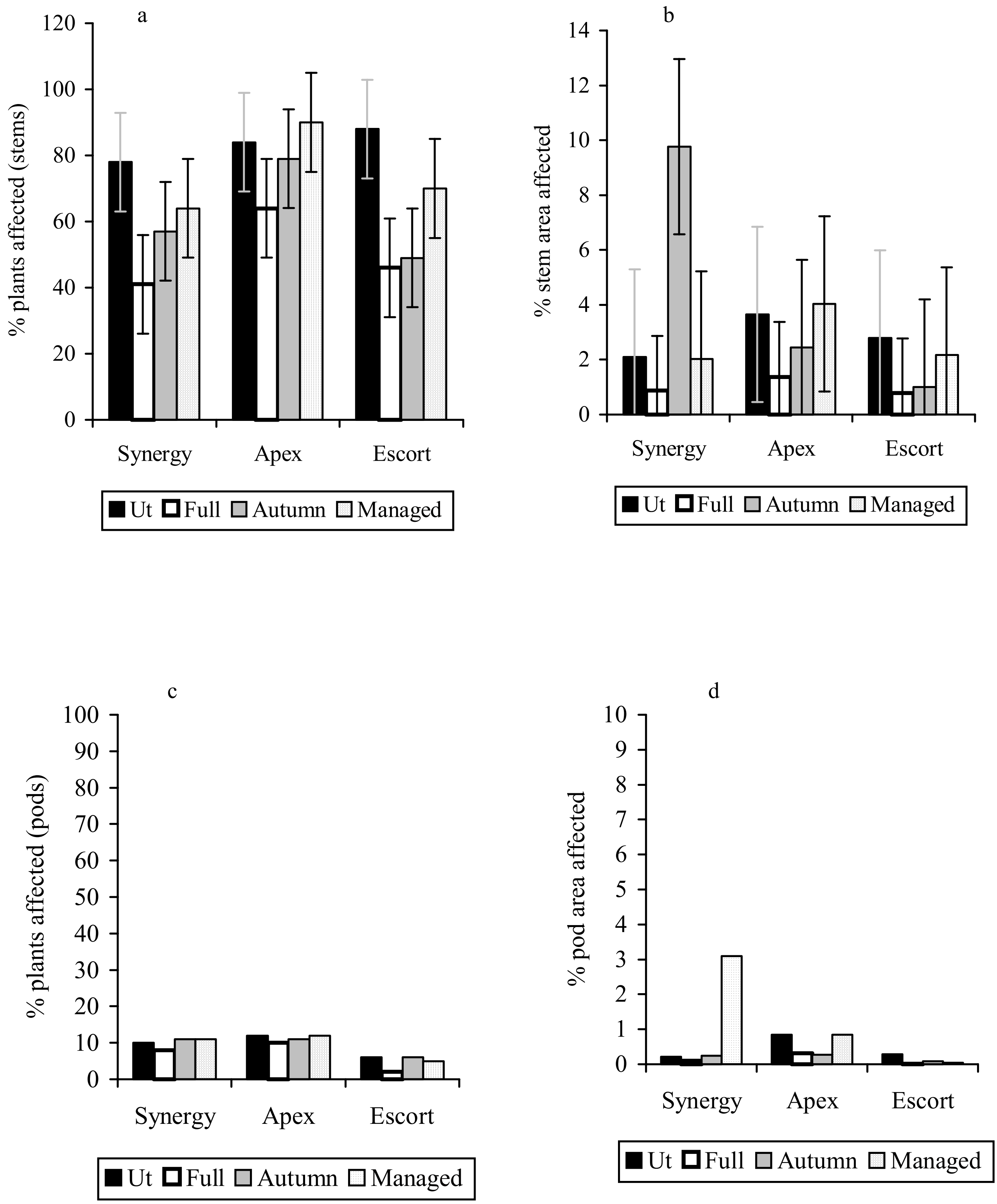
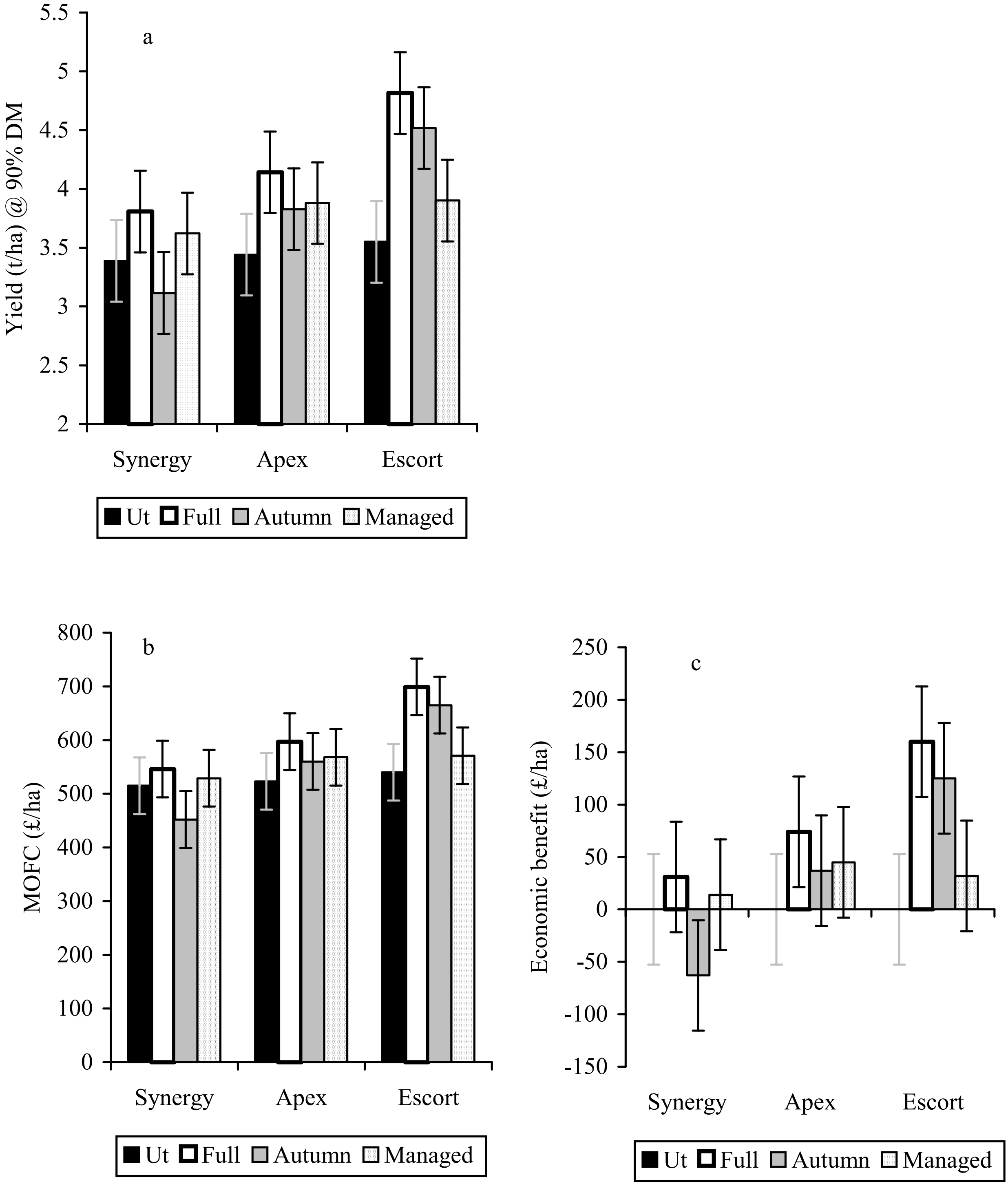


Figure 36. Effect of fungicide on yield and margins over fungicide costs, Aberdeen, 2001 – 2002.

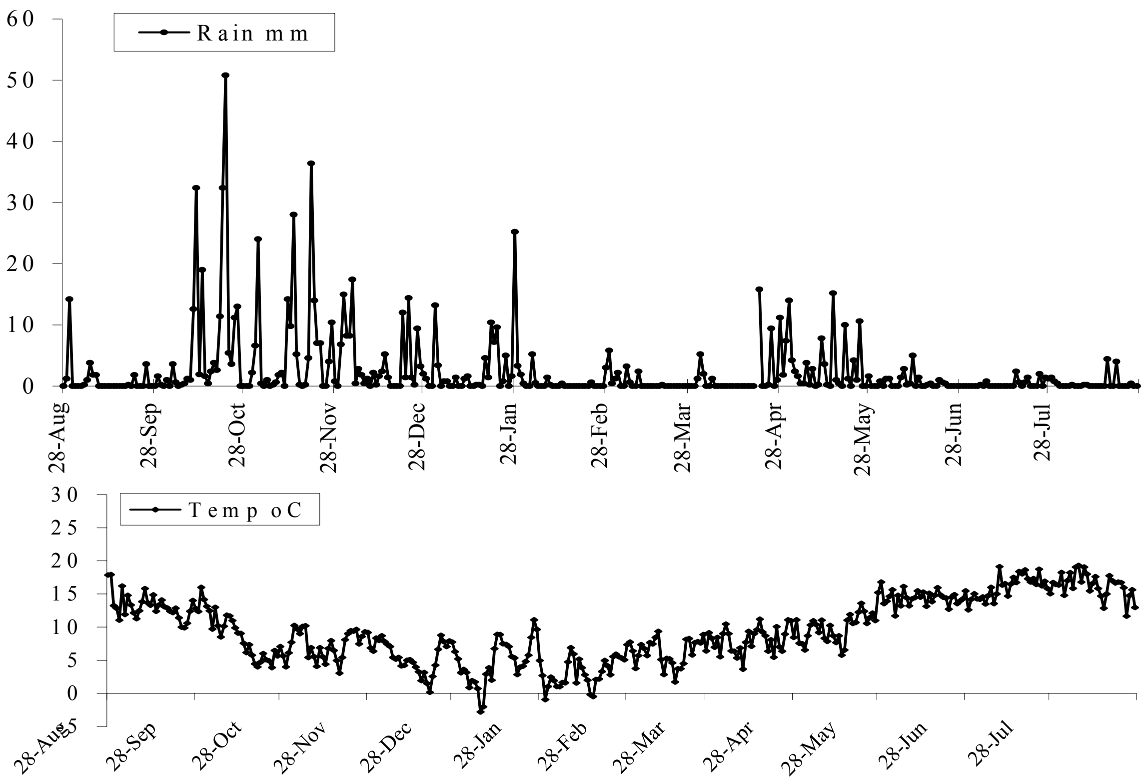


SAC Aberdeen 2002 - 2003

*Weather, 2002-2003*

Autumn 2002 was the wettest autumn experienced in Aberdeenshire for many years, particularly during the months of October and November, with 50mm+ of rain occurring on some days (Figure 37). Despite digging drains to remove this excess water, parts of the trial site were under water at least three times during the autumn/winter. Heavy snow and frost in January prevented sampling. From May to August 2003, conditions were very dry, (the driest for approximately ten years), with little rain during the time (during a six week period there was no rainfall at all). Plants lost leaves prematurely through drought. An advantage of the dry conditions was that oilseed rape crops were harvested on the earliest date in memory and drying costs were nil.

Figure 37. Rainfall and temperature, Aberdeen, 2002-2003.




*Development of light leaf spot in untreated plots, 2002-2003*

Light leaf spot first appeared in all plots in mid-December and rapidly increased to very high levels of disease incidence (40 – 88% plants affected) in late January (Figure 38). The disease reached a maximum in late March, when disease incidence for all cultivars was 100% and severity 16.5 – 21%. The disease progress curves for all three cultivars were similar, with disease on the resistant cultivar Escort initially developing slightly more slowly but reaching a similar maximum at the same time as Synergy and Apex.

*Efficacy of fungicide programmes against l**ight leaf spot**, 2002 – 2003*

Prior to applying the spring fungicides in mid-February, the incidence of light leaf spot in the cultivar Escort was slightly lower (72%) than that of Synergy and Apex (90%) but disease severity was significantly lower at 1% compared with 13% (Figure 39, Appendix Table 18). All fungicide programmes reduced disease incidence and severity: there were no differences in disease levels between treatments involving applying two autumn fungicides or delaying fungicide application until first signs of light leaf spot infection. Despite applying two fungicide sprays to the Full and Autumn programmes, disease incidence in Synergy and Apex at this time was still >40%, but in Escort was <20% plants affected.

Four weeks after applying spring fungicides to the Full and Managed programmes, there were no differences in disease incidence between these programmes and the Autumn only programme in Synergy and Apex (Figure 40, Appendix Table 18). At this time, all fungicide programmes reduced disease incidence in Escort, the Full programme reduce incidence to 60%, the Autumn to 75% and the Managed to 87.5%. All fungicide programmes reduced light leaf spot severity, with the Full programme followed by the Autumn programme the most effective, significantly so in Synergy and Apex compared with the untreated.

Light leaf spot incidence on stems was high, with >80% plants affected in all cultivar/fungicide combinations (Figure 41, Appendix Table 19). Severity of light leaf spot on stems was <10% area infected and all fungicide programmes reduced these levels to a certain degree. Similarly, incidence of light leaf spot on pods was high, >67% plants affected, and fungicides had little effect on this. The severity of light leaf spot on pods was highest in the cultivar Apex, 10% pod area affected in untreated plots: fungicide did not reduce pod disease.

*Phoma control*

Levels of Phoma leaf spot were negligible in all three cultivars this season, never higher than 8% plants affected, 0.08% leaf area infected in untreated plots (Appendix Table 20). Fungicides had no effect.

*Plant counts, 2002 - 2003*

Plant counts in untreated plots in December 2002 were 85 – 92 plants/m$^2$ for Apex and Escort and 56 plants/m2 for Synergy (Appendix Table 21). These densities were higher than the previous season. Plant losses in untreated plots during the season were also lower, 1% for Escort, 10.6% for Apex and 18% for Synergy. Fungicide application did not significantly reduce these plant losses during the season.

*Yield and yield components*

Untreated plots of Synergy and Escort gave similar yields, 3.68 t/ha and 3.62 t/ha respectively (Figure 42, Appendix Table 22). Apex yielded slightly lower at 3.34 t/ha. Fungicide applications tended to increase yields of both Synergy and Apex, but these increases were not significant. Fungicide had no effect on yield of Escort.

Calculating margins over fungicide costs and economic benefits showed that the Autumn only programme gave a positive benefit of £11-28/ha in Apex and Synergy. However, these benefits were not significant and in most cases there were actually losses from applying fungicides this season. That is, fungicide application was not cost effective on any cultivar this season (Table 22).

<u>General Results, 2000 - 2003</u>

Autumn rainfall was highest in 2000 and 2002, lowest in 2001. Despite this, light leaf spot appeared in untreated plots in 2001 in mid-November, four weeks earlier than in the wetter years of 2000 and 2002. However, disease progress was more rapid in 2000/2001 and 2002/2003 compared with 2001/2002, with higher disease incidence nd disease sev erity on leaves. Thus, in the wet seasons build up of light leaf spot was more rapid and more severe than in the drier season.

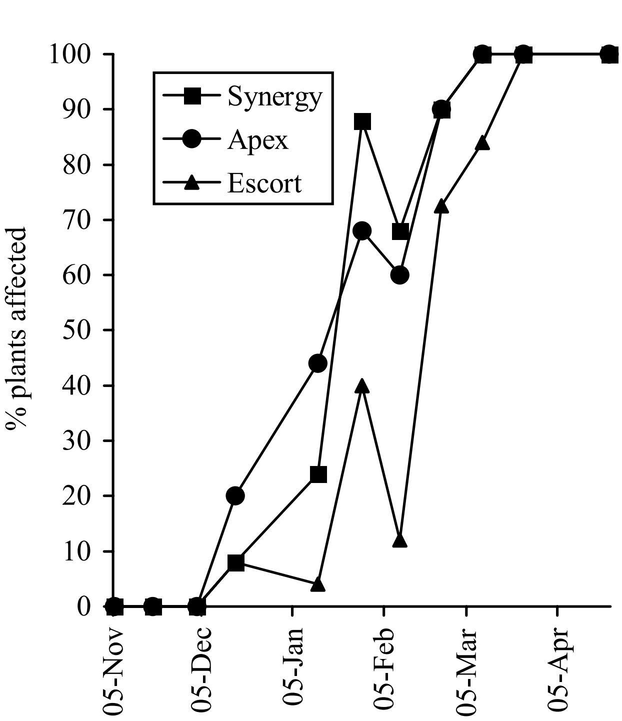
Levels of light leaf spot on individual cultivars varied throughout the season. Disease tended to develop more slowly on the resistant cultivar Escort than on the susceptible cultivars Synergy and Apex. However, by stem extension (GS 3.5) the incidence of light leaf spot on all three cultivars was almost identical with approximately 100% plants affected. Synergy and Apex developed similar levels of light leaf spot severity (leaf area affected), with Apex slightly more susceptible than Synergy. Light leaf spot severity was generally much lower on Escort compared with Synergy and Apex. Thus, the order of susceptibility to light leaf spot on leaves was Apex then Synergy then Escort. This order is as expected from the UK resistance ratings for each cultivar (see Table 14). This order was less clear with respect to stem and pod infection.

Incidence of light leaf spot was high in all three years, approximately 100% plants affected. The effect of an autumn fungicide on disease incidence varied depending on date and season but, in general, over the three years of trials, fungicide did not reduce incidence of light leaf spot below 40% by stem extension.

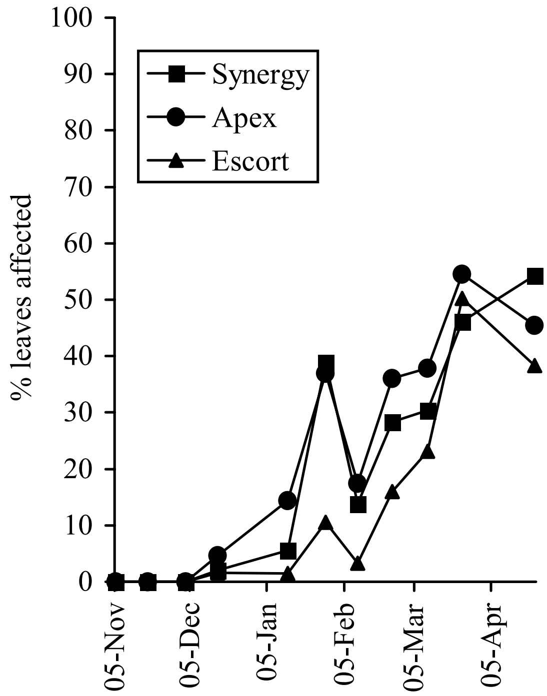
Application of fungicide had more of an effect on light leaf spot severity than on incidence. The Full and Autumn programmes were most effective in reducing light leaf spot severity. Delaying fungicide application until first signs of light leaf spot (Managed programme), reduced light leaf spot compared with the untreated but was not as effective as (but not significantly different to) an autumn fungicide. Adding a spring fungicide to the two autumn sprays (Full programme) tended to improve control of light leaf spot severity later in the season, but was generally not significantly different to the Autumn only programme.

Figure 38. Development of light leaf spot in untreated plots, Aberdeen, 2002-2003.

**(a) Incidence on plants**




**(b) Incidence on leaves**




**(c) Severity**

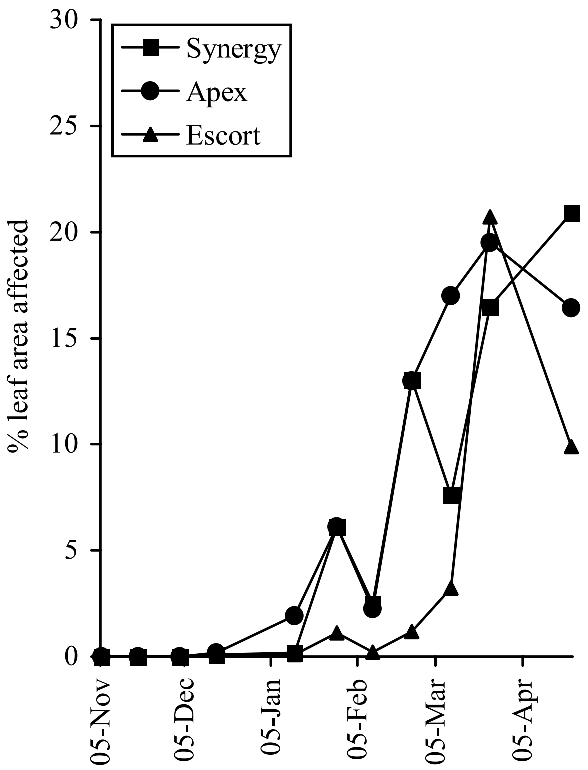


Figure 39. Effect of fungicide on incidence and severity of light leaf spot, Aberdeen, 24 Feb 2003, pre – spring fungicide application.

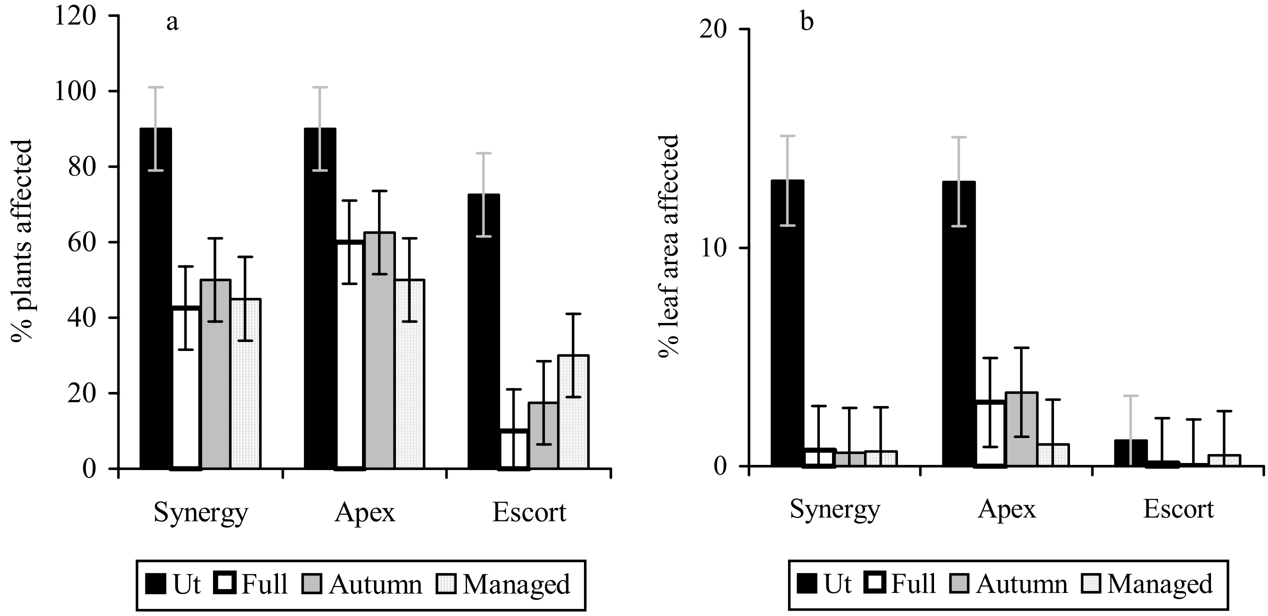



Figure 40. Effect of fungicide on incidence and severity of light leaf spot, Aberdeen, 22 Apr 02, post-spring. fungicide application

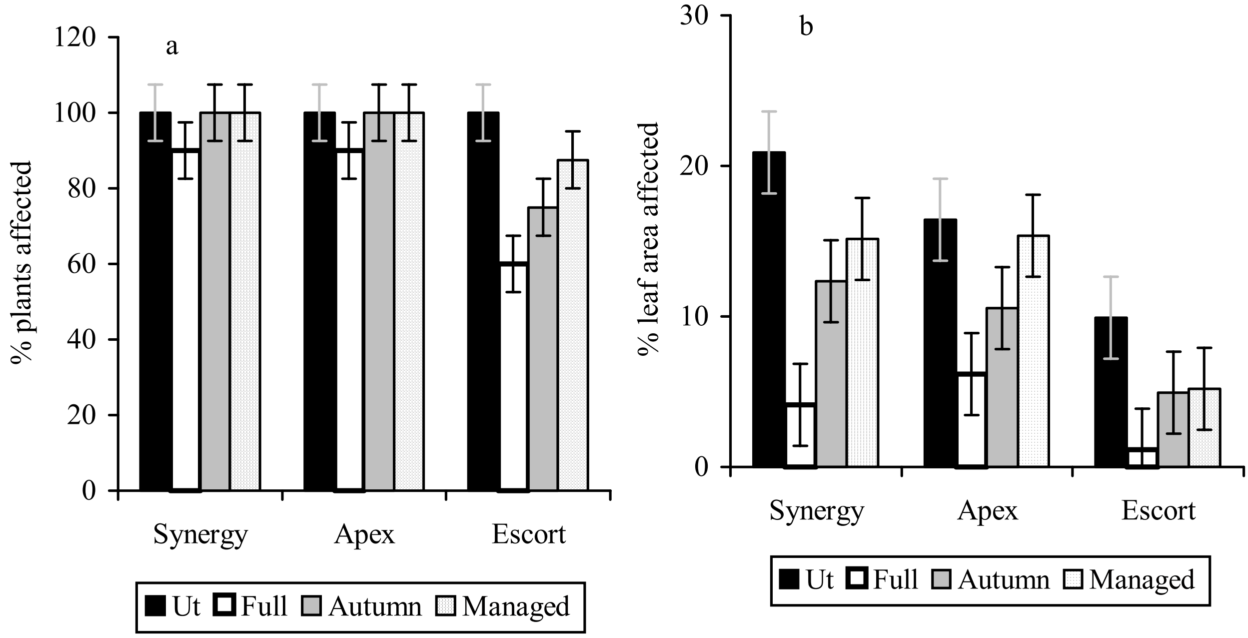


Figure 41. Effect of fungicide on incidence and severity of light leaf spot on stems and pods, 17 Jul 2003.

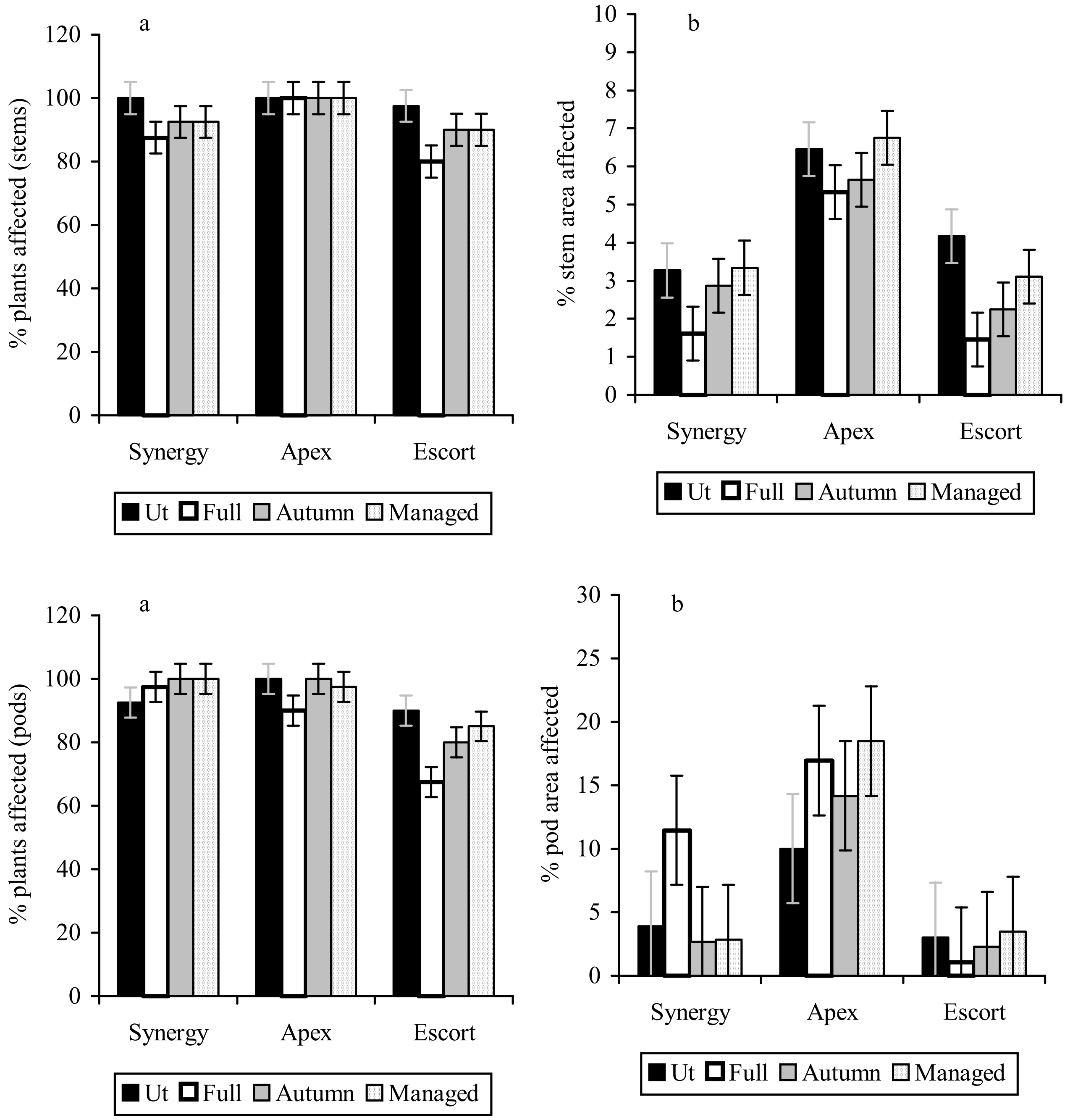
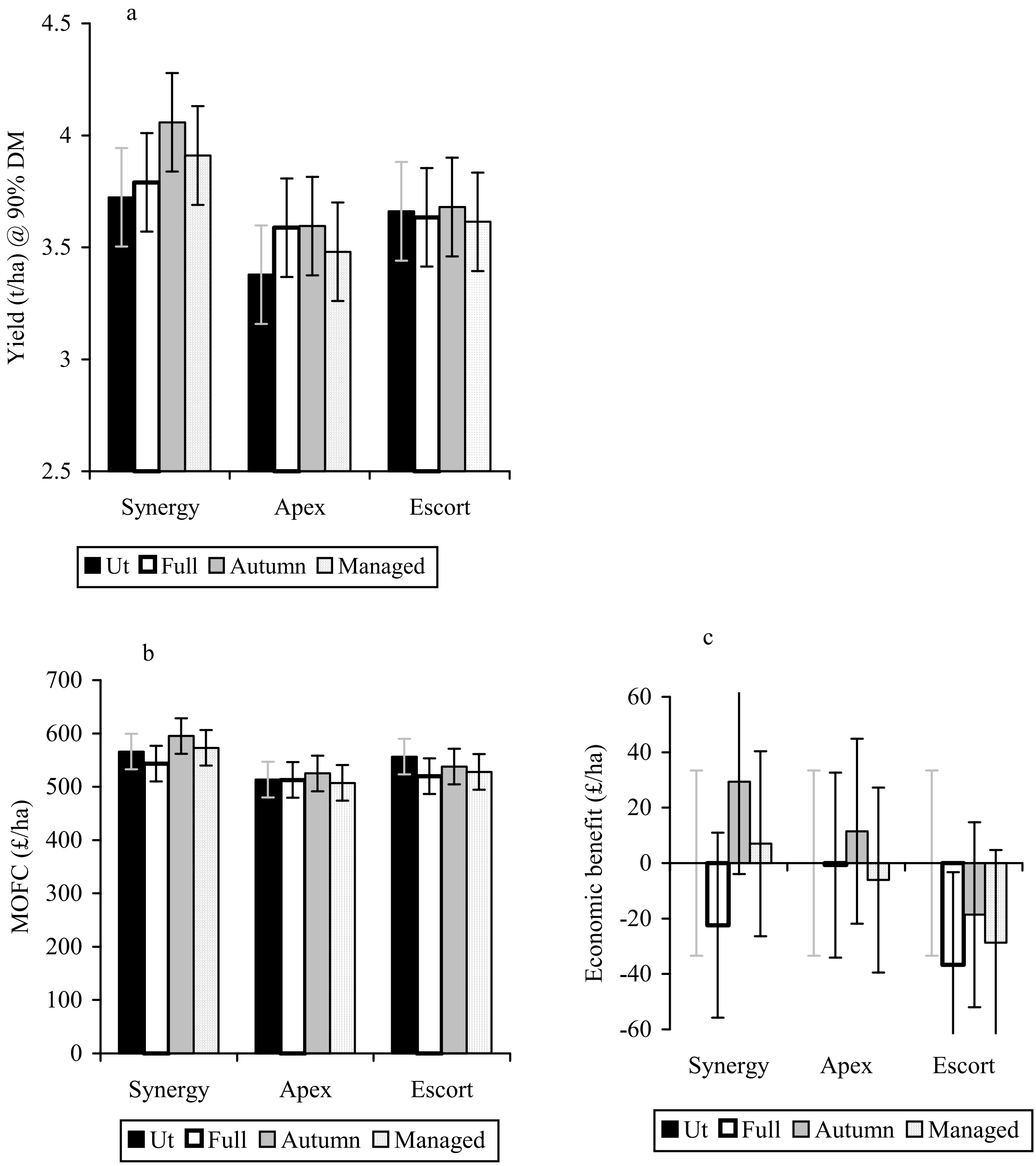


Figure 42. Yield and margins over fungicide costs, Aberdeen, 2002-2003.



Fungicide application reduced severity of light leaf spot over winter. Fungicide application reduced plant deaths over-winter but not significantly in any of the three years.

Yields of all three cultivars tended to be relatively constant over the three-year period, except for Apex that yielded much less in 2000/2001 than in subsequent years. The mean three year yields in untreated plots were 3.51 t/ha for Synergy, 3.20 t/ha for Apex and 3.67 t/ha for Escort (Table 42). All three cultivars tended to show a yield response to fungicide application. Apex showed very large yield responses to the Full and Autumn programmes in 2000/2001 (Figure 30). Escort showed good yield responses to fungicide programmes, especially the Full and Autumn programmes, in 2000/2001 and 2001/2002, but showed no yield responses in 2002/2003.

Over the three year period of this work, Synergy showed no yield responses to fungicide (Table 42). The Full and Autumn programmes significantly increased yield of cvs Apex and Escort compared with the untreated, but delaying fungicide application until first signs of light leaf spot (Managed programme) did not improve yield.

Economic returns from a Full and Autumn fungicide programmes were good for cvs Apex and Escort in 2000/2001 and 2001/2002, particularly for cv. Escort 2001/2002 where yield benefits of £124 - £154/ha were achieved (Figure 36). Over the same period, returns from Synergy were poor. In 2002/2003, poor yield responses in all cultivars resulted in little or negative economic returns, that is, a loss of money (Figure 42).

Over the three year period, applying fungicide to Synergy gave little economic return or indeed gave a financial loss of £10 – 16/ha (Table 42). The light leaf spot susceptible cultivar Apex gave the best economic returns. With Apex and Synergy, the Full programme gave higher returns (£47.20/ha & £43.40/ha respectively) than the Autumn programme (£57.70/ha & £51.20/ha), but these were not significantly different. In all three cultivars, the Managed programme gave some reduction in light leaf spot levels but was not economic.

Table 42. SAC Aberdeen experiments: Mean yield, margin over fungicide costs (MOFC) and economic benefits 2000 – 2003.

| Cultivar | Treatment | Yield | MOFC | Economic benefit |
|---|---|---|---|---|
| | | t/ha @ 90% DM | £/ha | £/ha |
| | | | | |
| Synergy | Untreated | 3.541 | 538.2 | 0 |
| | Full | 3.781 | 540.2 | 2.0 |
| | Autumn | 3.591 | 522.4 | -15.6 |
| | Managed | 3.644 | 528.7 | -9.5 |
| | | | | |
| Apex | Untreated | 3.242 | 493.2 | 0 |
| | Full | 3.801 | 543.3 | 53.2 |
| | Autumn | 3.677 | 535.5 | 45.4 |
| | Managed | 3.336 | 481.8 | -2.9 |
| | | | | |
| Escort | Untreated | 3.707 | 563.5 | 0 |
| | Full | 4.278 | 615.9 | 52.4 |
| | Autumn | 4.153 | 607.8 | 44.4 |
| | Managed | 3.868 | 562.7 | -0.7 |
| | | | | |
| SED | | 0.165 | 25.09 | 31.38 |
| | | (0.154) | (23.43) | (23.17) |
| df | | 25 | 25 | 26 |
| LSD | | 0.338 | 51.48 | 66.70 |
| | | (0.318) | (48.25) | (47.62) |
| Signif. Cv x Treat | | ns | ns | ns |
| Signif. Cv | | ** | ** | ns |
| Signif. Treat | | *** | * | * |

(Figures in brackets are when compared means with the same level of cultivar)

8.3.2 Fungicide spray timing experiments

Rothamsted 2000-2003

*Leaf development of marked plants*

Fig. 43 shows leaf production and loss over time and the effect this had on mean number of leaves/plant. In the first 70 days after sowing, the rate of leaf production was similar in 2000/01, 2001/02 and for large plants in 2002/03, averaging one leaf every 7 days (Fig. 43a ). Thereafter, the rate of leaf production on large plants in 2002/03 was greater than in 2000/01 and 2001/02 and was slower in 2001/02 than in 2000/01. Leaf production on small plants in 2002/03 was slower than on large plants in 2002/03 or on plants 2000/01 or 2001/02. Up to 200 days after sowing, the rate of leaf loss was similar in the first two seasons and on large plants in 2002/03, but was slower on small plants in 2002/03. There was a rapid increase in leaf loss at about 200 days after sowing in 2001/02 and 2002/03 and from about 235 days after sowing leaf production on the main stem ceased.

Up to the time when leaf 10 was present on the majority of plants (70 days after sowing in 2000/01, 2001/02 and on large plants in 2002/03; 120 days after sowing on small plants in 2002/03), leaf production was rapid whereas leaf loss was negligible. The mean number of leaves/plant therefore also increased rapidly (Fig. 43b). From this time to about 170 days after sowing, leaf loss occurred at a similar rate to leaf production and the number of leaves/plant remained relatively constant. Although leaf production on small plants in 2002/03 was initially slow, so also was leaf loss and, by 90 days after sowing, mean number leaves/plant was similar to that in 2000/01 and 2001/02. The rapid increase in leaf production and mean number leaves/plant in 2001/02 and 2002/03 at around 180 - 220 days after sowing coincided with stem extension and the rapid decline thereafter coincided with flower and pod canopy development (see Table 16).

In 2001/02 and 2002/03, the first 10 -14 leaves were present for progressively longer periods and thereafter successive leaf numbers were present for progressively shorter periods (Table 16). In 2002/03, the rate of loss of the first ten leaves was greater on large plants than on small plants and the time these leaves were present on small plants was up to 25 days more than on large plants.

Leaf lengths were measured at different times and therefore comparisons are difficult (Table 44). In 2002/03, a high proportion of leaves 6 and 7 were measured on the two occasions when the length of the longest leaf was recorded on large and small plants. It was found that these leaves reached a similar length whether on large or small plants, although the time of their development was approximately 30 days later on small plants. In all seasons GS 3,5 (flower buds raised above leaves) was reached by approximately 225 days after sowing (late March/early April). Thereafter, the rate of development was similar in the first two seasons, but faster in 2002/03, with pod and seed development occurring about 10 days earlier. The growing season (number of days from sowing to harvest) was also shorter in 2002/03 (Table 44). The average number of pods/plant at harvest was 180, 170, 415 and 150 in 2000/01, 2001/02, 2002/03 (large plants) and 2002/03 (small plants), respectively. The average diameter of stem bases at harvest was 1.9 cm in 2001/02 and 2.6 cm and 1.4 cm on large and small plants respectively in 2002/03.

*Development of phoma epidemics*

In 2002/03, the first major ascospore release was on 21 October, approximately 30 days later than in 2000/01 and 2001/02 (26 September in 2000 and 18 September in 2001). Consequently, the phoma leaf spot epidemic also developed later in 2002/03 then 2000/01 and 2001/02 (Figs. 44 & 45). At the time of these initial ascospore releases, >50% of leaves
1-6 were present in 2000/01 and 2001/02, while in 2002/03, >50% of leaves 1-9 or 1-4 were present on large and small plants, respectively. Once ascospore release had begun, it continued until at least the end of January with no periods of more than 10 days without at least 20 spores/$m^3$. However, the maximum ascospore release differed greatly between seasons: 58 days after sowing in 2000/01; 85 days after sowing in 2001/02 and 102 days after sowing in 2002/03. The number of lesions/leaf on marked plants also differed between seasons with the maximum number occurring on leaf 6 in 2000/01, leaf 5 in 2001/02, leaf 11 on large plants in 2002/03 and leaf 8 on small plants in 2002/03 (Table 44). The very early and severe phoma leaf spot epidemic in 2000/01 resulted in severe stem canker at harvest (Figs 44 & 45).

Although the phoma leaf spot epidemic in 2001/02 was equally early, it was not so severe, and stem canker severity was also less severe. Phoma leaf spot severity in 2002/03 was slightly greater than in 2001/02, but stem canker severity was considerably less. In 2002/03, phoma leaf spot affected a greater percentage of leaves with a greater number of lesions on large plants than on small. However, the final stem canker score was lower on large plants than on small plants and, whereas stem pith was affected in 72% of large plants, it was affected in 80% of small plants.

*Other diseases/pests etc*

Light leaf spot affected leaves, stems and pods in each season and required treatment with tebuconazole in the spring. Powdery mildew developed in October 2001 and by November affected 70% of leaves. Pigeons and slugs caused some damage in each season. Frost damage in 2000/01 prevented leaf assessments on the marked plants after February.

*Effect of flusilazole + carbendazim timing on phoma and stem canker epidemics*

In each season, F1 treatment (Table 16), applied at the start of the phoma epidemic, resulted in large, significant decreases in phoma leaf spot 1 month after application and was still giving good control after 2 months (Table 45). Treatment F2 also reduced phoma leaf spot, but F3 did not reduce phoma leaf spot in any season, although F3 applied at half-rate after an earlier half-rate application reduced phoma leaf spot more than any of the single full-rate treatments. Treatment R (routine) gave significant reductions at every assessment. Since F1 gave very good control of early phoma leaf spot and continued to give better control than F2 even 2 months after its application, it might be expected that F1 would also give the greatest reductions in stem canker. However, in 2000/01 and 2001/02, when stem canker was most severe, F1 gave poorer control than F2 or F3 and only F3 resulted in significant reductions in stem canker severity. In 2002/03, no single full-rate treatment gave a significant reduction in stem canker severity. In every season, two half-rate treatments (especially F2+F3) gave greater reductions in stem canker severity than single full-rate treatments, and R gave almost complete control. Autumn applications reduced light leaf spot in all seasons and powdery mildew in 2001/02 but failed to give complete control (data not shown).

*Effect of tebuconazole on stem canker*

Comparisons between stem canker scores on untreated marked plants and those treated with tebuconazole in April showed that the fungicide had little or no effect on this disease in all seasons.

*Effect of fungicide timing on yield (Fig. 46 & Table 46)*

Treatment T, which gave good control of light leaf spot epidemics, increased yields by around 1 t/ha in 2000/01 and 2001/02. Treatment R+T produced an additional yield increase of > 1 t/ha in the seasons when stem canker was severe. In 2000/01 F2 and F3 produced larger yield benefits than F1, but in 2001/02, F1 produced higher yields. In both seasons, two half-rate applications produced higher yields than single full-rate applications (Fig. 46). In 2002/03, when the stem canker epidemic was slight and yields were low, there were no significant treatment effects.

Table 43. Length of longest leaf on winter oilseed rape (cv Apex) from Rothamsted experiments in 2000/01, 2001/02, 2002/03.

| Days after sowing | Length of longest leaf (cm) | | |
|---|---|---|---|
| | 2000/01 | 2001/02 | 2002/03 |
| 42 | | 18.6 [a] | |
| 47 | 16.4[a] | | |
| 50 | | | 9.5 [a] |
| 57 | | | 13.7 [a] |
| 58 | | | 20.8(6) [b] (large plants)[c] |
| 58 | | | 9.7(3) [b] (small plants) [c] |
| 62 | 24.2(6) [b] | | |
| 72 | | | 20.3 [a] |
| 85 | | 34.7(8) [b] | |
| 146 | 31.6 [a] | | |
| 156 | | | 20.3(8) [b] (small plants) [c] |
| 161 | | | 31.6(13) [b] (large plants) [c] |

[a]Mean of 25 untreated, destructively sampled plants

[b]Mean of 30 untreated, marked plants (leaf number of longest leaf in parenthesis)

[c]In 2002/03, there were two periods of emergence, giving a mixture of large and small plants

Table 44. Leaf presence, maximum number of lesions and lesion degree days for each leaf number on 30 untreated, marked plants in winter oilseed rape (cv Apex) experiments at Rothamsted in 2000/01, 2001/02 and 2002/03.

| Leaf no. | 2000/01 | | | 2001/02 | | | 2002/03 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Large plants | | | Small plants | | |
| | Mean leaf presence (days) [a] | max. no. lesions [b] | lesion degree days[c] | Mean leaf presence (days) [a] | max. no. lesions [b] | lesion degree days[c] | Mean leaf presence (days) [a] | max. no. lesions[a] | lesion degree days[c] | Mean leaf presence (days) [a] | max. no. lesions[a] | lesion degree days[c] |
| 1 | | | | | | | | 0 | 0 | | 0 | 0 |
| 2 | | 12 | 1106 | | | | | 0 | 0 | | 2 | 461 |
| 3 | | 31 | 3348 | | 19 | 3884 | | 1 | 260 | 63 | 12 | 2038 |
| 4 | 44* | 73 | 8441 | | 46 | 7983 | | 2 | 203 | 62 | 30 | 4548 |
| 5 | 50* | 165 | 13455 | | 55 | 9147 | | 11 | 1452 | 66 | 37 | 5405 |
| 6 | 54* | 300 | 31867 | 60* | 41 | 5887 | 62 | 8 | 1292 | 87 | 47 | 7272 |
| 7 | 64 | 288 | 37257 | 64* | 45 | 5179 | 71 | 25 | 3364 | 96 | 43 | 5745 |
| 8 | 76 | 262 | 35588 | 75* | 35 | 2823 | 79 | 41 | 5492 | 98 | 49 | 7018 |
| 9 | | 209 | 26572 | 89* | 39 | 4561 | 87 | 89 | 11365 | 99 | 32 | 4882 |
| 10 | | 123 | 14753 | 102 | 23 | 2399 | 97 | 96 | 14696 | 101 | 30 | 5826 |
| 11 | | 81 | 7143 | 104 | 9 | 1273 | 106 | 128 | 20357 | 94 | 10 | 2114 |
| 12 | | 32 | 3328 | 106 | 4 | 980 | 115 | 114 | 21399 | 91 | 17 | 4697 |
| 13 | | 37 | 2676 | 97 | 4 | 402 | 109 | 84 | 13796 | 86 | 8 | 2472 |
| 14 | | | | 88 | 5 | 445 | 120 | 70 | 14913 | 84 | 6 | 1373 |
| 15 | | | | 78 | 4 | 632 | 115 | 76 | 15969 | 73 | 2 | 303 |
| 16 | | | | 71 | 1 | 142 | 111 | 42 | 8759 | | 2 | 659 |
| 17 | | | | 68 | 6 | 643 | 112 | 40 | 7388 | | 0 | 0 |
| 18 | | | | 63 | 3 | 356 | 106 | 27 | 5855 | | 1 | 486 |
| 19 | | | | 64 | 0 | 0 | 100 | 26 | 5167 | | 0 | 0 |
| 20 | | | | 68 | 0 | 0 | 98 | 10 | 2596 | | 0 | 0 |
| 21 | | | | 70 | 0 | 0 | 96 | 9 | 1835 | | 0 | 0 |
| 22 | | | | 73 | 1 | 419 | 98 | 36 | 6667 | | 0 | 0 |
| 23 | | | | 73 | 0 | 0 | | 7 | 952 | | 0 | 0 |
| 24 | | | | | | | | 4 | 711 | | | |
| 25 | | | | | | | | 6 | 1067 | | | |
| 26 | | | | | | | | 1 | 211 | | | |

[a]only those leaf numbers that were observed from development to abscission on 30 marked plants are included, except figures marked *, which include estimates of leaf numbers present from 25 destructively sampled plants.
[b]total maximum number of lesions found on each leaf of each leaf number on any assessment date. Only those leaf numbers where all 30 leaves on marked plants were observed at least once are included.
[c]total number of days each lesion was present x average daily temperature ($^oC$)

Table 45. Effect of flusilazole + carbendazim fungicide treatments on phoma leaf spot and stem canker in winter oilseed rape (cv. Apex) experiments at Rothamsted in 2000/01, 2001/02 and 2002/03.

| Fungicide treatment | % leaves with phoma leaf spot | | | | | | Stem canker | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | % plant | Sev. 0-4 | % plant | Sev. 0-4 |
| 2000/01 | 24 Oct | 13 Nov | 8 Jan | 13 Feb | 26 Mar | 8 May | 13 June | 13 June | 10 July | 10 July |
| Untr + T | 11.2 | 33.5 | 33.3 | 14.7 | 15.9 | 1.8 | 100 | 2.0 | 98.1 | 2.9 |
| Routine+T | | 3.6 | 19.7 | 6.4 | 0 | 2.0 | 0 | 0 | 6.7 | 0.1 |
| F1+T | 3.1 | 1.3 | 33.0 | 9.1 | 19.2 | 2.4 | 96.7 | 1.3 | 100 | 2.2 |
| F2+T | | 29.5 | 20.5 | 8.6 | 10.6 | 3.0 | 70.0 | 0.9 | 96.7 | 2.0 |
| F3+T | | | 31.6 | 4.6 | 7.8 | 1.0 | 80.0 | 0.9 | 90.0 | 1.6 |
| F1&2+T | 4.2* | 12.5 | 28.4 | 8.2 | 14.5 | 2.4 | 100 | 1.7 | 96.7 | 2.2 |
| F1&3+T | | 13.4 | 26.4 | 8.2 | 6.9 | 3.5 | 80.0 | 1.1 | 80.0 | 1.1 |
| F2&3+T | | 34.6 | 22.6 | 3.9 | 6.6 | 2.3 | 80.0 | 0.9 | 76.7 | 1.0 |
| F pr. | 0.004 | <.001 | 0.003 | 0.125 | <.001 | 0.401 | <.001 | <.001 | <.001 | <.001 |
| SED | 1.2 | 2.8 | 3.3 | 3.6 | 2.8 | 1.0 | 9.0 | 0.2 | 7.56 | 0.4 |
| df | 4 | 12 | 14 | 17 | 14 | 14 | 14 | 14 | 13 | 13 |
| 2001/02 | 12 Nov | 19 Nov | 12 Dec | 16 Jan | 15 Feb | 18 April | 11 June | 11 June | | |
| Untr + T | 13.7 | 10.3 | 4.1 | 4.2 | 3.5 | 1.7 | 86.7 | 1.9 | | |
| Routine+T | | | 0 | 0.5 | 0 | 0 | 6.7 | 0.1 | | |
| F1+T | 8.8 | 3.1 | 0.6 | 1.1 | 6.2 | 2.1 | 46.7 | 0.6 | | |
| F2+T | | | 1.8 | 1.1 | 6.3 | 2.3 | 43.3 | 0.5 | | |
| F3+T | | | | 2.4 | 2.6 | 1.5 | 43.3 | 0.4 | | |
| F1&2+T | 9.7* | 3.5* | 1.5 | 0.5 | 3.8 | 4.6 | 43.3 | 0.6 | | |
| F1&3+T | | | 0* | 1.1 | 2.4 | 4.2 | 43.3 | 0.5 | | |
| F2&3+T | | | 5.1* | 1.0 | 1.6 | 2.2 | 30.0 | 0.3 | | |
| F pr. | 0.397 | 0.069 | 0.123 | 0.428 | 0.063 | 0.004 | 0.002 | <.001 | | |
| SED | 3.4 | 2.4 | 2.4 | 1.7 | 1.9 | 0.9 | 15.7 | 0.2 | | |
| df | 4 | 4 | 14 | 14 | 14 | 14 | 16 | 16 | | |
| 2002/03 | 20 Nov | 13 Dec | 16 Jan | 12 Feb | 24 Mar | 7 May | 5 June | 5 June | 2 July | 2 July |
| Untr + T | 2.3 | 19.2 | 24.9 | 16.8 | 13.4 | 0.8 | 86.7 | 1.1 | 96.7 | 1.3 |
| Routine+T | | | | 1.8 | 0.8 | 1.1 | 10.0 | 0.1 | 16.7 | 0.2 |
| F1+T | 0.8 | 2.2 | 5.5 | 14.9 | 13.1 | 0.3 | 60.0 | 0.7 | 76.7 | 0.9 |
| F2+T | | | 18.5 | 10.4 | 13.1 | 0.3 | 40.0 | 0.5 | 83.3 | 0.9 |
| F3+T | | | | 17.4 | 4.0 | 0 | 40.0 | 0.4 | 73.3 | 0.9 |
| F1&2+T | 1.7* | | 6.5 | 4.1 | 13.3 | 0.5 | 36.7 | 0.5 | 70.0 | 0.8 |
| F1&3+T | | | | 6.0 | 5.2 | 0.3 | 43.3 | 0.6 | 53.3 | 0.6 |
| F2&3+T | | | | 9.3 | 2.8 | 0 | 26.7 | 0.3 | 43.3 | 0.6 |
| F pr. | 0.676 | 0.016 | 0.001 | 0.003 | <.001 | 0.762 | <.001 | 0.003 | 0.001 | 0.014 |
| SED | 1.6 | 2.2 | 2.7 | 3.5 | 2.1 | 1.6 | 12.0 | 0.2 | 13.7 | 0.2 |
| df | 4 | 2 | 6 | 14 | 14 | 14 | 14 | 14 | 14 | 14 |

* only first of two ½ rate applications applied

Table 46. Effect of flusilazole + carbendazim fungicide treatments on yield of winter oilseed rape (cv. Apex) experiments at Rothamsted in 2000/01, 2001/02 and 2002/03.

| | 2000/01 | | | 2001/02 | | | 2002/03 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Yield at 90% dry matter (t/ha) | Oil yield (t/ha) | % Oil | Yield at 90% dry matter (t/ha) | Oil yield (t/ha) | % Oil | Yield at 90% dry matter (t/ha) | Oil yield (t/ha) | % Oil |
| Untreated | 2.91 | 1.24 | 47.2 | 2.82 | 1.19 | 46.8 | | | |
| Untr + T | 4.04 | 1.74 | 48.0 | 3.55 | 1.57 | 49.1 | 3.06 | 1.38 | 50.0 |
| R+T | 5.24 | 2.96 | 48.7 | 4.83 | 2.13 | 49.2 | 3.16 | 1.43 | 50.2 |
| F1+T | 4.26 | 1.86 | 48.5 | 4.30 | 1.92 | 49.7 | 3.05 | 1.39 | 50.4 |
| F2+T | 4.72 | 2.05 | 48.3 | 4.09 | 1.82 | 49.5 | 3.31 | 1.49 | 50.1 |
| F3+T | 4.73 | 2.04 | 47.9 | 4.17 | 1.87 | 49.7 | 3.18 | 1.43 | 50.2 |
| F1&2+T | 4.84 | 2.11 | 48.5 | 4.37 | 1.93 | 49.1 | 3.13 | 1.41 | 50.0 |
| F1&3+T | 4.88 | 2.12 | 48.4 | 4.37 | 1.95 | 49.7 | 3.33 | 1.49 | 49.9 |
| F2&3+T | 4.77 | 2.07 | 48.1 | 4.47 | 2.00 | 49.7 | 3.22 | 1.44 | 49.6 |
| | | | | | | | | | |
| SED | 0.27 | 0.12 | 0.32 | 0.22 | 0.09 | 0.41 | 0.13 | 0.06 | 0.32 |
| df | 16 | 16 | 16 | 16 | 16 | 16 | 14 | 14 | 14 |

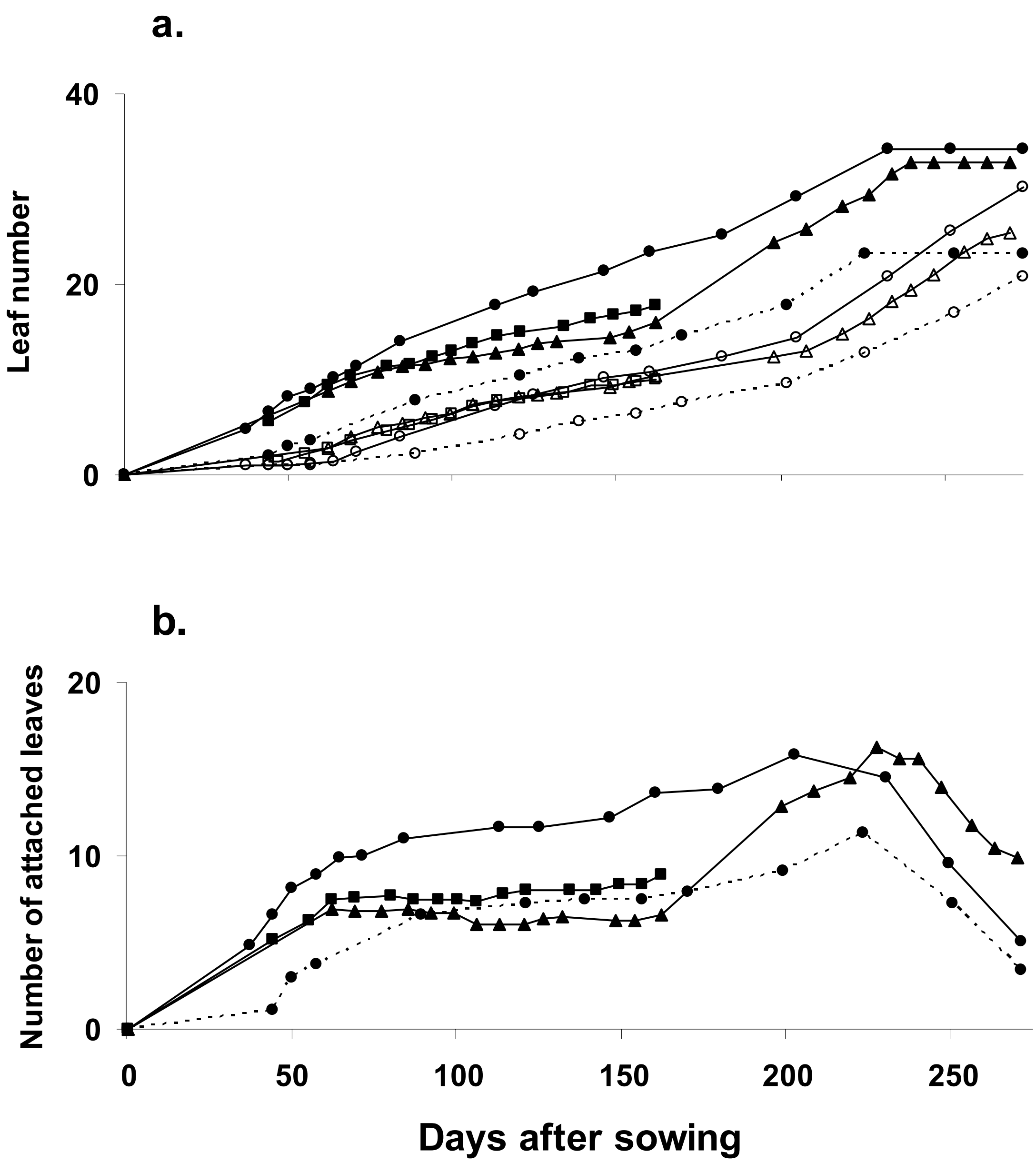



Fig. 43. Leaf development on 30 untreated marked plants in 2000/01, 2001/02 and 2002/03.

a. mean oldest (■▲●) and mean youngest (□ ∆○) attached true leaf in 2000/01 (■□), 2001/02 (▲∆) and 2002/03 (●○) (in 2002/03 large plants shown with solid line, small plants shown with broken line)

b. mean number of attached leaves (youngest leaf number – oldest leaf number + 1) in 2000/01 (■), 2001/02 (▲) and 2002/03 (●) (in 2002/03 large plants shown with solid line, small plants shown with broken line)

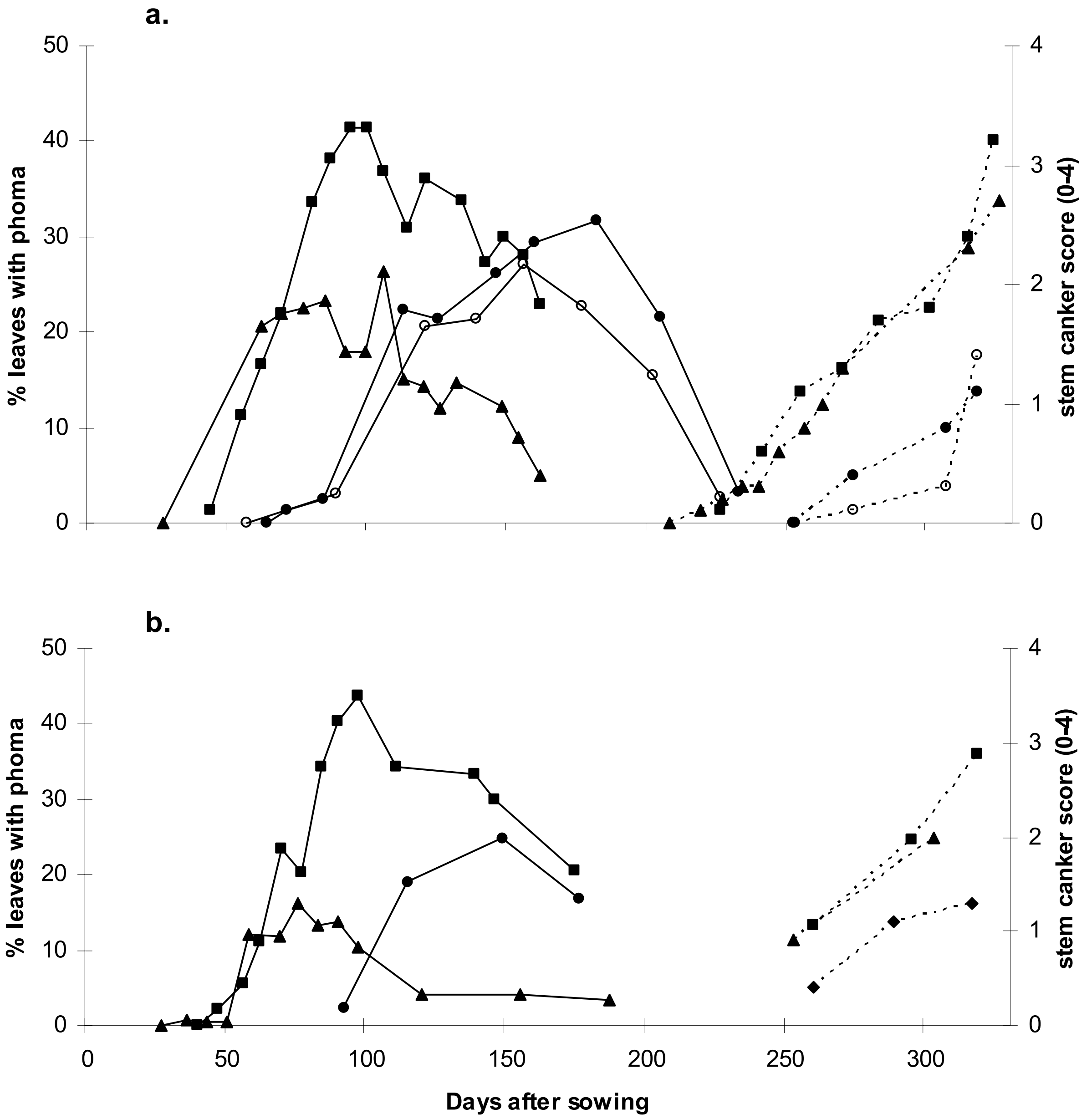



Fig 44. Development of phoma leaf spot and stem canker on untreated, marked and unmarked winter oilseed rape plants (cv. Apex) in 2000/01, 2001/02 and 2002/03

**a.** % leaves affected by phoma leaf spot (solid lines) and stem canker score (0-4 scale) (broken lines) on 30 untreated, marked plants in 20002000/01 (■), 2001/02 (▲) and 2002/03 large plants (●) and 2002/03 small plants (○).

**b.** % leaves affected by phoma leaf spot (solid lines) and final stem canker score (0-4 scale) (broken lines) on 30 destructively sampled plants, treated with tebuconazole in spring, in 20002000/01 (■), 2001/02 (▲) and 2002/03 (●).

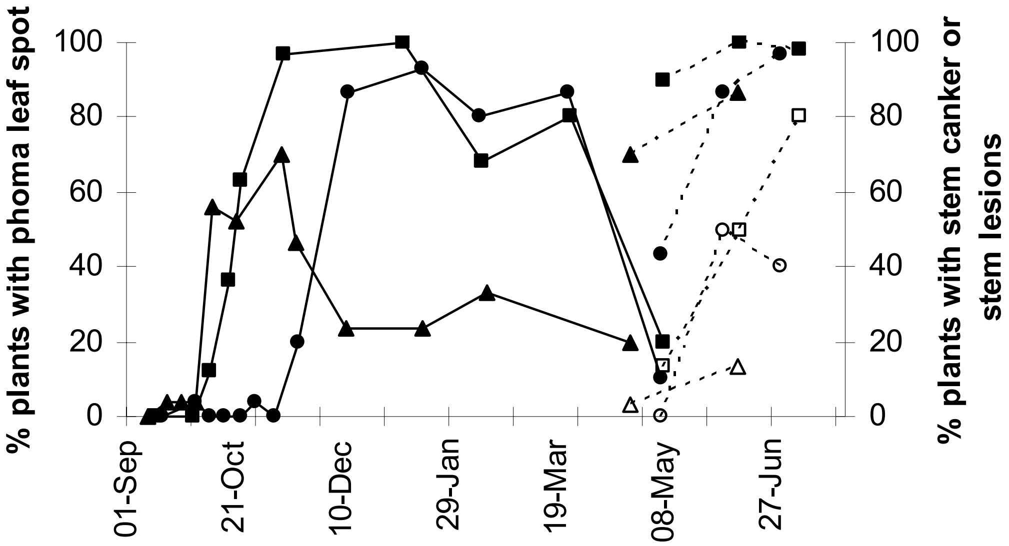



Fig. 45. Incidence (% plants affected) of phoma leaf spot (solid lines) in 2000/01 (■), 2001/02 (▲) and 2002/03 (●), stem canker (broken lines) in 2000/01 (■), 2001/02 (▲) and 2002/03 (●) and upper stem lesions (broken lines) in 2000/01 (□), 2001/02 (Δ) and 2002/03 (○) on 25 or 30 destructively sampled plants, treated with tebuconazole in spring.

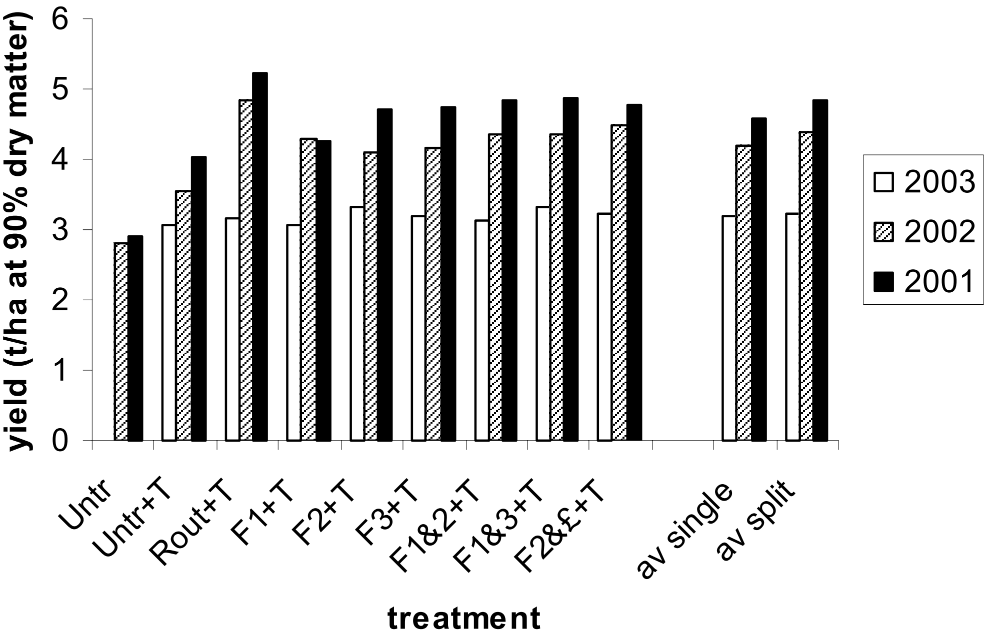



Figure 46. Effect of flusilazole + carbendazim in the autumn and of tebuconazole in the spring on yield of winter oilseed rape (cv. Apex) in 2000/01, 2001/02 and 2002/03.

## 8.4 Discussion

### 8.4.1 Cultivar x fungicides experiments

<u>Boxworth</u>

The phoma leaf spot epidemic developed steadily in October and a high incidence developed only from mid November onwards. The first spray was applied on 10 November, but programmes gave generally less effective stem canker control than in 2002 and 2003. The first spray appears to have been slightly too late to prevent early phoma (which had been present since October) reaching the stem. Previous work (ADAS unpublished data) has suggested that on small plants fungicides must be applied within 10-14 days of symptoms appearing to achieve control. On larger plants and under cool conditions that slow growth of the pathogen within the petiole, there may be a rather longer period to achieve control.

Good control of phoma leaf spot was obtained from December onwards, but this had little impact on yield. Final canker severity index was 36 and the lowest in the three years of this project. As there is considerable evidence that only moderate and severe cankers affect yield, stem canker incidences of 25 or less (equivalent to 100% with slight (index 1) lesions) are unlikely to give significant yield responses. The small positive responses in this experiment, notably on cv. Apex are consistent with the other data on disease severity and yield loss. Plants grew strongly in late autumn and large plant size would delay *L. maculans* reaching the stem and hence reduce final canker severity. Cultivar factors appeared to be influencing stem canker control, which was more effective on cv. Apex than the other two cultivars. Cultivar resistance may influence the growth of phoma within the petiole, but no data are available for this. Spray timing is likely to be more critical on cultivars where phoma grows most rapidly down the petiole. Further work beyond this project is required to investigate timing of sprays for stem canker control in relation to cultivar resistance and incidence of phoma leaf spot.

An early and severe phoma leaf spot epidemic in 2002 produced a high incidence of stem canker, with moderate to severe cankers on all cultivars. The highest yielding treatment showed a yield response of 0.85 t/ha following good canker control. The timing of the first fungicide spray co-incided with the main increase in phoma leaf spotting and was a key factor. Significant yield benefits were obtained with the Managed programme, even though only one spray was targeted at phoma control. The control of canker was poor in the Managed programme, which still significantly reduced the most severe cankers (index 3 and 4 categories).

There were some effects of cultivar resistance on phoma development and control. Escort again showed resistance to the leaf spot stage and control of canker on susceptible cv. Pronto was more difficult to achieve than on cvs Apex and Escort.

This experiment provided new information on the management of early phoma epidemics and the benefits of control on moderately resistant cultivars. Well-timed autumn sprays provided very good control of canker and no additional benefits were obtained from a third fungicide treatment in the spring. Plants had just reached the 6-leaf stage as phoma appeared and this almost certainly contributed to the success of the fungicidal control.

In 2002/2003, a particularly late phoma leaf spot epidemic developed on small plants (GS 1,5 –1,6), presenting a new scenario in plant size x epidemic combinations. There was a very high incidence of stem canker and of phoma stem lesions, but with a moderately high severity score. The highest yielding treatment showed a yield response of 1.16 t/ha. The impact of canker on yield was perhaps greater than might have been expected because plants were smaller than usual and had some stress during the winter from wet soils followed by dry periods in April and during seed development. The first fungicide was applied on 18 November just as phoma leaf spotting increased rapidly. It showed good persistence, probably because plants showed limited leaf loss after the application and there were cold periods during the winter. The various programmes indicated that fungicides can provide almost complete control of canker and the importance of autumn sprays. There was a disappointing contribution from cultivar resistance.

Aberdeen

In a previous HGCA funded project (Forecasting light leaf spot on winter oilseed rape, HGCA Project No. OS41), it was shown that rainfall, rather than inoculum level, was the driving factor in development of light leaf spot in Scotland. With heavy rainfall in autumn 2000 and 2002, but drier conditions during autumn 2001, it was expected light leaf spot would appear early in the season, possibly early November, during the wet years and later during the dry years. Results showed, however, that light leaf spot appeared in mid-November during the drier season but in mid-December during the wetter seasons. Subsequent to initial infection, however, disease development was more rapid and more severe in the seasons with a wetter autumn/winter than in the season with the drier autumn/winter.

Disease progress curves for light leaf spot were typical of those found in Scotland, that is the disease appeared in both susceptible and resistant cultivars at the same time. Disease development is usually slower in a resistant cultivar than in a susceptible cultivar but the maximum incidence (approaching 100% in untreated plots) occurred at GS 3.5 in both susceptible and resistant cultivars. In Scotland, application of an autumn fungicide usually reduces disease incidence and severity early in the spring but by stem extension fungicide has little, if any, affect on incidence of light leaf spot, irrespective of cultivar resistance. This situation was again found in the present study. Fungicide had more of an affect on disease severity, which again is typical for Scotland.

In the HGCA project ‘Forecasting light leaf spot’, a severe epidemic of light leaf spot was defined as >25% plants affected with light leaf spot. The aim of applying a fungicide in the autumn is to reduce the incidence of light leaf spot to below 25% plants affected. In all three years of this present study, the disease epidemic in untreated plots was very severe in all three cultivars (80 – 100% plants affected). The incidence of light leaf spot in the spring after applying two fungicide sprays in the autumn was >40%, even in the resistant cultivar Escort (2 out of 3 years). Thus, even by applying two half doses of fungicide in the autumn a low disease epidemic was not achieved. This poses the question, how much fungicide is required to reduce disease epidemics in Scotland below the severe category, even in resistant cultivars?

The cultivar Apex is not particularly suited to Scottish conditions and is not recommended for growing in Scotland (Anon, 2003), but despite this cv. Apex gave the best economic returns from fungicide application over the three year period. Synergy, a popular cultivar in Scotland until 2002 actually cost money over the three year period. Returns from fungicide application to Synergy have been variable since the cultivar was first recommended in 1996, despite good disease control, and this has again been shown here. It is likely that cv. Synergy will be replaced very quickly with other, more profitable cultivars.

This work has shown that light leaf spot epidemics in the north of Scotland are so severe that all cultivars, including those with relatively robust resistance to light leaf spot, are heavily infected with the disease. Fungicide sprays applied in the autumn give good disease control but yield responses and economic returns do not always mirror these disease reductions. Delaying fungicide application until first signs of disease is a poor strategy for control of light leaf spot in Scotland and likely to cost the grower money rather than bring the grower an income. These variations in disease control, yield benefits and economic benefits between cultivars and seasons are factors that need to be taken into account when developing a DSS for winter oilseed rape that will be appropriate for use by Scottish growers.

8.4.2 Fungicide spray timing experiments

<u>Rothamsted</u>

*Plant and pathogen development on marked plants*

These experiments provide evidence for the importance of early phoma epidemics in causing severe stem canker epidemics. Plant development was similar in 2000/01 and 2001/02. The timing of the phoma epidemic was also similar, but severity was considerably lower in 2001/02. This resulted in a lower stem canker score at harvest, but not as low as in 2002/03 when the phoma epidemic was equally severe, but developed later. Plants that emerged early in 2002/03 had a clear advantage over those that emerged later.

Although there was some evidence that individual leaf numbers were no larger, the rate of leaf production and therefore the number of leaves present and overall leaf area, was much greater on large plants. There was therefore a higher probability that ascospores would land on large plants and consequently the number of affected leaves, the number of lesions/leaf and number of lesions/plant were higher on large plants. Despite the greater level of phoma leaf spot, stem canker severity was lower on large plants. This may have been because the early, most infected leaves (up to leaf 10) stayed on small plants for longer, giving the pathogen more time to reach the crown of the plant, and also because stems of large plants were almost twice as thick as those of small plants and therefore better able to tolerate infection. This suggests that lower sowing rates, giving fewer, larger plants would result in less severe stem canker.

*Fungicide timing in relation to plant and pathogen development*

In these experiments, the fungicide timing that was most effective at reducing early phoma leaf spot (F1) was least effective at reducing stem canker severity. However, the evidence presented supports the view that early phoma epidemics cause the most damaging stem canker epidemics. This suggests that flusilazole + carbendazim has greater curative activity than previously thought, so that even if the pathogen infects the leaf and causes a phoma lesion, it is prevented from reaching the crown of the plant and causing a stem canker. In these circumstances, the most effective time of application would be when the greatest number of highly infected leaves are present. In 2000/01 and 2001/02, when stem canker control gave yield benefits, this was at around GS 1,10. It is also possible that phoma leaf spot lesions on leaves 10 -14 are more likely to result in stem canker because these leaves stay on the plant for longer than earlier or later leaves, giving the pathogen longer to reach the crown of the plant. However, since pathogen growth is governed by temperature and these leaves are generally present when temperatures are low, this is a less likely explanation.

## Chapter 9

## User-centred design approach in PASSWORD

### 9.1 Introduction

The PASSWORD project agreed to adopt a style of development known as 'user-centred', this means that the end-users of a system are consulted at every stage of the design from initial concept to final product (Arvinze, 1992). Two main products emerged from the project from the user perspective, the web-based forecasting information on Light Leaf Spot and Phoma and the PC based DSS system based on DORIS (Northing and Walters, in prep.). Only the web-based system was developed in sufficient detail to be tested by users in its final form. The development of any PC-based system under LINK does not go to final product and may stop at a stage somewhat earlier than alpha testing. The mechanisms and intent of the user-centred process for the PC system therefore do not include the testing of the system by end-users in their own time and environment but focus instead on requirements and reaction to design ideas presented in demonstration format.

The mechanisms and responses to the various key stages of the user-centred approach in PASSWORD are summarised below under relevant headings.

### 9.2 User requirements analysis

This was the first phase of the project and was intended to provide the basis for the design and development of the resulting system. Four workshop events were planned, the specific aim of which was to ensure that the initial design met the stated needs of the users by:

a) Identifying the main concerns associated with pest and disease control decisions.
b) Prioritising the areas in which users felt more support was needed.
c) Providing answers to questions the technical partners felt important to pose to users prior to engaging in the first stage of design and development.

Workshops were arranged at CSL on 13 February 2002 and on 14 February 2002 at ADAS Boxworth, each with separate half-day meetings for farmers and consultants. Thirteen farmers, thirteen consultants, one plant breeder, two manufacturers and two technical managers took part in the events. All groups followed the same general format which included: an introduction to the project and to the focus group; group discussion on three aspects of pest/disease decision making (whether to act, when to act, and what to apply); individual and group discussion on areas in which additional support is needed; and the types of approach PASSWORD should adopt.

The results relating to the discussions in the decision making session were analysed according to a method generated in Management Science (Arvinze, 1992). In this method, the questions to which the decision-maker needs answers to make an effective decision were categorised into three types:

State – questions about the current state of anything in the decision area

Action – questions about how the decision maker can get to a desired point

Projection – questions about what will happen 'if' the user makes changes to any of the decision variables.

It was useful to split the issues in this way because identifying state questions provides information about the type of data the user needs to have close to hand (i.e. within encyclopaedia or database) and the action and projection issues provide an indication of the types of models needed in the system. The information currently used to support these questions was also collected and collated as a means of identifying sources to populate information structures within the new system.

## 9.3 Summary of results

### 9.3.1 General summary of factors in decision process

The decision to act against pests/diseases

Participants use information about weather conditions (past, current and forecast), time of year, warnings and crop observations as basic data when deciding to act against both pests and diseases. Other issues important to some groups are the management style of the grower and the growers work priorities, the thickness and strength of the crop and pest/disease thresholds. Disease based decisions also take into account the past history of the field/area, the cultivar and sowing date. For some decision takers the level of nitrogen in the crop may also be an important factor. The high degree of insurance spraying reduces the complexity of decision making in pest management. Pesticides are included in the tank mix with other treatments to avoid problems starting and to cut down on field walking. Information about the crop's position in the rotation is also important in the decision to act against pests and the presence of a seed dressing may also be considered. General issues listed by single groups include: previous sprays, management ability of the grower, grower perception, volunteer crops, crop value and environmental issues.
Participants use this information to decide:

- Whether it is possible to control the pest/disease problem.
- What the implications (financial) of acting or not acting will be.

Much of the historical data (field, rotation and weather) is kept in hand-written records or held by individuals as experience. Some computer recording does take place but not extensively. External sources of independent information are sought on warnings (e.g. ADAS, farming press, Watch, UAP, Manufacturers, AICC), cultivar (e.g. NIAB, AICC, breeders), threshold levels (e.g. ADAS).

Choice of active ingredients/product

The choice of products or active ingredients for managing pest and disease in OSR is largely based on: the products stated effectiveness against the problem, the rate it can be applied at, its compatibility with other products in the tank mix, any other benefits it might have (e.g. as a growth regulator) and the time of year. Information about products is gained from the manufacturer's label, independent trials, ADAS, advertising, the HGCA and also from personal contacts. Product cost, environmental impact and the management style of the grower are also taken into account much more if the decision relates to pest management. Product cost is obtained from personal contacts and environmental impact is judged on data from the manufacturer's label. Other issues, which were listed by some decision-makers, are: safety implications (label), trials results (e.g. TAG (formerly Morley and ARC)), availability, physical capability, farmer attitude, previous applications, and any threat to the crop from the product. Participants use this information to decide:

- Whether it is cost effective to use a particular product against the problem.
- How well the choice will fit with other applications at the same time (e.g. tank mix).
- What is the most environmentally friendly choice for their situation.

When to take action

The main issues that participants consider when deciding when to make applications against pests and diseases are the degree of urgency and the current and forecast weather. The impact of the weather on the chosen product and the physical capability of the grower are also important. Weather forecasts are obtained from a variety of sources, e.g. Metfax, radio and TV. Product information is gained from the manufacturers and previous experience of using the product. Other issues listed by individual groups were: timing issues for given product, potential for damage to the crop, threshold, time of year, growth stage, previous cropping and the window of tolerance. Participants use this information to decide:

- Whether it is cost effective to spray at a given time.
- How much of a window of opportunity they have.
- How well the choice will fit with other applications at the same time (e.g. tank mix).

Areas for additional support

The most popular headings for additional support facilities after initial analysis appeared to be 'information about products/actives' and 'basic pest and disease biology' (Figure 53). Participants wanted rapid access to a single source of up to date detailed technical data, culled from independent sources where feasible. They also wanted access to anecdotal data when concrete data is not available. Specifically they wanted information on:

- Dose response curves
- Resistance issues

- Environmental impact
- Operator safety
- Weather sensitivity
- Secondary effects (anecdotal and scientific)
- What works best on which pest
- Persistence of sprays

They also wanted access to a single source of pest and disease information containing pest/disease lifecycles, data on relative importance to OSR, canopy management, thresholds and a summary of what to look out for at particular times. Specifically, they were looking for information on:

- Disease information: life cycle, progress over season, importance of specific diseases, identification, thresholds
- Plant information: plant development, nutrition, yield sensitivity, source of response to treatment, canopy management,
- Pest information: life cycle, progression over season, importance of given pests, thresholds
- Virus information – life cycle, importance
- Crop management information: what to look for and when (critical dates), pictorial support for pest/disease levels

Electronically delivered farm specific warnings were specifically requested by three of the four groups and mentioned by the fourth (but not ranked). The need for some feedback on the impact of local conditions on pest and disease progression suggests the development of models but the implication was that the warnings would be delivered by an external agency.

Both consultant groups requested support for optimising the spray decision, i.e. support for identifying the ideal rate and date of application, particularly for disease management. The ability to manipulate some of the variables in decision making (e.g. what if'ing) was also rated highly by one of them. Both of the Boxworth groups specifically listed slug management as an area in which they wanted more support, both in terms of basic biological information and product choice/application. Areas for support which were of interest to individual groups, were: integrating the pest disease management strategy (high rating from a farmer group); up to date daily weather provision (high rating – consultant group); and crop intelligence (medium rating – consultant group).

There seemed to be a feeling that systems which the participants would actually be using would be best delivered on a CD for installation on their own machines, but updated via the Internet. Although one of the groups felt that using the system over the Internet was the better option it was highlighted by one group that a percentage of users do not, and will not, have access to high speed connections. Pest and disease warnings were felt to be best delivered to them from outside e.g. via email or fax. Most groups believed that information that needs to be regularly updated should be delivered via the Internet.

## 9.4 Conclusions

The focus groups represented a wealth of experience in terms of the participant's years working with OSR and hectares managed and they were extremely valuable in generating a considerable amount of data on the decision making process and the issues that consultants and farmers consider. While there is considerable overlap of issues and information between the four listed aspects of the decision process; each uses slightly different types of information, and to a greater or lesser degree. Support was definitely felt to be necessary with a wide range of facilities suggested. The analysis shows that a large quantity of local and field based information, which is held either on paper or in the heads of consultants and growers, is used in decision making. This information has to either be incorporated into the decision support system or the user will have to be made very aware that it has not been. If data has to be incorporated into a system to make it locally relevant then there may be a need to support the activity (e.g. helplines, data entry wizards).

The primary issue with non-local data is location. The participants currently obtain information, when they have time, from a wide range of sources and with varying degrees of confidence. A single, validated source of data on product, pests, diseases and crop management seems to be a primary concern. The development of models to provide local forecasts of potential pest and disease problems seems to be useful but as the basis of a service rather than for on-site use. Models to support optimisation and 'what'ifing', possibly on a strategic basis, will be useful to some decision-makers, particularly consultants.

Screen shots from the DORIS and Wheat Disease Manager systems were shown to the workshop groups and were well received. There was insufficient time to explore these in great detail and it is suggested that this is the primary focus of the next set of user workshops. In the future, the project should be able to present a first draft of presentation ideas (paper or computer base) to users and get specific feedback on the fit to the decision task. As the support priorities listed here were based on a relatively small, and potentially biased, sample of individuals it was suggested that it might also be useful to validate the main findings with a much wider audience (i.e. through a postal survey).

## 9.5 Postal Survey

As a result of the previous activity a postal survey was conducted whose aims were:

1. To validate requirements gathered in user groups
2. To prioritise requirements
3. To check delivery format options

.

The questionnaire was distributed to people on the CSL mailing list and the returns were sent directly to CSL for entry onto a web-based recording system. Twenty-five people responded to the survey and the results from their questionnaire returns are given below. The maximum possible score would be 50 if all participants considered the information very useful.

### 9.6 Results of postal survey

The breakdown of respondents to the survey was as follows: 19 farmers; 2 farm managers; 1 farmer/distributor consultant; 3 not stated. The mean area of oilseed rape managed by the respondents was 76.7 ha. A simple form of ranking was used to get a value for each of the areas rated by users from Very useful to Not at all useful, where only items marked useful received a score of 1 and those ‘very useful’ a score of 2. Figures 46-52 illustrate the results of this exercise.

#### 9.6.1 Information usefulness

Figure 46. Most useful information on pesticides.

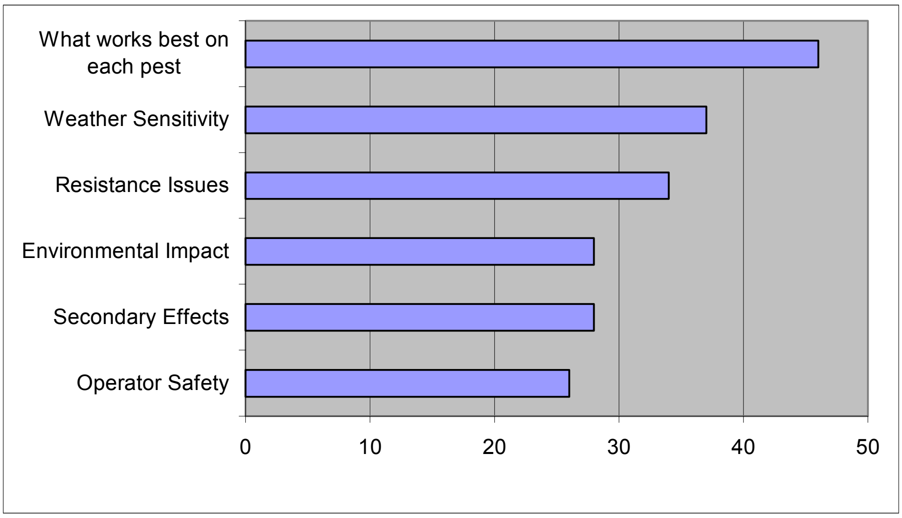



Figure 47. Most useful information on pests.

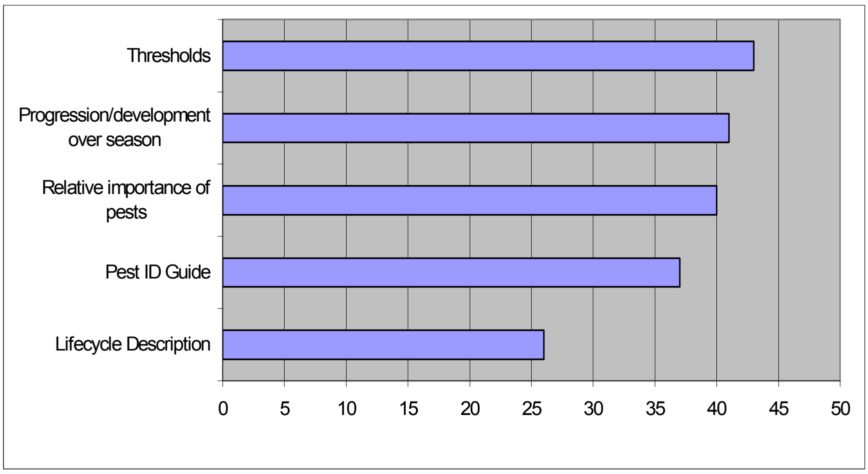


Figure 48. Most useful information on diseases.

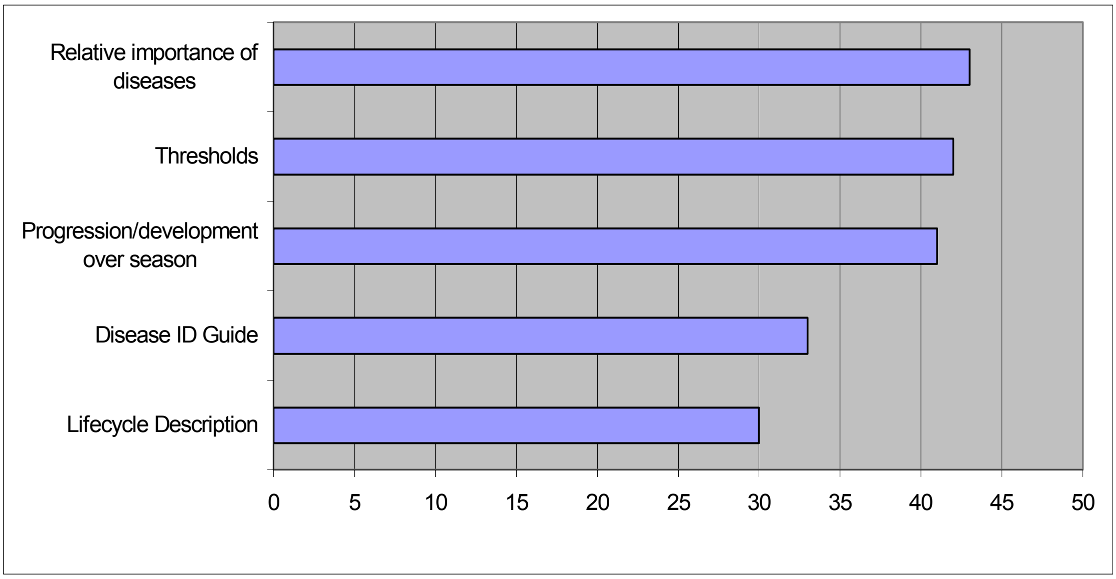



Figure 49. Most useful information on OSR.

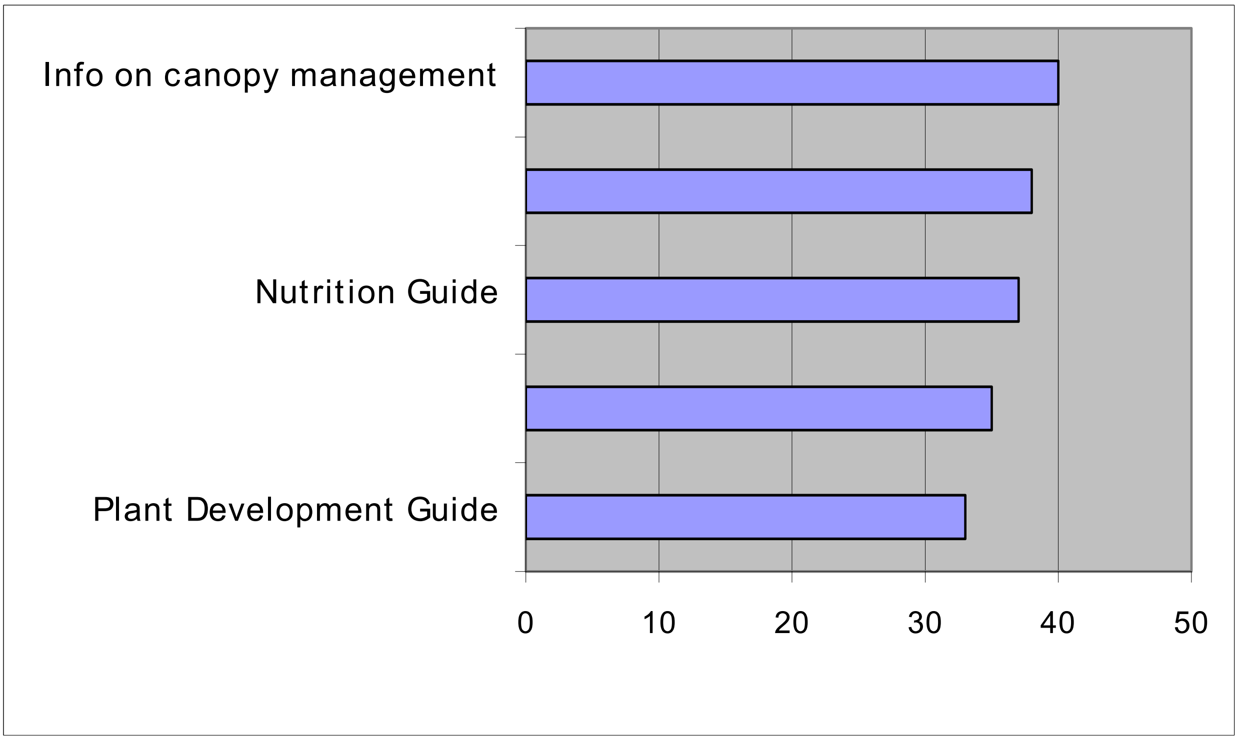


Figure 50. Most important information on viruses.

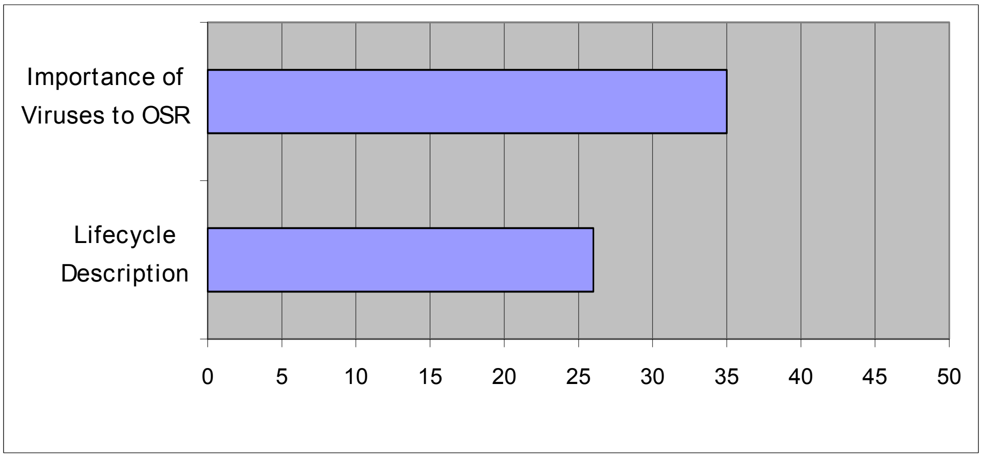
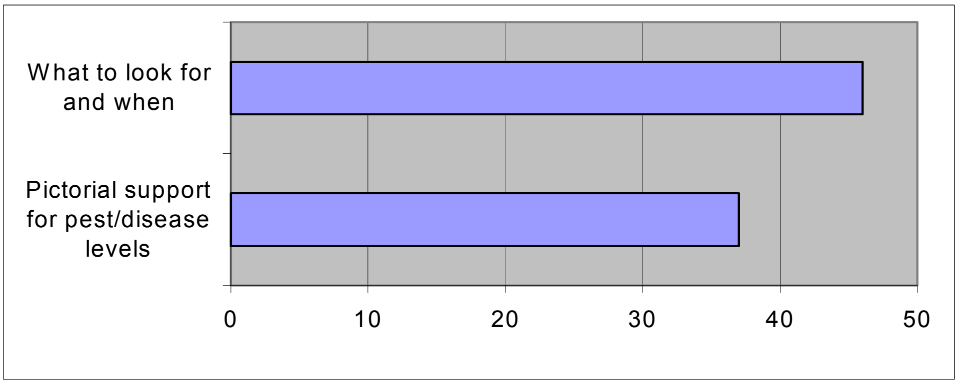


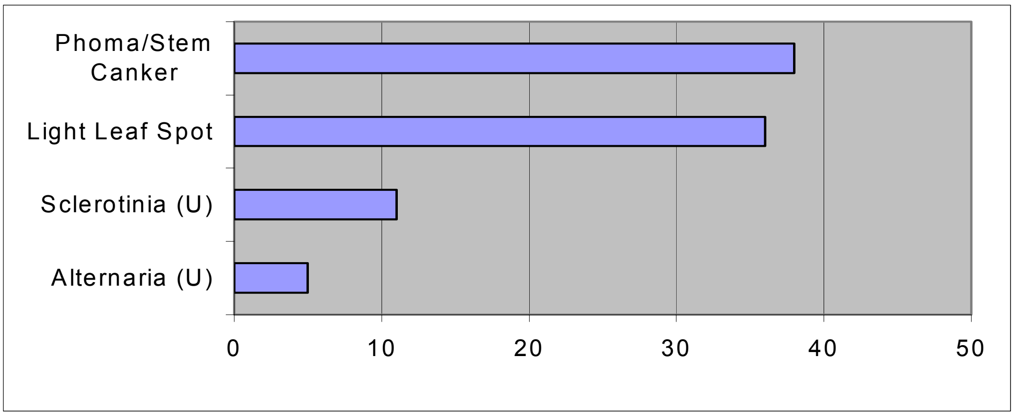

Figure 51. Most useful information on general management.




Respondents also listed other information they felt would be very useful (Variations within field canopy; Manipulation of canopy using Nitrogen; Establishment techniques; Cost of treatment vs yield benefit analysis) and other areas they thought would be useful (Use of ICM in relation to crop management; Harvesting techniques; Desiccation timings & products; Use of PGR where/when/what; Best fungicides for each scenario; Information to be as specific as possible to locality; Drilling date differences (seed rate); Growth stage 'windows' for treatment timings)

When asked what areas they felt were most useful to be supported by models, respondents suggested that Phoma/Stem canker and Light leaf spot were the most important to them.

Figure 52. Usefulness of model based support for diseases.




The final activity of this component of the project was to brainstorm and decide on the basic structure for the interface to the integrated pest and disease management system. The only general model support areas that were not validated by the postal survey were the requests for droplet spectrum and water volumes, LERAP calculator for mixes, effects of pests on potential yield and canopy management guidelines.

Overall ranking of user requirements

Figure 53. Ranking of top user requirements.

| Information/model item | |
|---|---|
| What product works best on each pest | 46 |
| What to look for and when | 46 |
| Thresholds(P) | 43 |
| Relative importance of diseases | 43 |
| Thresholds(D) | 42 |
| Dose response curves | 42 |
| Progression/development over season(P) | 41 |
| Progression/development over season(D) | 41 |
| Rate & date support: Pesticides | 41 |
| Relative importance of pests | 40 |
| Info on canopy management | 40 |

Overall the survey supported the data from the workshops and provided some means of identifying the most important requirements for information and model based support as far as the users were concerned.

Respondents stated that they would prefer the biological and model based information to be delivered via CD/PC (15/25) but to have it updated by the Internet (18/25), they preferred their spray timing and rate information to be delivered via the Internet (15/25) and warnings via email (16/25).

The recommendation from this exercise was to proceed with the priority requirements, to deliver model and biological information via the PC/CD route but with Internet updating capabilities with model support via the web if there was time.

## 9.7 Demonstrations and user feedback at Cereals & Sprays & Sprayers 2002

By the middle of 2002, some of the ideas generated by the team had taken a visual form and it was possible to use the event to generate feedback on the ideas. To this end a PowerPoint™ demonstration was devised, employing screen shots from the existing DORIS software and incorporating the changes that the team foresaw the new functionality of disease management to take. The existing web pages generated by the project were also demonstrated. Questionnaires to obtain user views of both elements of the PASSWORD user interface were devised and anyone who stopped to look at the display was asked to take part in completing them.

Results from model-based demonstration

Thirty-one people answered some or all of the PASSWORD questions; of the twenty-five people who gave some indication of occupation, six were consultants, thirteen were farmers, two technical support personnel from agrochemical companies, a seed merchant, a student and an R & D manager.

*Information display*

The majority of respondents were ambivalent about the usefulness of the national pest and disease information, but thought the regional pest/disease information was useful. Most of the eighteen respondents thought the information in the graphs was easy to read. Users found the regional information more useful than the national and felt it helped in the decision making process. They were not so happy to see it on the screen all of the time and it was suggested it should have disappeared after the models were run and/or could be called up when wanted. Users were interested in seeing other types of information on the screen, particularly current and past weather (rainfall) data and current levels of pest/disease, cultivar resistance and threshold levels, i.e. how close is current projected level to threshold, economic threshold, plus more general feedback on economics, i.e. current price, profit from adding sprays.

*Models*

Most of the people who answered this question thought it would be easy to obtain the information required to run the models and thought they would be able to enter the data without additional help. Most of the eighteen

respondents also thought it would be easy to enter the data required to run the models. Users thought most of the input questions were easy to answer but wanted support for identifying pest/disease levels. Several people thought that the picture of damage related to the actual number entered and wanted this level of support, i.e. good quality images showing levels of pest & disease attack with corresponding numbers.
Just over half thought the information provided by the models would be useful to them. However, a number of people felt that the screen was hard to read and the advice not specific enough. Ideas for tidying up the screen included lining the text up, making the advice section more prominent and clearly labelling the different feedback areas.

*Spray entry process*

The majority of respondents thought it would be easy to select and enter a spray from the spray entry dialog and most thought they would find the information on the chemicals useful.
Entering the spray was considered to be easy but the information on the chemical was generally thought to be overcrowded and hard to read. Users would like the most important aspects of the information to be separated out as bullet points and the rest hidden until they want to call it up. Key items of information included rates, basic price, warnings on non-target organisms, spray quality and choice of nozzles (fine/medium) etc, one person suggested that the key items from the Pesticide Guide be listed.

Most of the eighteen respondents thought the screen communicated the important factors in OSR pest/disease management well and said they would find the information on the display useful. While users liked the ability to see the risk levels, some people expressed a desire to see the risk against specific pests and diseases and also the treatment against those pests and diseases. They wanted to be able to tell if the treatment they applied was for all or some of the risks identified. It was also suggested that some feedback on margin would be useful, particularly if it could show what the impact on margin would be if they went on with the treatment a week later.

*Web systems – questionnaire development*

The Light Leaf Spot forecast and background information was available on the web for some time during the lifetime of the project and a further site for Phoma was developed in the third year of the project. The LLS web site was frequently visited by users and it was thought to be a useful exercise to ask visitors what they thought of the various pages. To this end, a SNAP survey questionnaire was developed and delivered to CSL for incorporation into the web pages. Each site had a general questionnaire and questionnaire for each of the main pages.

*Model based DSS user interface*

The final exercise in this phase of the project was the specification of the user interface to the pest/disease integrated DSS. Discussions took place between the consortium members and a Requirements Document which outlined the requirements for the user interface was circulated. The consortium has used this document as the basis for its decisions on the form of the user interface to be expanded on in the next phase of the project. The table below highlights the main requirements for display. The project has benefited from the views expressed by potential users in determining design features and priorities. Additional areas for development that were outside the scope of this project have been identified. The prototype DSS should continue to be demonstrated to potential users during the next development phase of the project. It is clear that individual users have a range of preferences for obtaining information. Some will use DSS, whilst others will prefer simple warnings and guidance to be delivered by their advisers. These issues will need to be considered further during discussions about commercialisation of the system.

Table 49. User requirements for decision information.

| Requirements for decision information | Display requirement |
|---|---|
| Is there a problem? | Indicate points in time where pest/disease will be a problem given currently stated control measures (if any)<br>- have to show risk from pest separate from risk from disease? |
| When should I act - when is it economic to act? | Indicate most economic point in time for action for pest/disease<br>- indication for each action and for combined? |
| What is the window of opportunity for acting for pests/diseases? | Show period in time during which action is still economic – show reduction in value decreasing over time. |
| Is it possible to control the problem? | Provide indication of impact of user selected treatments on problem. Provide indication of system selected treatments on problem.<br>Show users selected treatment points.<br>Show system suggested treatment points. |
| What are the financial implications of acting/not acting? | Show effect of chosen programme (may be nothing) on estimated problem in terms of potential loss. |
| What are the relative contributions of each problem at this time? | Provide some indication of the relative contributions of pests/diseases to overall loss. |
| What is the threshold above which action is necessary and where am I in relation to it? | Provide a visual(or other) indicator of the point at which it becomes economic to take action against pests/disease. |
| What is the persistence of the treatment? | Show expected persistence for each user selected treatment. |
| Is it possible to control the problem? | Provide feedback to indicate removal of problem if treatments are forecast to be effective. |
| Integrating pest/disease management strategy. | Put both pest and disease information on a single screen. |

# Chapter 10

# PASSWORD Module Development

## 10.1 Introduction

One of the main purposes of this project was to develop a delivery mechanism for the knowledge acquired during the research phase. The delivery mechanism had to meet several important criteria to justify the resource invested in it. These criteria were:

1. The delivery mechanism must supply useful and accurate information
2. The information should be provided in an easily understandable format
3. The mechanism should be readily available to those who want it at a cost effective price.

The requirement to meet all these criteria is absolute. Failure to do so will lead to the failure of the developed product. If the mechanism does not supply appropriate information uptake by the industry will be low. If the information provided is useful, but delivered in a manner that does not allow for easy comprehension, then uptake will also be damaged. If the first two criteria are met, but the costs of purchase and maintenance are greater than the potential savings, again very few people will use it.

This element of the report will concentrate on the development of the mechanism with regards to the first two criteria. The consortium has little influence over the third criteria as the medium for the delivery mechanism is as a ArableDS module and hence its availability is reliant upon the successful launch of the ArableDS shell.

### 10.1.1 Decision Support Systems for Arable Crops (ArableDS)

ArableDS has been designed as a PC-based system and is made up of a decision support system (DSS) shell into which multiple DSS's can be plugged, databases for weather and pesticide data and a fully functional farm management system. The PASSWORD entity has been developed as a ArableDS compliant module and as such has to adhere to the prescribed 'look and feel' of the ArableDS brand. An ArableDS compliant pest module (DORIS: Decision support for Oilseed Rape Invertebrate pestS) has already been developed and is reaching the final stages of validation (Defra project number: AR0306). The ability for PASSWORD (and DORIS) to conform to the ArableDS 'look and feel' has been greatly enhanced by the provision of a ArableDS toolkit, which contains the basic building blocks of the modules. Building upon the structure of DORIS and using the toolkit has ensured that PASSWORD both conforms to the ArableDS requirements and, on release, will be familiar to the users of the DORIS module.

As has already been discussed in the section on the user centred design approach and in Parker (1999, 2001), user consultation is an extremely important process in the development of decision support systems, particularly where the design of the interface is concerned. The ArableDS system and the DORIS and PASSWORD modules have gone through thorough user consultation processes and the results of these consultations have been used to drive the design of the interfaces and the format and extent of the information provided via these systems.

10.1.2 Decision support for Oilseed Rape Invertebrate pestS (DORIS)

The development of the DORIS module was driven by the specific requirements of the consultation groups. This led to an integrated holistic system that contains models and information on all the main damaging invertebrate pests of winter oilseed rape (see Northing and Walters, in prep.) for a description of the development process and final system). The number of pests and the complexities of their interactions and temporal range (Figure 1) are such that all the consultation groups highlighted as extremely important the need for the decision-making processes on each to be dealt with in an integrated manner. This required the system to:

1. have only one model run and associated output that covered all the pests relevant at a particular time of the growing season;
2. deal with the economic implications of potential treatment against multiple pests;
3. deal with the economic implications of tank mixing the pest control with disease or weed control;
4. consider the effect of treatment against pests on the potential for control by natural enemies.

The science that underpins the development of this system has been discussed at length (Walters *et al*, 2003) and in detail (Walters & Lane, 1994; Walters *et al*, 2001). The validation project of this system is now nearing completion and both the field scale validation trials and the historical validation exercises indicated that

a) DORIS users have the ability to incorporate a more rational approach to insecticide use in their decision making processes and thus improve the timing of control decisions, increase their profit margins and reduce the risk of environmental damage (Northing et al, in prep)
b) Widespread uptake and use of the DORIS system could dramatically reduce the amount of pesticide use in oilseed rape with associated savings to the industry (Walters and Northing, in prep.).

This system therefore has the potential to be a major contributor to an increase in the sustainability of arable farming in the UK. The integration of detailed disease control strategies with DORIS in a new module (PASSWORD) should, following a similarly successful validation stage, improve the usefulness and scope of oilseed rape DSS's and provide the basis for a rational decision making policy for both pests and diseases in this important crop.

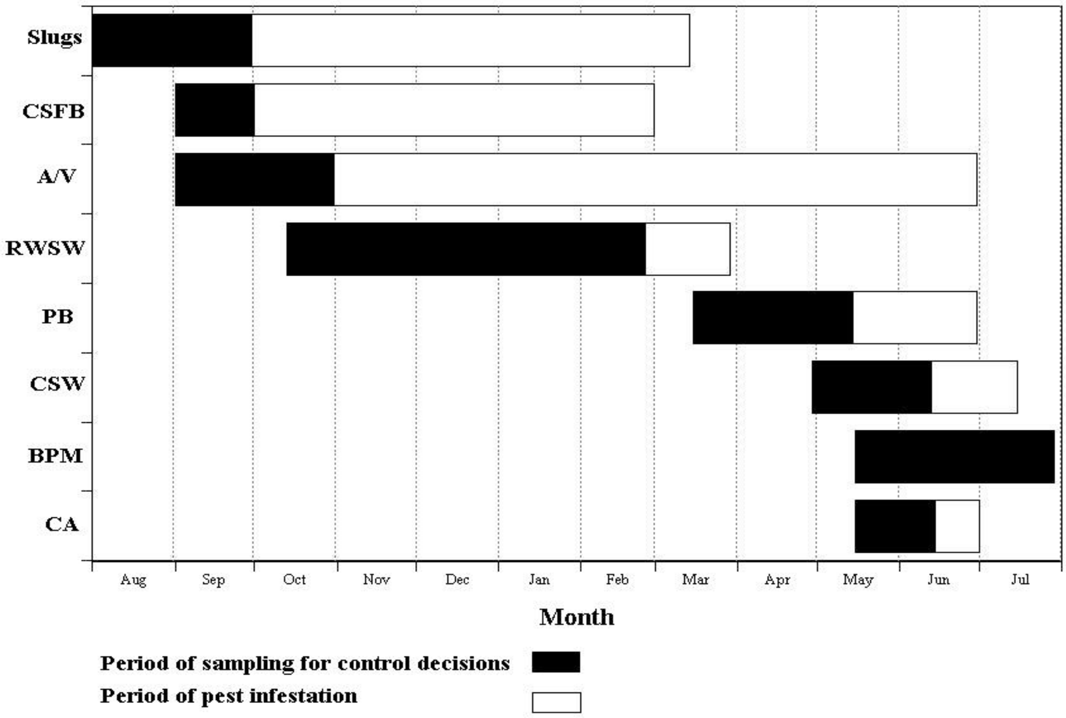



Figure 54. Temporal spread of the main damaging invertebrate pests of winter oilseed rape. (CSFB=Cabbage Stem Flea Beetle; A/V=Aphids as virus vectors; RWSW=Rape Winter Stem Weevil; PB=Pollen Beetle; CSW=Cabbage Seed Weevil; CPM=Brassica Pod Midge; CA=Cabbage Aphid)

The DORIS system is on course for release to the ArableDS consortium in 2004.

### 10.2 PASSWORD development

The development process of the PASSWORD module began by considering the current position of the DORIS module, the associated user consultation results and the likely type of data and models that would be available for the two main Winter Oilseed Rape fungal diseases, *Leptosphaeria maculans* (phoma stem canker) and *Pyrenopeziza brassicae* (light leaf spot (LLS)).

Initial amendments to the DORIS module had to include a change to the way in which the disease considerations were dealt with. DORIS asked the question 'are you going to tank mix?' and this affected the financial implications of treatment against the pest under review. In PASSWORD, the system provides information on whether and when to treat against diseases, so the pest models have to access this information to change the financial aspect of the models. Otherwise, the pest elements of the new system were essentially left unchanged.

The majority of the actionable user consultation requests had been integrated into the DORIS system prior to the beginning of the PASSWORD development. The overall requirements for simplicity and integration were kept in mind throughout the addition of the disease elements.

Phoma stem canker

A considerable amount of work went into the development of models describing the dynamics of phoma stem canker epidemics (see Chapter 3 'A mechanistic model for describing dynamics of phoma stem canker epidemics'). However, the developers of this model felt that it was not currently usable in the DSS. After much deliberation, an alternative was made available at the end of the project for incorporation into the system (see Chapter 4 'Phoma progress model'). This new model allows us to predict the date at which 10% of plants showed symptoms, the date of the onset of stem canker, the final stem canker severity and the associated yield loss. These predicted dates are highlighted in the display area (Figure 55f) alongside the output from a second model.

The second model for phoma leaf spot develiopment uses environmental data to predict the number of hours per day where the infection criteria are met (see Chapter 3 and Biddulph *et al.*, 1999). Starting from the dates on which the infection criteria were met, predictions are made about when the symptoms from these potential infection episodes will become apparent in the crop. The provision of this information in the display area enables the user to see how great the potential for infection is and also highlights key times when they could go out into the crop to look for symptoms.

Light leaf spot

The development of a usable light leaf spot model was also difficult. The search for an alternative eventually provided a model similar to the second phoma model for incorporation into the system at the end of the project. This model also uses environmental variables to predict the days when certain infection criteria are met. These days are then used as the starting point of a model to predict when light leaf spot symptoms will become visible in the crop (see Chapter 6 for further details on the model used). The output from these models is also presented in the display area.

Risk Bars

The outputs from the disease models are then combined with the yield loss and fungicide effect models to estimate the time period where the crop is most at risk from these diseases and the times when the application of treatment will accrue a financial benefit. The associated risk from each disease is displayed on the risk bar (Figure 56ii) and the time period when treatment will provide a financial return is displayed on the spray timing bar (Figure 56v). After treatment an indicator will appear on the spray indicator bar (Figure 56iv).

Fungicide and yield effects

Some of the fungicide effect models are described in Chapter 5 'Light leaf spot fungicide effects', whilst the importance of a programmed approach to phoma control has been demonstrated using real data within the module. The output from the disease models and default values for regional yield loss (for those users who do not have their own historic data) are combined with financial calculations to provide an estimate of the overall financial impact of the current predicted levels of disease. Calculations are then made to predict the time period during which treatment of the crop will be cost effective. The financial implications of the treatments that have taken place, the current pest and disease levels and any proposed treatments are estimated and shown on the financial impact bar (Figure 55i). As these are only estimates, a range (defined by colour gradation) is given on the bar. The levels on the bar are initially provided relative to a 'good' and 'low' return from the crop. For those who then want to have this quantified in terms of yield loss and financial return, they can click on the 'cost-benefit analysis' button (Figure 55h). This then shows a 'pop up' box with an estimate of actual yield loss and expected financial return from the current disease levels and associated treatments. The pest elements within the system have been developed in such a way as to make any specific predictions of yield loss and overall return extremely difficult to predict with any kind of accuracy, so this has not been attempted.

<u>Pesticides</u>

The ArableDS databases include extensive, regularly updated information on the pesticides available for use in winter oilseed rape against the various pests and diseases covered by PASSWORD. This is provided by CSL's LIAISON database, which is well recognised as being accurate and reliable. Once the user has decided to treat their crop, they will need to enter into the system the data on the chemicals used. This can be done either from the farm management part of ArableDS or by clicking in the 'spray' button (second from left on the toolbar – Figure 55l). Once the treatment details have been entered a graded indicator will appear on the spray line of the risk bars for the disease (or pest) against which the treatment was targeted. This fades out to indicate that the treatment becomes less effective over time. Treatments that have taken place are then incorporated into the relevant model algorithms.

<u>Scenario Generation</u>

An important element within the ArableDS system is the ability to generate different scenarios and see what effects these will have in the crop. The two main elements of scenario generation functionality within PASSWORD are

- The treatment markers (Figure 55e) on the timeline (Figure 55d) highlight the system recommended treatment date for maximum return. It is possible to click and drag these markers along the timeline to see what the financial implications are of treating the crop on a different date.
- The predictions for the disease models are reliant on weather data. The model output for the future is based on mean regional weather data. The system therefore allows the user to change the weather data currently in use to see what would happen if the environmental conditions were more or less favourable to disease progress.

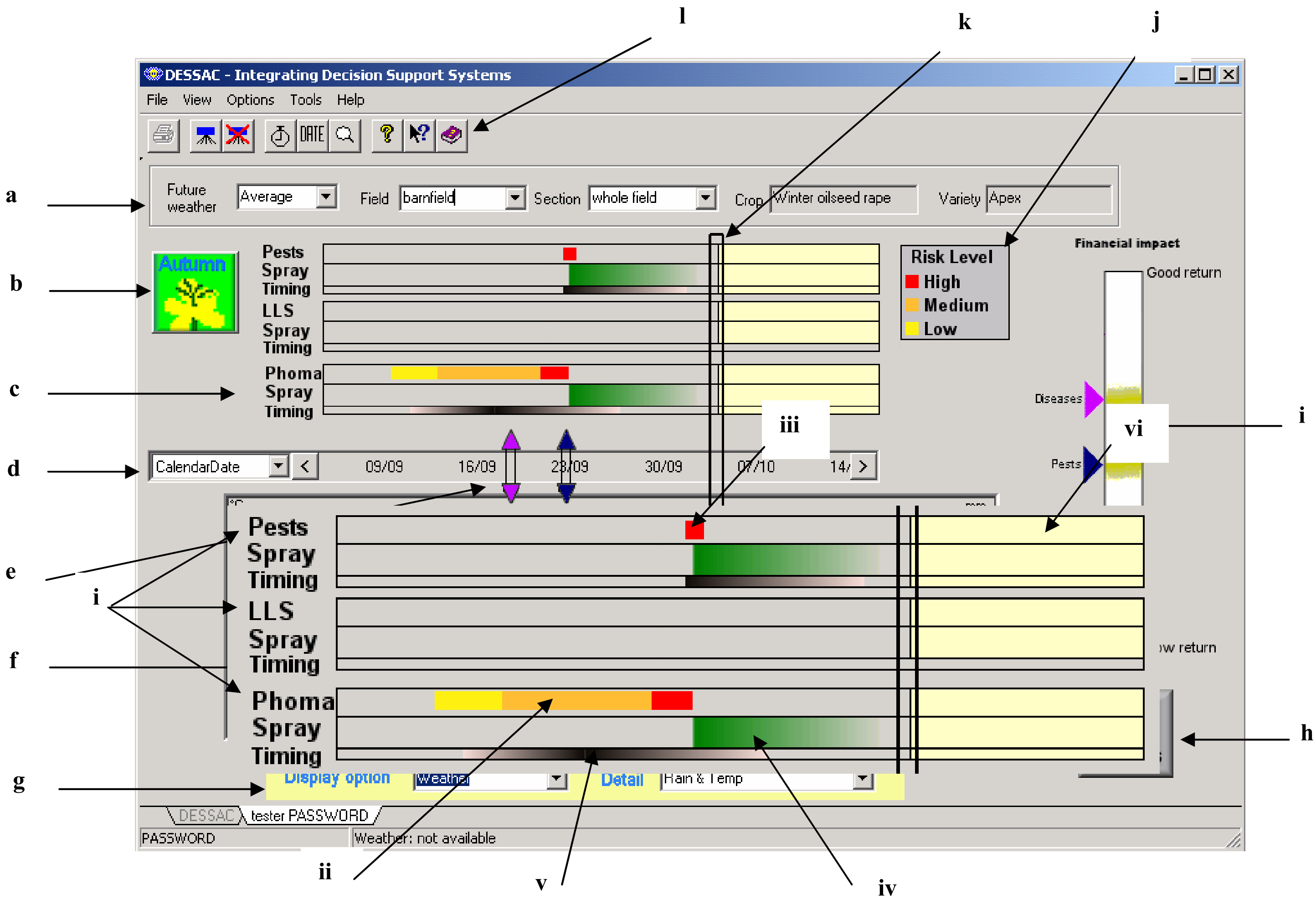



Figure 55. Screenshot of the main interface of the PASSWORD module. (a – l are described below).

Interface description

From Figure 55:

**a) Farm Bar:** Contains the information on the fields and field sections on the current farm and allows changes between them. Only fields that are currently sown with winter oilseed rape are available for use within the PASSWORD module. Also allows the user to change the weather data used in the future predictions of disease.

**b) Model run button:** Clicking on this button allows the user to enter information on the latest pest sampling. The disease models run automatically on beginning the module or changing between fields or field sections.

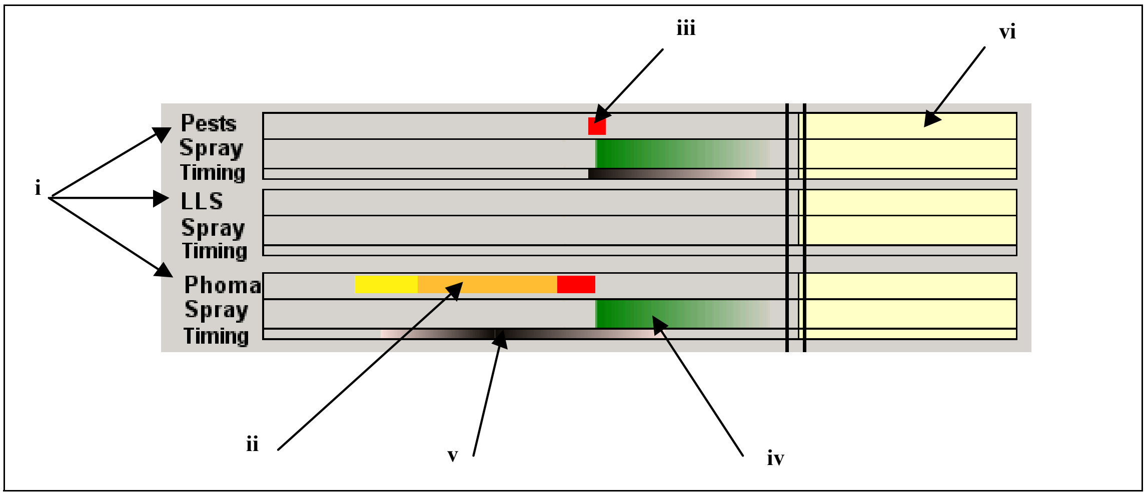



**Figure 56. Screenshot of the risk bars (Figure 2C) (i-vi are described below).**

c) **Risk bars (from Figure 56):**

i) **Pests and diseases:** There are three sets of risk bars in the interface, one set for the pests (dealt with holistically) and a separate set for each of the two diseases that PASSWORD currently deals with. Each set contains three bars – 'risk', 'spray' and 'timing'.

ii) **Risk 'events' (disease):** The output from the disease models is translated using the yield loss and fungicide effect algorithms to provide a risk assessment based on how great the problems could become if some form of treatment is not applied. There are three levels of risk, 'low, medium or high'.

iii) **Risk 'events' (pests):** The output from the pest models is interpreted with reference to financially worthwhile thresholds rather than yield loss.

iv) **Spray indicator:** This indicates that a treatment has been applied against the pests or diseases and fades out over time to indicate the decreasing efficacy of the treatment.

v) **Spray timing indicator:** This indicates the time period during which a spray application is cost effective. This is graded (light-dark) in conjunction with the period when the treatment application has the greatest effects on the output from the financial implications.

vi) **Prediction region:** The area highlighted in yellow (i.e. after today's date) is where the predicted risk events and other predictions (treatment deterioration, spray timing) are entered.

d) **Timeline:** Shows the timescale that is currently on view. The Risk Bars and the display area are linked to this timeline so that changing the scope of the timeline will also change the display area and the risk bar.

e) **Treatment Markers:** These highlight the models recommended timing of fungicide (pink) and insecticide (blue) treatments. These markers can be dragged along the time line enabling the visualisation of the financial impact of treating earlier or later. The timing of the treatment affects the output from the yield loss and treatment effect algorithms that are used to provide the data for the financial implications bar. Thus, moving the treatment markers will potentially change the information provided on the financial implications bar.

f) **Display area:** This area contains the information chosen via the display options. Choices include a variety of weather data, historical pest or disease incidence from the Defra funded OSR pest and disease surveys and data from the models on the development of the diseases.

g) **Display options:** These 'drop down' boxes allow the user to choose what is to be displayed in the display area.

h) **Cost Benefit analysis:** Clicking on this button will display a 'pop up' box containing estimates of the financial effects of the disease levels and current treatment regime.

i) **Financial impact bar:** This allows the user to visualise the relative effects of the pests and diseases on the overall return from their crop.

j) **Key:** The key refers to the level of risk associated with the pests and diseases.

k) **Date indicator:** This indicates todays date on the display

l) **Toolbar:** There are various buttons on the toolbar that provide the same functionality as some options from the normal menu system. They include access to the help files and encyclopaedic information, functions to change the date in view and the scope of the display and how to add and remove treatments from the risk bars.

Debugging and Exception handling

To maximise the uptake and continued use of PASSWORD it is extremely important that this module is demonstrably accurate (in this case with regards to the models within the system rather than with regards to the field situation which is to be tested via model validation in the next project), stable and robust (i.e. able to cope with unexpected inputs). To ensure that this is the case, regular debugging checks have taken place. These included

1. step-by-step monitoring of the code inputs and output;
2. using the Microsoft Visual Studio ™ 'watch' facility to ensure that important variables are allocated at the correct time and with the correct value;
3. running the program in a mode which monitors how much time the program spends dealing with each specific function.

These three methods ensure that the majority of the procedural bugs (i.e. errors in code which cause inefficiency or inaccuracy) are identified well in advance of the system being released to the end users.

Exceptions (errors which may cause the program to crash, such as memory problems or use of incorrect data types) are handled within the code, where required, as the code is being constructed.

This ensures that when the user enters incorrect data or uses the system in an unexpected way the program realises this and informs the user. Unhandled exceptions will cause the program to crash. These debugging and exception handling techniques should minimise the amount of technical problems experienced by the users. Any problems that do remain should be picked up in the final rounds of Beta testing prior to the commercial release of this module.

Encyclopaedic information

An important part of the ArableDS concept is the provision of comprehensive encyclopaedic information. This information has been presented as HTML files viewed via a system derived from Microsoft's Internet Explorer TM. This ensures that the information is provided in a manner that should be familiar to most users of the system.

The provision of comprehensive encyclopaedic information is something that scored very highly in the requirements from the user group consultations. In particular these potential users wanted to have easy access to images of typical and atypical disease symptoms, of pests and of OSR growth stages. There was little resource allocated to this part of the system in this project and so much of the final encyclopaedia is made up of the information collated in the development of DORIS. However, some elements of disease information have been incorporated including disease life cycles and some images of symptoms.

Regional Risk Assessments

The code that generates the Internet based regional risk models for LLS and phoma (see 'Incorporation of Phoma Risk Models into a Web-Enabled Phoma Forecast' and 'Light leaf spot forecast development and validation') have been amended so that they are compatible with the technology used within the encyclopaedia. These have been incorporated into the encyclopaedia in a way that will be familiar to those who use the Internet based systems and the results can also be accessed via the menu system on the interface. This allows the user to look at the predicted regional risks alongside their field specific information.

Fungicide effects

Information and examples from the research work on the effect of the timing and the number of fungicide treatments on disease incidence, severity and yield has been included within the encyclopaedia. Figure 4 shows an example of how this data is summarised. This is an interactive graph developed using HTML, JavaScript and Cascading Style Sheets. Lines can be added or removed from the graph using the tick boxes under the title 'Graph Display' at the left hand side of the screen. Yield response of all the possible fungicide combinations is also available alongside comprehensive technical notes. These techniques are used to display data from multiple sites for the two diseases.

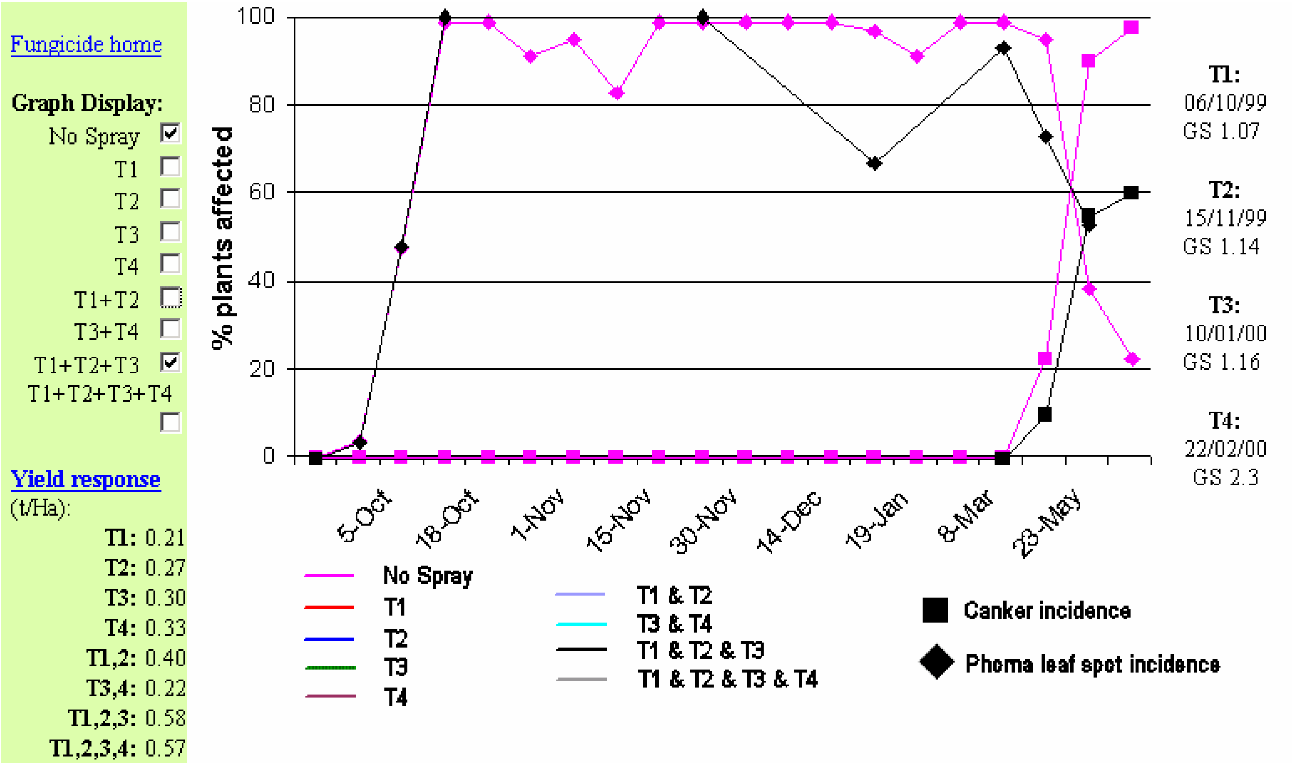



Figure 56. Screenshot from the PASSWORD encyclopaedia showing a summary of fungicide effects on an early phoma epidemic.

Help Files

As with any complex computer program there will be a period of time as the user gets used to the system where help files will be invaluable. To meet this requirement, the PASSWORD module has its own set of help files that complement those of the ArableDS shell. These help files can be accessed directly from the interface and include information on all the main interface elements and how to make best use of the system.

### 10.3 Conclusions

The PASSWORD prototype system provides integrated information on the risk to user's winter oilseed rape crops from the major pests and the two main diseases. The extensive encyclopaedic information is a valuable resource alongside the risk assessments and allows the users to put their results into context. Prior to any commercial release, this prototype system needs to have the disease models validated and undergo a final round of Beta testing. The expectation is that this will have been fully completed and the system released to the ArableDS consortium in advance of the 2006 growing season.

# Chapter 11

## Final discussion

The use of DORIS provided a cost-effective means of extending the DSS to diseases and disease control by combining pest and disease problems within a single system. New models have been produced and incorporated into the DSS and these operate on a User Interface designed to be compatible with the ArableDS system. Users have been consulted during the development of the system and key features include a minimal requirement for data input and an economic appraisal of decision outputs. The system is updated during the season and can run 'what if' scenarios against forecast, historic or long term mean weather data. For those users who do not have specific data for their area or farm, default values are available on a regional basis for yield loss from light leaf spot and stem canker in relation to cultivar resistance. Estimates of potential yield loss are required to guide the number of fungicide applications.

A new disease forecast and a crop risk assessment scheme has been developed for stem canker. Prediction of the date when 10% plants have phoma leaf spotting, the relationship between leaf and stem canker development and the relationship between yield loss and disease severity require further testing and this is now underway (harvest years 2004 and 2005). Infection events for phoma leaf spot and light leaf spot are identified, based on weather data, and this predicts dates when new symptom expression is expected. Uncertainties about the movement of initial inoculum into crops in early autumn preclude the use of mechanistic models for stem canker and light leaf spot. However, use of molecular diagnostic tests may enable mechanistic models to be validated and used in future for the major diseases of winter oilseed rape.

This project has brought together disparate field and laboratory projects on the major diseases of oilseed rape, providing a synthesis of existing data and predictive models. The DSS will enable existing research to be more fully exploited, improving understanding disease control requirements by Industry. The DSS integrates decisions on pest control with those diseases for the first time. Some economies can be made where application costs can be shared and the DSS will give the overall optimal spray date. There is an encyclopaedic section supporting stem canker and light leaf spot and potential users requested more comprehensive information than is currently available in the DSS. Users welcomed illustrations of pest and disease symptoms and damage thresholds. However, many spent little quality time examining crops and they will need to be convinced of its value for decision making in relation to more general warnings of pest and disease activity.

Improved management and higher yields of oilseed rape are considered essential for the survival of the winter oilseed rape crop under Agenda 2000. Improved decision making could contribute up to 0.5 t/ha of yield from improved disease control. This project addressed fundamental scientific issues relating to prediction and management of epidemics, whilst raising outputs and improving crop production margins.

The sustainability of oilseed rape will be enhanced by the project through improved targeting of appropriate agrochemical doses. Few data are available to differentiate between commercial products and this is an area for investigation in future. Suggestions of triazole resistance in light leaf spot in Scotland are of particular concern because there are no satisfactory alternative products. Field experiments in this project demonstrated that control is difficult in wet years when late autumn or winter sprays cannot be applied. Use of cultivars with a high level of resistance to light leaf spot has become increasingly important for disease management.

Improved disease control and more effective use of fungicides using guidance from the DSS has potential to increase average yields by up to 0.5 t/ha (equivalent to £75/ha or £30 million/annum). Environmental benefits will be achieved through reduction in unnecessary spraying (160, 000 ha, receiving 1.5 sprays/crop), particularly for insect pests, which under current conditions rarely cause economic damage. Insecticides are a low cost input and benefits are cost savings on products of £0.6 million/annum. Closer attention to detail during crop monitoring (outside the scope of this project) is also expected to improve overall management of the crop, notably the crop canopy in the spring, with further yield improvements of up to 0.5 t/ha. Direct benefits in reduced pesticide costs and improved yield from the DSS are estimated to be £30-40 million/annum.

The use of oilseed rape as a model system for integration of decisions on pests and diseases should contribute to whole crop DSS for oilseed rape and be of generic value to other crops.

This project has addressed Defra priorities of pesticide minimisation. More efficient crop production will also improve utilisation of other agrochemicals, including nitrogen. Changes in farm practice and improvements in control of pest and diseases could be monitored through the ADAS/CSL surveys of oilseed rape diseases and through surveys of pesticide use.

There will benefits to the Industry through strengthening the technical breadth ofArableDS by including a major (500,000 ha) non-cereal crop. Advantage can betaken of lessons learnt in the pioneering developments in ArableDS to assist in the dissemination this DSS. Whilst DORIS will be made available to ArableDS for autumn2004, PASSWORD will undergo a two year phase of testing the new disease modelsand be available from autumn 2006.

**Acknowledgements**

The project team are grateful for the contributions made by colleagues in ADAS, CSL, Rothamsted and SAC in carrying out field experiments and analysing data.  We also thank those farmers who have participated in the winter oilseed rape disease survey since 1976 as this led directly the development of disease forecasts.

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**Appendix – Further details of field experiments (Appendix 1. ADAS Boxworth; Appendix 2. SAC Aberdeen; Appendix 3. Rothamsted).**

Appendix 1 Boxworth site details

Table 1. Site Details, ADAS Boxworth, 2000 – 2003.

| | 2000/2001 | 2001/2002 | 2002/2003 |
|---|---|---|---|
| Site: | ADAS Boxworth, Cambs. | ADAS Boxworth, Cambs. | ADAS Boxworth, Cambs. |
| Grid Reference: | TL348624 | TL348629 | TL339620 |
| Soil type: | Clay | Clay | Clay |
| Soil Series: | Hanslope | Hanslope | Hanslope |
| Drainage: | Moderate | Moderate | Moderate |
| Soil analysis: | P 17 mg/l (Index 2); pH 8.2<br>K 272 mg/l (Index 3)<br>Mg 105 mg/l (Index 3) | P 16 mg/l (Index 2); pH 7.8<br>K 295 mg/l (Index 3)<br>Mg 89 mg/l (Index 3) | P 12 mg/l (Index 1); pH 7.9<br>K 195 mg/l (Index 2+)<br>Mg 66 mg/l (Index 2) |
| Cultivations: | Disced, flat lifted, disced, rolled, power harrowed, rolled. | Level lifted, power harrowed, rolled, power harrowed, rolled, drilled, rolled. | Cultivated, power harrowed, drilled, rolled. |
| Sowing date: | 01 Sept 00 | 30 Aug 01 | 06 Sept 02 |
| Seed rates: | 60 seeds/$m^2$ Pronto, 120 seeds/$m^2$ Apex and Escort | 60 seeds/$m^2$ Pronto, 120 seeds/$m^2$ Apex and Escort | 60 seeds/$m^2$ Pronto, 100 seeds/$m^2$ Apex and Escort |
| Previous crop: | 2000 Wwheat<br>1999 Wwheat<br>1998 Wbeans | 2001 Wwheat<br>2000 Wwheat<br>1999 Wbeans | 2001 Wwheat<br>2000 Wwheat<br>1999 Wbeans |
| Autumn fertiliser: | 40 kg/ha N (as Nitram) 12/9/00 | 26 kg/ha N (as Urea) 23/9/01 | 26 kg/ha N (as Urea) 23/9/01 |
| Spring N: | 95 kg/ha N (as Nitram) 22/2/01<br>95 kg/ha N (as Urea) 12/4/01 | 105 kg/ha N (as Nuram 35) 02/3/02<br>105 kg/ha N (as Nuram) 25/03/02 | 100 kg/ha Ammonium sulphate 19/2/03<br>110 kg/ha N (as NH4NO334.5%) 19/2/03 ; 18/3/03 |
| Trace elements: | Mg Sulphate 19/05/01 | Phosphate (Omex) 600 l/ha 19/5/02 | |
| Herbicides: | Laser 1 l/ha 8/10/00<br>Kerb 1.5 kg/ha 27/11/00; Galtak 1.5 l/ha 21/2/01; Shield 0.4 l/ha 21/2/00 | Laser 0.75 l/ha 24/9/01<br>Katamaran 2.0 l/ha 26/9/01; Kerb 1.7 kg/ha 29/10/01; Shield 0.5 l/ha 16/11/01 | Katamaran 2.0 l/ha 12/9/02 pre-em<br>Fusilade 250EW 07/10/02 + Wetter 0.09 l/ha<br>Aramo 1.0 l/ha 05/11/02 |
| Insecticides: | Toppel 0.25 l/ha 8/10/00 | Cypermethrin 0.25 l/ha 29/10/01 | Cypermethrin 0.25 l/ha 05/11/02<br>Marvik 0.15 l/ha 10/4/03 |
| Slug pellets: | Draza 5.5 kg/ha 10/10/00 and 26/10/00 | Draza 5.5 kg/ha 04/9/01 | Draza 5.5 kg/ha 16/9/02 |
| Desiccant | Glyphosate 3 l/ha 16/07/01 | Glyphosate 4 l/ha 11/07/02 | Reglone 3 l/ha + wetter 0.3 l/ha 09/07/03 |
| Harvest date: | 26/07/01 | 20/07/02 | 16/07/03 |

**Table 1(contd). Additional Site Details, ADAS Boxworth, 2000 – 2001**

Additional analyses in good and poor areas of crop to confirm sulphur deficiency.
Sulphur in plant material analysis 8/5/01.

| Determination | Poor sample | Good sample |
|---|---|---|
| Sulphur | 0.22% | 0.38% |
| Nitrogen | 6.74% | 5.33% |
| Nitrogen:Sulphur ratio | 30.6 | 14.0 |
| Manganese | 77.3 mg/kg | 73.3 mg/kg |

There was a Sulphur deficiency in both the poor and good samples.
There was no Manganese deficiency detected.
Criteria for Sulphur deficiency are 0.4% sulphur in leaves or nitrogen:sulphur ratios greater than 17.

Table 2. Spray application details, Boxworth 2000-2003.

Spray application equipment:

Sprayer: OPS
Nozzles: LD02F110 (Lurmark).
Water volume: 200 litres –225 litres (2001/02 only)
Pressure: 2.0 bar – 2.2 bar (2001/02 only)

Table 2a. Boxworth 2000/2001

| Target date | Products Applied | Actual Date | Growth Stage | Daily Weather (recorded from met station) |
|---|---|---|---|---|
| Late October | Punch C | 10/11/00 | 1,07 – 1,08 | Overcast, cool after previous wet conditions; crop wet.<br>Max temp 11.4°C<br>Min temp 2.5°C<br>Wind: 6-9.0 km/hr, moderate drift. |

| | | | | |
|---|---|---|---|---|
| Six weeks later | Plover +Bavistin | 18/12/00 | 1,10 – 1,12 | Sunny but cool, after previous frost and crop damp. Soil wet.<br>Max temp 6.5°C<br>Min temp –2.5°C<br>Wind: 3.0 km/hr, slight drift |
| Early March | Punch C | 7/3/01 | 2,1, 3,1 | Sunny,warm and crop dry, after previous dry conditions.<br>Max temp 10.2°C<br>Min temp 5.4°C<br>Wind: 3.0 km/hr, no drift. |
| April – pgr timing | Folicur 0.75 l/ha | 9/03/01 | 2,6-3,3<br>30cm tall | Overcast and cool, crop damp after previous showery and warm conditions.<br>Max temp 10.7°C<br>Min temp 7.2°C<br>Wind: none, no drift. |

Table 2b. Boxworth 2001/2002

| Target date | Products Applied | Actual Date | Growth Stage | Daily Weather (recorded from met station) |
|---|---|---|---|---|
| Late October | Punch C | 17/10/01 | 1,5 – 1,7 | Overcast, cool; crop dry<br>Max temp 17.9°C<br>Min temp 9.4°C<br>Wind: <1.2, no drift. |
| Six weeks later | Plover +Bavistin | 26/11/01 | 1.10-1,12 | Sunny but cool after previous frost and crop damp. Soil wet.<br>Max temp 9.4°C<br>Min temp 0.75°C<br>Wind: 1.2-2 km/hr, slight drift. |
| Early March | Punch C | 15/02/02 | 1,16 – 2,3 | Sunny,cool and crop damp, after previous shower conditions.<br>Max temp 7.7°C<br>Min temp –3.2°C<br>Wind: <1.2 km/hr, no drift. |
| April – pgr timing | Folicur 0.75 l/ha | 20/03/02 | 3,1 | Overcast and cool, crop damp after previous showery periods.<br>Max temp 15.2°C<br>Min temp 7.6°C<br>Wind: <1.2 km/hr, no drift. |

Table 2c. Boxworth 2002/2003

| Target date | Products Applied | Actual Date | Growth Stage | Daily Weather (recorded from met station) |
|---|---|---|---|---|
| Late October | Punch C | 18/11/02 | 1,6 | Overcast, cool; crop and soil damp<br>Max temp °C<br>Min temp°C<br>Wind: <1.2 kph, no drift |

| | | | | |
|---|---|---|---|---|
| Six weeks later | Plover +Bavistin | 05/12/02 | 1,8 | Overcast, cool and dry after dry showery weather.<br>Temperature 2.3°C<br>Humidity 37%<br>Wind: 1-2 km/hr, calm and no drift |
| Early March | Punch C | 10/02/03 | 3,1 | Overcast, cool and dry after dry cool weather.<br>Temperature 6.7°C<br>Humidity 88%<br>Wind: 3-6 km/hr, light breeze and slight drift |
| April – pgr timing | Folicur 0.75 l/ha | 08/04/03 | 3,5-3,6 | Warm, sunny and dry after previous dry and warm conditions<br>Max temp °C<br>Min temp °C<br>Wind: 1-2 km/hr, no drift |

Disease assessment records at Boxworth 2000-2003.

Table 3a. Boxworth 2000/2001

| Date of sample | Date assessed | Growth stage | Assessment | Assessment of | | |
|---|---|---|---|---|---|---|
| | | | | Leaves | Stems | Pods |
| 09.10.00 | 09.10.00 | 1,2 | 4 x10 plants/untreated controls/cultivar | + | | |
| 17.10.00 | 17.10.00 | 1,4 | " | + | | |
| 24.10.00 | 24.10.00 | 1,5-1,6 | " | + | | |
| 30.10.00 | 30.10.00 | 1,6 | " | + | | |
| 06.11.00 | 06.11.00 | 1,7 | " | + | | |
| 13.11.00 | 14.11.00 | 1,8 | " | + | | |
| 04.12.00 | 04.12.00 | 1,9 | " | + | | |
| 19.12.00 | 19.12.00 | 1,10-1,12 | All plots (10 plants/plot) | + | | |
| 07.02.01 | 09.02.01 | 3,1 | All plots (10 plants/plot) | + | | |
| 14.03.01 | 16.03.01 | 2,1-2,2, 3,1 | All plots (10 plants/plot) | + | | |
| 26.03.01 | 28.03.01 | 2,3, 3,1 | All plots (10 plants/plot) | + | + | |
| 09.05.01 | 9-10.05.01 | 4,5 | All plots (10 plants/plot) | + | + | |
| 29.05.01 | 29.05.01 | 5,9, 6,2 | All plots (10 plants/plot) | + | + | + |
| 27.06.01 | 27.06.01 | 6,3 | All plots -25 plants | + | + | + |

Plant numbers/$m^2$ were assessed after harvest in all plots in 0.25$m^2$ quadrats (5 quadrats/plot).

Table 3b. Boxworth 2001/2002.

| Date of sample | Date assessed | Growth stage | Assessment | Assessment of | | |
|---|---|---|---|---|---|---|
| | | | | Leaves | Stems | Pods |
| 12/10/01 done in situ | 12/10/01 | 1,3 – 1,6 | Control plots (10 plants/plot) | + | | |
| 19/10/01 | 19/10/01 | 1,5 – 1,7 | 24 plots (10 plants/plot) | + | | |
| 25/10/01 | 26/10/01 | 1,6 – 1,8 | Control plots (10 plants/plot) | + | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 19/11/01 | 19/11/01 | 1,12 – 1,16 | Control plots (10 plants/plot) | + | | |
| 28/11/01 | 29/11/01 | 1,10 – 1,12 | All plots (10 plants/plot) | + | | |
| 19/12/01 | 20/12/01 | 1,12 – 1,14 | Control plots (10 plants/plot) | + | | |
| 18/02/02 | 19-20/02/02 | 1,16 - 1,20<br>2,3 3,1 | All plots (10 plants/plot) | + | | |
| 25/03/02 | 26/03/02 | 3,3 | All plots (10 plants/plot) | + | + | |
| 22/04/02 | | 4,5 | All plots (10 plants/plot) | + | + | + |
| 29/05/02 | 29/05/02 | 5,9 | All plots (10 plants/plot) | + | + | + |
| 27/06/02 | 27/06/02 | 6,4 | All plots (25 plants/plot) | + | + | + |

Table 3c. Boxworth 2002/2003.

| Date of sample | Date assessed | Growth stage | Assessment | Assessment of | | |
|---|---|---|---|---|---|---|
| | | | | Leaves | Stems | Pods |
| 25/10/02 | 25/10/02 | 1,5 | Control plots (10 plants/plot) | + | | |
| 20/11/02 | 20/11/02 | 1,6 | Control plots (10 plants/plot) | + | | |
| 11/12/02 | 12-13/12/02 | 1,8 | All plots (10 plants/plot) | + | | |
| 08/01/03 | 08/01/03 | 1,14 | Plant counts only (all plots) | | | |
| 13/01/03 | 14-15/01/03 | 1,14 | All plots (10 plants/plot) | + | | |
| 10-12/02/03 | 12/02/03 | 3,1 | All plots (10 plants/plot) | + | | |
| 11/03/03 | 12/03/03 | 2,1 3,1 | All plots (10 plants/plot) | + | | |
| 07/04/03 | 09/04/03 | 3,5-3,6 | All plots (10 plants/plot) | + | | |
| 01/05/03 | 02/05/03 | 4,9 5,3 | All plots (10 plants/plot) | + | + | |
| 29/05/03 | 29/05/03 | 6,1 | All plots (10 plants/plot) | + | + | + |
| 24/06/03 | 24/06/03 | 6,3-6,4 | All plots (25 plants/plot) | + | + | + |
| 16/07/03 | 16/07/03 | 6,9 | Plant counts only (all plots) | | | |

Plant numbers/$m^2$ were assessed after harvest in all plots in $0.25m^2$ quadrats (5 quadrats/plot).

Table 4a. Disease development on winter oilseed rape plants and leaves in untreated control plots cv. Pronto (mean of 25 or 40 plants*) Boxworth 2000/2001.

| Date | G. stage | Leaves | | | | | Stems | | | | | Pods | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Assessed | | Downy mildew | Phoma | Light leaf spot | Bot rytis | Alter-naria | Phoma* | Light leaf spot | Botrytis * | Sclerotinia | Canker* | D. mildew | Alter-naria | Light leaf spot |
| 09.10.00 | 1,2 | 0 | 0 | 0 | | 0 | | | | | | | | |
| 17.10.00 | 1,4 | 75 (0.23) | 2.5 (0.01) | | | 0 | | | | | | | | |
| 24.10.00 | 1,5-1,6 | 65 (0.22) | 15 (0.04) | | | 0 | | | | | | | | |
| 30.10.00 | 1,6 | 78 (0.24) | 20 (0.05) | | | 0 | | | | | | | | |
| 06.11.00 | 1,7 | 80 (0.36) | 40 (0.11) | | | 0 | | | | | | | | |
| 14.11.00 | 1,8 | 63 (0.35) | 100 (0.63) | | | 3 tr | | | | | | | | |
| 04.12.00 | 1,9 | 65 (0.21) | 95 (0.98) | 0 | 0 | 0 | | | | | | | | |
| 19.12.00 | 1,10-1,12 | 63 (0.09) | 100 (0.74) | 0 | 0 | 0 | | | | | | | | |
| 09.02.01 | 3,1 | 0 | 80.0 (1.93) | 0 | 0 | 0 | | | | | | | | |
| 16.03.01 | 2,2, 3,1 | 0 | 97.5 (0.65) | 0 | 0 | 0 | | | | | | | | |
| 28.03.01 | 2,3, 3,1 | 0 | 100 (0.80) | 2.5 (0.03) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | |
| 9-10.05.01 | 4,5 | 41 (0.12) | 97.5 (0.76) | 58 (0.62) | 0 | 0 | 8 (1.9) | 2.5 (0.01) | 0 | 0 | 61 (17.1) | | | |
| 29.05.01 | 5,9, 6,2 | 0 | 20 (0.16) | 2.5 (0.05) | 2.5 (0.01) | 0 | 20 (5.6) | 7.5 (0.10) | 0 | 0 | 95 (38.8) | | | |
| 27.06.01 | 6,3 | | | 0 | 0 | 0 | | | | | 98 (43.5) | | | |

Table 4b. Disease development on winter oilseed rape plants and leaves in untreated control plots cv. Apex (mean of 25 or 40 plants*) Boxworth 2000/2001.

| Date | G. stage | Leaves | | | | | Stems | | | | | Pods | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| assessed | | Downy mildew | Phoma | Light leaf spot | Botrytis | Alter-naria | Phoma* | Light leaf spot | Botrytis* | Sclerotinia | Canker* | Downy mildew | Alter-naria | Light leaf spot |
| 09.10.00 | 1,2 | 0 | 2.5 (0.25) | 0 | | 0 | | | | | | | | |
| 17.10.00 | 1,4 | 88 (0.29) | 15 (0.24) | | | 0 | | | | | | | | |
| 24.10.00 | 1,5 -1,6 | 80 (0.24) | 20 (0.09) | | | 0 | | | | | | | | |
| 30.10.00 | 1,6 | 68 (0.21) | 35 (0.10) | | | 0 | | | | | | | | |
| 06.11.00 | 1,7 | 88 (0.31) | 45 (0.19) | | | 0 | | | | | | | | |
| 14.11.00 | 1,8 | 68 (0.13) | 100 (0.93) | | | 3 tr | | | | | | | | |
| 04.12.00 | 1,9 | 68 (0.31) | 93 (1.00) | 0 | 0 | 0 | | | | | | | | |
| 19.12.00 | 1,10-1,12 | 58 (0.10) | 100 (1.25) | 0 | 0 | 0 | | | | | | | | |
| 09.02.01 | 3,1 | 0 | 80.0 (2.04) | 0 | 0 | 0 | | | | | | | | |
| 16.03.01 | 2,2, 3,1 | 3 (0.08) | 100 (0.92) | 0 | 0 | 0 | | | | | | | | |
| 28.03.01 | 2,3, 3,1 | 0 | 100 (1.15) | 2.5 (0.05) | 0 | 0 | 0 | | | | 0 | | | |
| 9-10.05.01 | 4,5 | 30 (0.06) | 100 (0.98) | 57.5 (1.87) | 0 | 0 | 0 | 2.5 (0.30) | 0 | 0 | 12.5 (3.1) | | | |
| 29.05.01 | 5,9, 6,2 | 0 | 18 (0.16) | 27.5 (0.73) | 0 | 0 | 5 (1.25) | 50 (3.7) | 0 | 0 | 85 (34.4) | | | |
| 27.06.01 | 6,3 | | | 0 | 0 | 0 | | | | | 97 (34.8) | | | |

Table 4c. Disease development on winter oilseed rape plants and leaves in untreated control plots cv. Escort (mean of 25 or 40 plants*) Boxworth 2000/2001.

| Date | G. stage | Leaves | | | | | Stems | | | | | Pods | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| assessed | | D. mildew | Phoma | Light leaf spot | Bot rytis | Alter-naria | Phoma* | Light leaf spot | Botr ytis* | Sclerotin ia | Canker* | D. mildew | Alter-naria | Light leaf spot |
| 09.10.00 | 1,2 | 0 | 0 | 0 | | 0 | | | | | | | | |
| 17.10.00 | 1,4 | 43 (0.06) | 5 (0.01) | | | 0 | | | | | | | | |
| 24.10.00 | 1,5-1,6 | 43 (0.05) | 13 (0.04) | | | 0 | | | | | | | | |
| 30.10.00 | 1,6 | 65 (0.13) | 15 (0.04) | | | 0 | | | | | | | | |
| 06.11.00 | 1,7 | 88 (0.29) | 53 (0.14) | | | 0 | | | | | | | | |
| 14.11.00 | 1,8 | 55 (0.08) | 93 (0.36) | | | 0 | | | | | | | | |
| 04.12.00 | 1,9 | 50 (0.18) | 80 (0.45) | 0 | 0 | 0 | | | | | | | | |
| 19.12.00 | 1,10-1,12 | 63 (0.08) | 88 (0.34) | 0 | 0 | 0 | | | | | | | | |
| 09.02.01 | 3,1 | 0 | 65 (1.28) | 0 | 0 | 0 | | | | | | | | |
| 16.03.01 | 2,2, 3,1 | 0 | 70 (0.35) | 0 | 0 | 0 | | | | | | | | |
| 28.03.01 | 2,3, 3,1 | 0 | 93 (0.38) | 10.0 (0.10) | 0 | 0 | 0 | 0 | | | 0 | | | |
| 9-10.05.01 | 4,5 | 50 (0.30) | 95 (0.51) | 47.5 (1.55) | 0 | 0 | 0 | 2.5 (0.01) | | | 45 (12.5) | | | |
| 29.05.01 | 5,9, 6,2 | 0 | 13 (0.08) | 2.5 (0.01) | 2.5 (0.01) | 0 | 7.5 (2.5) | 0 | | 0 | 83 (32.5) | | | |
| 27.06.01 | 6,3 | | | 0 | 0 | 0 | | | | | 85 (30.0) | | | |

Table 5a. Disease development on winter oilseed rape plants and leaves in untreated control plots cv. Pronto (mean of 25 or 40 plants*) Boxworth 2001/2002.

| Date | G. stage | Leaves | | | | | | Stems | | | | Pods | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| assessed | | Downy mildew | Phoma | Light leaf spot | Bot rytis | Alter-naria | P. mildew | Phoma * | Light leaf spot | Scleroti nia | Canker * | Downy mildew | Botr ytis | Alter-naria | Light leaf spot | P. mildew |
| 12/10/01 | 1,3 – 1,6 | 67.5 (0.370) | 5.0 (0.01) | | | | | | | | | | | | | |
| 19/10/01 | 1,5 – 1,7 | 70.0 (0.20) | 95.0 (0.84) | | | | | | | | | | | | | |
| 26/10/01 | 1,6 – 1,8 | 60.0 (0.168) | 97.5 (0.91) | | | | | | | | | | | | | |
| 19/11/01 | 1,12/ 1,16 | 0.0 (0.0) | 100.0 (2.62) | | | | | | | | | | | | | |
| 29/11/01 | 1,10/ 1,12 | 12.5 (0.15) | 100.0 (3.69) | | | | | | | | | | | | | |
| 20/12/01 | 1,12/1, 14 | 5 (0.02) | 77.5 (0.69) | | | | | | | | | | | | | |
| 20/02/02 | 2,3 3,1 | 0 | 92.5 (0.65) | 5 (0.06) | | | | | | | | | | | | |
| 26/03/02 | 3,3 | 75 (0.49) | 52.5 (0.20) | 32.5 (0.25) | 0 | 0 | 0 | | | | 12.5(0. 15) | | | | | |
| 22/04/02 | 4,5 | 2.5 (0.01) | 57.5 (0.83) | 45 (1.48) | 0 | 0 | 0 | 5 (0.05) | 7.5 (0.25) | | 45(0.5 5) | | | | | |
| 29/05/02 | 5,9 | 0 | 10.0 (0.21) | 65 (3.19) | 12.5 (0.27) | 5 (0.01) | 0 | 10 (0.1) | 35 (0.75) | | 100 (2.08) | | | | 32.5 (0.17) | |
| 27/06/02 | 6,4 | | | | | | 7.75 (stem) | 12 (0.14) | 41 (4.2) | | 93 (2.8) | | | 0.075 | 1.75 | 2.63 |

Table 5b. Disease development on winter oilseed rape plants and leaves in untreated control plots cv. Apex (mean of 25 or 40 plants*) Boxworth 2001/2002.

| Date | Growth stage | Leaves | | | | | | Stems | | | | Pods | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| assessed | | Downy mildew | Phoma | Light leaf spot | Botrytis | Alter-naria | Powdery mildew | Phoma * | Light leaf spot | Sclerotinia | Canker * | Downy mildew | Botrytis | Alter-naria | Light leaf spot | P. mildew |
| 12/10/01 | 1,3 – 1,6 | 60.0 (0.309) | 0.0 (0.00) | | | | | | | | | | | | | |
| 19/10/01 | 1,5 – 1,7 | 85.0 (0.355) | 100.0 (1.38) | | | | | | | | | | | | | |
| 26/10/01 | 1,6 – 1,8 | 65.0 (0.193) | 90.0 (0.760) | | | | | | | | | | | | | |
| 19/11/01 | 1,12 – 1,16 | 0.0 (0.0) | 100.0 (1.88) | | | | | | | | | | | | | |
| 29/11/01 | 1,10 – 1,12 | 27.5 (0.192) | 100.0 (4.53) | | | | | | | | | | | | | |
| 20/12/01 | 1,12 – 1,14 | 0 | 77.5 (0.68) | | | | | | | | | | | | | |
| 20/02/02 | 1,18, 2,3,3,1 | 0 | 85.0 (0.60) | 2.5 (0.04) | | | | | | | | | | | | |
| 26/03/02 | 3,3 | 37.5 (0.24) | 32.5 (0.12) | 30.0 (0.59) | 0 | 0 | O | | | | 15 (0.18) | | | | | |
| 22/04/02 | 4,5 | 0 | 40 (0.34) | 75 (5.00) | | | | 0 | 22.5 (0.65) | | 42.5 (0.48) | | | | | |
| 29/05/02 | 5,9 | 7.5 (0.24) | 2.5 (0.53) | 77.5 (9.48) | 0 | 0 | 0 | 12.5 (0.18) | 67.5 (3.75) | | 75 (1.65) | | | | 37.5 (0.91) | |
| 27/06/02 | 6,4 | | | | | | 7 (stem) | 13 (0.15) | 66 (1.4) | | 93 (2.12) | | | 0.1 | 10.0 | 2.25 |

Table 5c. Disease development on winter oilseed rape plants and leaves in untreated control plots cv. Escort (mean of 25 or 40 plants*) Boxworth 2001/2002.

| Date | Growth stage | Leaves | | | | | | Stems | | | | Pods | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| assessed | | Downy mildew | Phoma | Light leaf spot | Botrytis | Alter-naria | Powdery mildew | Phoma * | Light leaf spot | Sclerotinia | Canker * | Downy mildew | Botrytis | Alter-naria | Light leaf spot | Powdery mildew |
| 12/10/01 | 1,3 – 1,6 | 52.5 (0.15) | 17.5 (0.11) | | | | | | | | | | | | | |
| 19/10/01 | 1,5 – 1,7 | 70.0 (0.26) | 95.0 (0.81) | | | | | | | | | | | | | |
| 26/10/01 | 1,6 – 1,8 | 60.0 (0.15) | 87.5 (0.57) | | | | | | | | | | | | | |
| 19/11/01 | 1,12 – 1,16 | 0.0 (0.0) | 100.0 (0.77) | | | | | | | | | | | | | |
| 29/11/01 | 1,10 – 1,12 | 10.0 (0.07) | 92.5 (1.46) | | | | | | | | | | | | | |
| 20/12/01 | 1,12 – 1,14 | 5 (0.01) | 52.5 (0.30) | | | | | | | | | | | | | |
| 20/02/02 | 1,18 2,3 3,1 | 0 | 72.5 (0.30) | 2.5 (0.05) | | | | | | | | | | | | |
| 26/03/02 | 3,3 | 45.0 (0.20) | 32.5 (0.09) | 15.0 (0.13) | 0 | 0 | 0 | | | | 7.5 (0.08) | | | | | |
| 22/04/02 | 4,5 | 0 | 30 (0.16) | 40.0 (0.44) | | 5.0 tr | | 0 | 7.5 (0.08) | | 30 (0.35) | | | | | |
| 29/05/02 | 5,9 | 0 | 12.5 (0.19) | 47.5 (3.76) | | 7.5 (0.04) | | 12.5 (0.25) | 32.5 (0.65) | | 75 (1.45) | | | | 35 (0.63) | |
| 27/06/02 | 6,4 | | | | | | 7.75 (stem) | 8 (0.08) | 3 (0.04) | | 88 (2.14) | | | 0.125 | 0.275 | 3.25 |

Table 6a. Disease development on winter oilseed rape plants and leaves in untreated control plots cv. Pronto (mean of 25 or 40 plants*) Boxworth 2002/2003.

| Date | G. stage | Leaves | | | | | | Stems | | | | Pods | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| assessed | | Downy mildew | Phoma | Light leaf spot | Botrytis | Alter-naria | P. mildew | Phoma * | Light leaf spot | Sclerotinia | Canker* | Downy mildew | Botrytis | Alter-naria | Light leaf spot | P. mildew |
| 25/10/02 | 1,5 | 42.50 (0.24) | 2.5 (0.06) | | | | | | | | | | | | | |
| 20/11/02 | 1,6 | 0.0 (0.0) | 62.5 (0.37) | | | | | | | | | | | | | |
| 12/12/02 | 1,8 | 0.0 (0.0) | 97.5 (1.83) | | | | | | | | | | | | | |
| 14/01/03 | 1,14 | 2.5 (0.03) | 100.0 (3.58) | | | | | | | | | | | | | |
| 12/02/03 | 3,1 | 2.5 (0.02) | 97.5 (1.82) | 0 | | | | | | | | | | | | |
| 12/03/03 | 2,1 3,1 | 12.5 (0.23) | 100.0 (3.84) | 2.5 (0.03) | 0 | 0 | 0 | | | | | | | | | |
| 09/04/03 | 3,5-3,6 | 0 | 97.5 (1.19) | 15.0 (0.36) | 0 | 0 | 0 | 2.5 (0.03) | | | 0 | | | | | |
| 02/05/03 | 4,9 5,3 | 0 | 32.5 (0.41) | 0 | 0 | 0 | 0 | 27.5 (0.35) | | | 15.0 (0.15) | | | | | |
| 29/05/03 | 6,1 | 2.5 (0.04) | 85.0 (2.31) | 0 | 0 | 0 | 0 | 47.5 (0.80) | 0 | | 57.5 (0.95) | | | | | |
| 24/06/03 | 6,3-6,4 | | | | | | | 94.0 (1.62) | | | 98.0 (2.05) | | | | | |

Table 6b. Disease development on winter oilseed rape plants and leaves in untreated control plots cv. Apex (mean of 25 or 40 plants*) Boxworth 2002/2003.

| Date | G. stage | Leaves | | | | | | Stems | | | | Pods | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| assessed | | Downy mildew | Phoma | Light leaf spot | Botrytis | Alter-naria | Powdery mildew | Phoma * | Light leaf spot | Sclerotinia | Canker * | Downy mildew | Botrytis | Alter-naria | Light leaf spot | P. mildew |
| 25/10/02 | 1,5 | 45.0 (0.25) | 0.0 (0.00) | | | | | | | | | | | | | |
| 20/11/02 | 1,6 | 0.0 (0.0) | 80.0 (0.42) | | | | | | | | | | | | | |
| 12/12/02 | 1,8 | 5.0 (0.03) | 100.0 (1.69) | | | | | | | | | | | | | |
| 14/01/03 | 1,14 | 2.5 (0.03) | 100.0 (3.08) | | | | | | | | | | | | | |
| 12/02/03 | 3,1 | 2.5 (0.04) | 100.0 (2.41) | 0 | | | | | | | | | | | | |
| 12/03/03 | 2,1 3,1 | 7.5 (0.08) | 100.0 (3.13) | 0 | 0 | 0 | 0 | | | | | | | | | |
| 09/04/03 | 3,5-3,6 | 0 | 92.5 (1.38) | 5.0 (0.02) | 0 | 0 | 0 | 2.5 (0.50) | | | 0 | | | | | |
| 02/05/03 | 4,9 5,3 | 0 | 77.5 (0.81) | 10.0 (0.46) | 0 | 0 | 0 | 7.5 (0.10) | | | 7.5 (0.08) | | | | | |
| 29/05/03 | 6,1 | 0 | 90.0 (2.62) | 0 | 0 | 0 | 0 | 20.0 (0.28) | 0 | | 47.5 (0.67) | | | | | |
| 24/06/03 | 6,3-6,4 | | | | | | | 85.0 (1.20) | | | 99.0 (1.97) | | | | | |

Table 6c. Disease development on winter oilseed rape plants and leaves in untreated control plots cv. Escort (mean of 25 or 40 plants*) Boxworth 2002/2003.

| Date | G. stage | Leaves | | | | | | Stems | | | | Pods | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| assessed | | Downy mildew | Phoma | Light leaf spot | Botrytis | Alter-naria | Powdery mildew | Phoma* | Light leaf spot | Sclerotinia | Canker * | Downy mildew | Botrytis | Alter-naria | Light leaf spot | P. mildew |
| 25/10/02 | 1,5 | 35.0 (0.14) | 0.0 (0.0) | | | | | | | | | | | | | |
| 20/11/02 | 1,6 | 0.0 (0.0) | 80.0 (0.48) | | | | | | | | | | | | | |
| 12/12/02 | 1,8 | 0.0 (0.0) | 100.0 (1.61) | | | | | | | | | | | | | |
| 14/01/03 | 1,14 | 2.5 (0.05) | 100.0 (2.68) | | | | | | | | | | | | | |
| 12/02/03 | 3,1 | 2.5 (0.02) | 97.5 (1.46) | 0 | | | | | | | | | | | | |
| 12/03/03 | 2,1 3,1 | 15.0 (0.26) | 100.0 (2.90) | 0 | 0 | 0 | 0 | | | | | | | | | |
| 09/04/03 | 3,5-3,6 | 0 | 75.0 (0.65) | 2.5 (0.02) | 0 | 0 | 0 | 0 | | | 0 | | | | | |
| 02/05/03 | 4,9 5,3 | 0 | 40.0 (0.46) | 0 | 0 | 0 | 0 | 15.0 (0.17) | | | 7.5 (0.08) | | | | | |
| 29/05/03 | 6,1 | 2.5 (0.03) | 77.5 (1.88) | 0 | 0 | 0 | 0 | 37.5 (0.45) | 0 | | 60.0 (0.87) | | | | | |
| 24/06/03 | 6,3-6,4 | | | | | | | 82.0 (1.25) | | | 95.0 (2.05) | | | | | |

**Appendix 2. Cultivar x fungicide experiments SAC Aberdeen.**

Table 7. Site Details, Aberdeen, 2000 – 2003.

| | 2000/2001 | 2001/2002 | 2002/2003 |
|---|---|---|---|
| Site: | Muirton of Barra, Oldmeldrum, Aberdeenshire | East Fingask, Oldmeldrum, Aberdeenshire | Field S2, Sunnybrae Farm, SAC, Craibstone Estate, Bucksburn, Aberdeen |
| Grid Reference: | NJ 783 267 | NJ 775 276 | NJ 871 115 |
| Soil Association: | Insch | Insch | Countesswells |
| Soil Series: | Insch 2 | Insch 3 | Terryvale |
| Drainage: | Freely drained | Freely drained | Poorly drained |
| Soil analysis: | | Ph 6.2, P – mod, K – mod, Mg – mod Organic matter 9.8% | |
| Cultivations: | Ploughed, Oyjord drill, Cambridge rolled | Ploughed, Oyjord drill, rolled | Ploughed, Oyjord drill, rolled |
| Sowing date: | 29 Aug 00 | 29 Aug 01 | 01 September 2002 |
| Seed rates: | Synergy 3.6 kg/ha | Synergy 3.6 kg/ha | Synergy 3.6 kg/ha |
| | Apex & Escort 6.0 kg/ha | Apex & Escort 6.0 kg/ha | Apex & Escort 6.0 kg/ha |
| Basal Fertiliser: | 300 kg/ha 5:24:24 N:P:K | 300 kg/ha 5:24:24 N:P:K + 18 kg/ha $SO_3$ | 250 kg/ha 10:25:25 N:P:K + 6 kg/ha $SO_3$ |
| Spring N: | 20 Mar 01 90 kg N/ha | 05 Mar 02 90 kg N/ha + 48 kg $SO_3$/ha | 05 Mar 02 90 kg N/ha + 48 kg $SO_3$/ha |
| Spring N: | 04 Apr 01 90 kg N/ha | 11 Apr 02 90 kg N/ha + 48 kg $SO_3$/ha | 20 Mar 02 90 kg N/ha + 48 kg $SO_3$/ha |
| Herbicide: | 01 Sep 00 2.5 l/ha Butisan S | 01 Sep 02 2.5 l/ha Butisan S | 2.5 l/ha Butisan S |
| | | 14 Nov 02 2.25 l/ha Laser +0.8% Fyzol | |
| Slug pellets: | 4.0 kg/ha Metarex Green | 4.0 kg/ha Metarex Green pre-emergence | 4.0 kg/ha Metarex green |
| Swathing date: | 16 August 2001 | 06 August 2002 | 22 July 2003 |
| Harvest date: | 23 August 2001 | 13 August 2002 | 31 July 2003 |
| Removal of straw: | Chopped and carted | Chopped and carted | Chopped and carted |
| Previous crop: | Winter barley | Winter Barley | Winter barley |

Table 8. Effect of fungicide on levels of light leaf spot, Aberdeen, 2000 – 2001.

| | | % Plants affected | | | | | | % Leaves affected | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | | 31 Oct 00 | 11 Dec 00 | 23 Jan 01 | 05 Apr 01 | 11 May 01 | 05 Jul 01 | 31 Oct 00 | 11 Dec 00 | 23 Jan 00 | 5 Apr 01 | 11 May 01 | 05 Jul 01 |
| GS | | 1.08-1.11 | 1.09-1.11 | 1.10-1.13 | 3.1 | 3.5-3.6 | 6.2 | 1.08-1.11 | 1.09-1.12 | 1.10-1.13 | 3.1 | 3.5-3.6 | 6.2 |
| Synergy | Untreated | 0 | 20.0 | 52.5 | 98.8 | 100.0 | 77.50 | 0 | 4.94 | 17.5 | 76.7 | 43.6 | 51.6 |
| | Full | - | 3.8 | 25.0 | 84.9 | 97.5 | 27.5 | - | 0.59 | 8.4 | 46.2 | 19.1 | 15.3 |
| | Autumn | - | 3.8 | 25.0 | 84.9 | 85.0 | 60.0 | - | 0.59 | 8.4 | 46.2 | 14.4 | 44.2 |
| | Managed[1] | - | 20.0 | 52.5 | 98.8 | 97.5 | 42.5 | - | 4.94 | 17.5 | 76.7 | 18.9 | 23.0 |
| Apex | Untreated | 0 | 17.5 | 38.8 | 97.4 | 97.5 | 62.5 | 0 | 4.21 | 15.8 | 81.2 | 42.4 | 36.5 |
| | Full | - | 2.5 | 20.0 | 92.5 | 80.0 | 55.0 | - | 1.07 | 6.9 | 61.2 | 21.6 | 30.2 |
| | Autumn | - | 2.5 | 20.0 | 92.5 | 82.5 | 50.0 | - | 1.07 | 6.9 | 61.2 | 20.4 | 24.9 |
| | Managed[1] | - | 17.5 | 38.8 | 97.4 | 85.0 | 42.5 | - | 4.21 | 15.8 | 81.2 | 16.1 | 15.9 |
| Escort | Untreated | 0 | 11.2 | 17.5 | 93.8 | 87.5 | 62.5 | 0 | 2.60 | 5.6 | 58.7 | 31.9 | 25.9 |
| | Full | - | 5.0 | 7.5 | 58.8 | 70.0 | 42.5 | - | 1.18 | 2.6 | 26.4 | 10.7 | 24.5 |
| | Autumn | - | 5.0 | 7.5 | 58.8 | 67.5 | 50.0 | - | 1.18 | 2.6 | 26.4 | 14.0 | 23.9 |
| | Managed[1] | - | 11.2 | 17.5 | 93.8 | 75.0 | 40.0 | - | 2.60 | 5.6 | 58.7 | 23.0 | 21.4 |
| SED | | - | 6.01 | 8.47 | 5.83 | 11.58 | 9.92 | - | 1.584 | 3.95 | 6.72 | 6.57 | 7.50 |
| | | | (6.45) | (9.41) | (5.62) | (13.00) | (10.52) | | (1.702) | (4.56) | (5.66) | (7.24) | (7.06) |
| df | | - | 33 | 33 | 33 | 27 | 27 | - | 33 | 33 | 33 | 27 | 27 |
| LSD | | - | 12.39 | 17.36 | 12.24 | 23.65 | 20.19 | - | 3.262 | 8.06 | 14.44 | 13.40 | 15.36 |
| | | | (13.12) | (19.15) | (11.44) | (26.67) | (21.59) | | (3.462) | (9.28) | (11.51) | (14.85) | (14.48) |
| Signif. Cv x Treat | | - | ns | ns | ** | ns | ns | - | ns | ns | ns | ns | * |
| Signif. Cv | | | ** | ** | ** | *** | ns | | ns | * | ** | ns | ns |
| Signif. Treat | | | ** | ** | *** | | *** | | ** | * | *** | *** | *** |

(figures in brackets are when comparing means with the same level of Cultivar)

[1] = untreated until 11 Apr 01

ns = not significant; * significant at p=0.05; ** significant at p=0.01; *** significant at p≤0.001

Table 8 (cont). Effect of fungicide on levels of light leaf spot, Aberdeen , 2000 – 2001.

| | | % Leaf area infected | | | | | | % stems affected | % stem area affected | % pod area affected |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | | 31 Oct 00 | 11 Dec 00 | 23 Jan 01 | 05 Apr 01 | 11 May 01 | 05 Jul 01 | 05 Jul 01 | 05 Jul 01 | 14 Aug 01 |
| GS | | 1.08-1.11 | 1.09-1.11 | 1.10-1.13 | 3.1 | 3.5-3.6 | 6.2 | 6.2 | 6.2 | 6.4 |
| Synergy | Untreated | 0 | 0.48 | 2.33 | 24.66 | 13.28 | 5.82 | 100.0 | 5.89 | 15.92 |
| | Full | 0 | 0.02 | 1.04 | 10.38 | 2.01 | 1.43 | 77.0 | 2.36 | 12.75 |
| | Autumn | 0 | 0.02 | 1.04 | 10.38 | 2.81 | 4.58 | 71.0 | 2.21 | 15.75 |
| | Managed[1] | 0 | 0.48 | 2.33 | 24.66 | 3.04 | 2.39 | 88.0 | 3.37 | 9.84 |
| Apex | Untreated | 0 | 0.25 | 2.08 | 27.05 | 10.56 | 6.69 | 93.0 | 5.79 | 8.17 |
| | Full | 0 | 0.12 | 0.75 | 14.68 | 2.43 | 4.20 | 89.0 | 3.39 | 3.25 |
| | Autumn | 0 | 0.12 | 0.75 | 14.68 | 3.01 | 2.79 | 84.0 | 3.06 | 5.00 |
| | Managed[1] | 0 | 0.25 | 2.08 | 27.05 | 1.33 | 1.88 | 85.0 | 3.04 | 4.58 |
| Escort | Untreated | 0 | 0.10 | 0.61 | 12.92 | 4.87 | 6.25 | 74.0 | 2.63 | 27.00 |
| | Full | 0 | 0.03 | 0.25 | 4.79 | 0.59 | 1.46 | 54.0 | 1.31 | 23.16 |
| | Autumn | 0 | 0.03 | 0.25 | 4.79 | 0.61 | 2.88 | 54.0 | 1.15 | 26.50 |
| | Managed[1] | 0 | 0.10 | 0.61 | 12.92 | 3.04 | 2.36 | 76.0 | 2.20 | 23.83 |
| SED | | - | 0.212 | 0.648 | 5.007 | 2.296 | 1.687 | 7.11 | 0.641 | 5.010 |
| | | | (0.173) | (0.700) | (3.356) | (2.358) | (1.633) | (7.11) | (0.618) | (4.156) |
| df | | - | 33 | 33 | 33 | 27 | 27 | 27 | 27 | 27 |
| LSD | | - | 0.458 | 1.334 | 11.182 | 4.671 | 3.445 | 14.49 | 1.308 | 10.437 |
| | | | (0.351) | (1.424) | (6.828) | (4.838) | (3.350) | (14.60) | (1.269) | (8.528) |
| Signif. Cv x Treat | | - | ns | ns | ns | ns | ns | ns | ns | ns |
| Sign. Cv | | | ns | ns | ns | ns | ns | *** | ** | ** |
| Sign. Treat | | | * | * | *** | *** | *** | *** | *** | ns |

(figures in brackets are when comparing means with the same level of Cultivar)

[1] = untreated until 11 Apr 01

ns = not significant; * significant at p=0.05; ** significant at p=0.01; *** significant at p≤0.001

Table 9. Development of phoma leaf spot in untreated plots, Aberdeen, 2000 – 2001.

| | 16 Oct 00 | 31 Oct 00 | 13 Nov 00 | 27 Nov 00 | 11 Dec 00 | 19 Dec 00 | 23 Jan 01 | 05 Apr 01 | 11 May 01 | 05 Jul 01 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | % Plants affected | | | | | |
| Synergy | 16.0 | 7.5 | 80.0 | 64.0 | 42.5 | 20.0 | 5.0 | 2.5 | 0 | 2.5 |
| Apex | 12.0 | 7.5 | 76.0 | 60.0 | 32.5 | 28.0 | 2.5 | 0 | 0 | 10.0 |
| Escort | 0 | 0 | 0 | 8.0 | 5.0 | 0 | 0 | 0 | 0 | 2.5 |
| | | | | | % Leaves affected | | | | | |
| Synergy | 3.79 | 1.26 | 16.13 | 12.58 | 8.35 | 2.96 | 1.00 | 1.14 | 0 | 0.96 |
| Apex | 2.26 | 1.34 | 15.23 | 13.67 | 5.73 | 6.29 | 0.56 | 0 | 0 | 4.19 |
| Escort | 0 | 0 | 0 | 1.72 | 0.91 | 0 | 0 | 0 | 0 | 1.00 |
| | | | | | % Leaf area affected | | | | | |
| Synergy | 0.76 | 0.15 | 2.36 | 1.04 | 0.46 | 0.12 | 0.13 | 0.05 | 0 | 0.02 |
| Apex | 0.44 | 0.16 | 1.84 | 0.92 | 0.33 | 0.20 | 0.08 | 0 | 0 | 0.12 |
| Escort | 0 | 0 | 0 | 0.16 | 0.04 | 0 | 0 | 0 | 0 | 0.12 |
| | | | | | Leaf length (mm) | | | | | |
| Synergy | 126.7 | 129.1 | 116.3 | 118.5 | 114.0 | 116.1 | 99.3 | 79.6 | - | - |
| Apex | 125.4 | 113.6 | 133.2 | 135.4 | 124.9 | 129.5 | 100.2 | 74.2 | - | - |
| Escort | 136.4 | 124.8 | 119.2 | 114.7 | 111.5 | 106.9 | 89.6 | 85.0 | - | - |
| | | | | | Petiole length (mm) | | | | | |
| Synergy | 63.5 | 54.8 | 47.0 | 45.2 | 48.2 | 45.2 | 36.1 | 38.8 | - | - |
| Apex | 55.0 | 49.8 | 55.5 | 58.4 | 52.2 | 55.4 | 37.9 | 40.1 | - | - |
| Escort | 62.2 | 55.9 | 49.7 | 48.8 | 42.6 | 41.5 | 31.5 | 39.5 | - | - |

Table 10. Effect of fungicide on levels of phoma leaf spot, Aberdeen, 2000 – 2001.

| | | % Plants affected | | | | % Leaves affected | | | | % Leaf area infected | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 31 Oct 00 | 11 Dec 00 | 23 Jan 01 | 05 Apr 01 | 31 Oct 00 | 11 Dec 00 | 23 Jan 01 | 05 Apr 01 | 31 Oct 00 | 11 Dec 00 | 23 Jan 01 | 05 Apr 01 |
| | | 1.08-1.11 | 1.09-1.11 | 1.10-1.13 | 3.1 | 1.08-1.11 | 1.09-1.11 | 1.10-1.13 | 3.1 | 1.08-1.11 | 1.09-1.11 | 1.10-1.13 | 3.1 |
| Synergy | Untreated | 7.5 | 37.5 | 2.5 | 6.25 | 1.26 | 7.02 | 0.43 | 1.77 | 0.15 | 0.44 | 0.06 | 0.16 |
| | Full | - | 7.5 | 0 | 2.50 | - | 1.37 | 0 | 0.51 | - | 0.07 | 0 | 0.05 |
| | Autumn | - | 7.5 | 0 | 2.50 | - | 1.37 | 0 | 0.51 | - | 0.07 | 0 | 0.05 |
| | Managed[1] | - | 37.5 | 2.5 | 6.25 | - | 7.02 | 0.43 | 1.77 | - | 0.44 | 0.06 | 0.16 |
| Apex | Untreated | 7.5 | 27.5 | 2.5 | 0 | 1.34 | 5.15 | 0.52 | 0 | 0.16 | 0.312 | 0.06 | 0 |
| | Full | - | 6.2 | 0 | 0 | - | 1.04 | 0 | 0 | - | 0.044 | 0 | 0 |
| | Autumn | - | 6.2 | 0 | 0 | - | 1.04 | 0 | 0 | - | 0.044 | 0 | 0 |
| | Managed[1] | - | 27.5 | 2.5 | 0 | - | 5.15 | 0.52 | 0 | - | 0.312 | 0.06 | 0 |
| Escort | Untreated | 0 | 3.8 | 0 | 0 | 0 | 0.72 | 0 | 0 | 0 | 0.025 | 0 | 0 |
| | Full | - | 2.5 | 0 | 0 | - | 0.44 | 0 | 0 | - | 0.019 | 0 | 0 |
| | Autumn | - | 2.5 | 0 | 0 | - | 0.44 | 0 | 0 | - | 0.019 | 0 | 0 |
| | Managed[1] | - | 3.5 | 0 | 0 | - | 0.72 | 0 | 0 | - | 0.025 | 0 | 0 |
| SED | | 3.91 | 5.01 | 1.54 | 2.452 | 0.674 | 0.965 | 0.289 | 0.652 | 0.097 | 0.069 | 0.039 | 0.062 |
| | | | (4.25) | (1.63) | (1.781) | | (0.868) | (0.297) | (0.430) | | (0.053) | (0.041) | (0.052) |
| df | | 6 | 33 | 33 | 33 | 6 | 33 | 33 | 33 | 6 | 33 | 33 | 33 |
| LSD | | 9.56 | 10.76 | 3.18 | 5.408 | 1.650 | 2.049 | 0.598 | 1.460 | 0.237 | 0.151 | 0.080 | 0.134 |
| | | | (8.65) | (3.31) | (3.624) | | (1.766) | (0.604) | (0.874) | | (0.107) | (0.084) | (0.106) |
| Signif. Cv x Treat | | ns | *** | ns | ns | ns | *** | ns | ns | ns | *** | ns | ns |
| Signif. Cv | | - | ** | ns | ns | - | ** | ns | ns | - | * | ns | ns |
| Signif. Treat | | - | *** | ns | ns | - | *** | ns | ns | | | | |

(figures in brackets are when comparing means with the same level of Cultivar)

<u>NO DISEASE FOUND ON 11 MAY 01</u>

[1] = untreated until 11 Apr 01

ns = not significant; * significant at p=0.05; ** significant at p=0.01; *** significant at $p \leq 0.001$

Table 11. Plant counts, Aberdeen, 2000 – 2001.

| Cultivar | Fungicide | Plants/$m^2$ 09 Nov 00 | Plants/$m^2$ 24 Aug 01 | Reduction % | % Ground Cover 18 Apr 01 |
|---|---|---|---|---|---|
| Synergy | Untreated | 53.9 | 46.8 | 9.3 | 35.8 |
| | Full | 52.3 | 48.6 | 2.0 | 55.5 |
| | Autumn | 52.3 | 48.6 | 8.4 | 52.5 |
| | Managed[1] | 53.9 | 46.8 | 1.7 | 53.8 |
| Apex | Untreated | 92.0 | 72.2 | 25.9 | 52.0 |
| | Full | 91.1 | 83.4 | 10.5 | 58.0 |
| | Autumn | 91.1 | 83.6 | 4.1 | 61.8 |
| | Managed[1] | 92.0 | 79.4 | 3.9 | 43.8 |
| Escort | Untreated | 85.4 | 72.2 | 10.5 | 63.8 |
| | Full | 82.5 | 82.4 | -0.7 | 72.8 |
| | Autumn | 82.5 | 79.6 | 3.3 | 68.2 |
| | Managed[1] | 85.4 | 79.0 | 9.8 | 65.2 |
| SED | | 7.25 | 6.46 | 17.35 | 9.29 |
| | | (4.34) | (6.04) | (14.29) | (9.17) |
| df | | 33 | 27 | 27 | 27 |
| LSD | | 16.46 | 13.22 | 36.18 | 18.94 |
| | | (8.83) | (12.40) | (29.32) | (18.82) |
| Signif. Cv x Treat | | ns | ns | ns | ns |
| Signif. Cv | | ** | *** | ns | * |
| Signif. Treat | | ns | *** | ns | ns |

(figures in brackets are when comparing means with the same level of Cultivar)

[1] = untreated until 11 Apr 01

ns = not significant; * significant at p=0.05; ** significant at p=0.01; ***significant at p≤0.001

Table 12. Yield and yield components, Aberdeen, 2000 – 2001.

| | | Fresh weight off combine kg | Dry weight % | Yield t/ha @ 90% DM | Yield benefit t/ha | Yield response % | MOFC £/ha | Economic Benefit £/ha |
|---|---|---|---|---|---|---|---|---|
| Synergy | Untreated | 14.20 | 89.02 | 3.511 | - | - | 533.7 | - |
| | Full | 15.23 | 88.53 | 3.745 | 0.234 | 6.7 | 531.1 | -2.6 |
| | Autumn | 14.80 | 87.56 | 3.600 | 0.089 | 2.5 | 520.1 | -13.6 |
| | Managed[1] | 14.28 | 85.48 | 3.399 | -0.112 | -3.5 | 484.3 | -49.4 |
| Apex | Untreated | 11.44 | 91.98 | 2.922 | - | - | 445.0 | 0 |
| | Full | 14.40 | 91.81 | 3.674 | 0.752 | 25.7 | 520.2 | 76.3 |
| | Autumn | 14.18 | 91.66 | 3.609 | 0.687 | 23.5 | 521.5 | 80.6 |
| | Managed[1] | 11.15 | 91.80 | 2.846 | -0.076 | -2.6 | 400.1 | -40.1 |
| Escort | Untreated | 15.53 | 90.66 | 3.909 | - | - | 594.2 | 0 |
| | Full | 17.43 | 90.63 | 4.386 | 0.477 | 12.2 | 628.5 | 34.3 |
| | Autumn | 16.88 | 90.89 | 4.261 | 0.352 | 9.0 | 620.5 | 26.4 |
| | Managed[1] | 16.23 | 90.72 | 4.088 | 0.179 | 4.6 | 589.0 | -5.2 |
| SED | | 0.653 | 1.011 | 0.173 | | | 26.29 | 32.52 |
| | | (0.630) | (1.078) | (0.175) | | | (26.56) | (27.70) |
| df | | 25 | 25 | 25 | | | 25 | 23 |
| LSD | | 1.336 | 2.057 | 0.353 | | | 53.65 | 68.23 |
| | | (1.297) | (2.211) | (0.360) | | | (54.69) | (57.30) |
| Signif. CV x treat | | * | ns | ns | | | ns | ns |
| Signif. CV | | *** | *** | *** | | | *** | ns |
| Signif. Treat | | *** | ns | *** | | | *** | *** |

(figures in brackets are when comparing means with the same level of Cultivar)

[1] = untreated until 11 Apr 01

ns = not significant; * significant at p=0.05; ** significant at p=0.01; *** significant at p≤0.001

MOFC based on fungicide costs of Punch C £26.50/l, Folicur £22.00/l (SAC Farm Management Handbook 2002/03); price of oilseed rape seed @ £152/t (SAC Weekly Economic Summary, Vol 29, No. 35, 05 September 2003)

Table 13. Effect of fungicide on levels of light leaf spot, Aberdeen, 2001 – 2002.

| | | % Plants affected | | | | | | % Leaves affected | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | | 29 Oct 01 | 10 Dec 01 | 22 Jan 02 | 11 Mar 02 | 18 Apr 02 | 07 Jun 02 | 29 Oct 01 | 10 Dec 01 | 22 Jan 02 | 11 Mar 02 | 18 Apr 02 | 07 Jun 02 |
| GS | | 1.06 | 1.08-1.11 | 1.09-1.12 | 3.1 | 3.5 | 6.1-6.5 | 1.06 | 1.08-1.11 | 1.09-1.12 | 3.1 | 3.5 | 6.1-6.2 |
| Synergy | Untreated | 0 | 0 | 5.0 | 17.5 | 97.5 | 87.5 | 0 | 0 | 0.90 | 6.25 | 34.43 | 34.3 |
| | Full | - | 0 | 5.0 | 5.0 | 62.5 | 30.0 | - | 0 | 0.90 | 0.70 | 14.70 | 6.8 |
| | Autumn | - | 2.5 | 0 | 7.5 | 40.0 | 40.0 | - | 0.51 | 0 | 0.92 | 8.58 | 9.1 |
| | Managed[2] | - | 0 | 5.0 | 2.5 | 85.0 | 57.5 | - | 0 | 1.82 | 0.70 | 22.65 | 12.2 |
| Apex | Untreated | 0 | 0 | 5.0 | 30.0 | 95.0 | 97.5 | 0 | 0 | 1.00 | 9.15 | 40.08 | 45.2 |
| | Full | - | 0 | 2.5 | 2.5 | 75.0 | 32.5 | - | 0 | 0.48 | 0.37 | 18.58 | 7.0 |
| | Autumn | - | 0 | 0 | 7.5 | 45.0 | 40.0 | - | 0 | 0 | 1.37 | 9.35 | 12.8 |
| | Managed[1] | - | 2.5 | 2.5 | 7.5 | 95.0 | 57.5 | - | 0.45 | 0.57 | 1.12 | 32.58 | 17.8 |
| Escort | Untreated | 0 | 2.5 | 5.0 | 45.0 | 87.5 | 92.5 | 0 | 0.61 | 1.15 | 7.65 | 29.48 | 42.1 |
| | Full | - | 0 | 0 | 0 | 47.5 | 42.5 | - | 0 | 0 | 0 | 8.00 | 8.1 |
| | Autumn | - | 2.5 | 5.0 | 2.5 | 42.5 | 62.5 | - | 0.48 | 1.11 | 0.37 | 9.33 | 13.7 |
| | Managed[2] | - | 0 | 2.5 | 5.0 | 90.0 | 67.5 | - | 0 | 0.60 | 0.77 | 23.53 | 21.9 |
| SED | | - | 2.06 | 3.93 | 8.49 | 13.02 | 8.66 | - | 0.423 | 0.996 | 2.759 | 3.874 | 6.00 |
| | | | (2.10) | (4.26) | (9.25) | (12.72) | (9.14) | | (0.435) | (1.105) | (3.051) | (3.871) | (6.39) |
| df | | - | 27 | 27 | 27 | 27 | 27 | - | 27 | 27 | 27 | 27 | 27 |
| LSD | | - | 4.20 | 8.01 | 17.30 | 26.57 | 17.62 | - | 0.860 | 2.031 | 5.628 | 7.891 | 12.21 |
| | | | (4.30) | (8.75) | (18.98) | (26.09) | (18.74) | | (0.892) | (2.268) | (6.261) | (7.943) | (13.11) |
| Signif. Cv x Treat | | - | ns | ns | ns | ns | ns | | ns | ns | ns | ns | ns |
| Signif. Cv | | | ns | ns | ns | ns | * | | ns | ns | ns | * | ns |
| Signif. Treat | | | ns | ns | *** | *** | *** | | ** | ns | *** | *** | *** |

(figures in brackets are when comparing means with the same level of Cultivar)

[1] = untreated until 10 Dec 01

[2] = untreated until 05 Feb 02

ns = not significant; * significant at p=0.05; ** significant at p=0.01; *** significant at p≤0.001

Table 13 (cont). Effect of fungicide on levels of light leaf spot, Aberdeen, 2001 – 2002.

| | | % Leaf area affected | | | | | | % plants with stems affected | % stem area affected | % plants with pods affected | % pod area affected |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | | 29 Oct 01 | 10 Dec 01 | 22 Jan 02 | 11 Mar 02 | 18 Apr 02 | 07 Jun 02 | 18 Jul 02 | 18 Jul 02 | 18 Jul 02 | 18 Jul 02 |
| GS | | 1.06 | 1.08-1.11 | 1.09-1.12 | 3.1 | 3.5 | 6.1-6.2 | 6.3 | 6.3 | 6.3 | 6.3 |
| Synergy | Untreated | 0 | 0 | 0.02 | 1.53 | 11.97 | 6.20 | 78.0 | 2.09 | 10.0 | 0.22 |
| | Full | | 0 | 0.02 | 0.03 | 4.01 | 0.54 | 41.0 | 0.87 | 8.0 | 0.10 |
| | Autumn | | 0.02 | 0 | 0.10 | 2.98 | 0.58 | 57.0 | 9.76 | 11.0 | 0.24 |
| | Managed[2] | | 0 | 0.09 | 0.01 | 7.31 | 1.37 | 64.0 | 2.03 | 11.0 | 3.10 |
| Apex | Untreated | 0 | 0 | 0.005 | 1.08 | 14.58 | 7.21 | 84.0 | 3.65 | 12.0 | 0.85 |
| | Full | | 0 | 0.002 | 0 | 5.49 | 0.39 | 64.0 | 1.37 | 10.0 | 0.32 |
| | Autumn | | 0 | 0 | 0.18 | 2.64 | 1.59 | 79.0 | 2.45 | 11.0 | 0.27 |
| | Managed[1] | | 0.02 | 0.02 | 0.11 | 9.89 | 2.40 | 90.0 | 4.04 | 12.0 | 0.85 |
| Escort | Untreated | 0 | 0.08 | 0.08 | 0.44 | 6.78 | 8.35 | 88.0 | 2.80 | 6.0 | 0.29 |
| | Full | | 0 | 0 | 0 | 1.32 | 1.08 | 46.0 | 0.78 | 2.0 | 0.02 |
| | Autumn | | 0.05 | 0.02 | 0.02 | 2.76 | 1.92 | 49.0 | 1.00 | 6.0 | 0.08 |
| | Managed[2] | | 0 | 0.01 | 0.08 | 4.42 | 2.75 | 70.0 | 2.18 | 5.0 | 0.05 |
| SED | | - | 0.039 | 0.050 | 0.605 | 1.946 | 1.504 | 13.75 | 3.178 | 1.81 | 1.225 |
| | | | (0.040) | (0.051) | (0.648) | (1.792) | (1.580) | (14.95) | (3.195) | (1.86) | (1.241) |
| df | | - | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 27 |
| LSD | | - | 0.079 | 0.101 | 1.232 | 3.994 | 3.060 | 28.01 | 6.471 | 3.68 | 2.494 |
| | | | (0.082) | (0.104) | (1.330) | (3.677) | (3.242) | (30.65) | (6.556) | (3.81) | (2.546) |
| Signif. Cv x Treat | | - | ns | ns | ns | ns | ns | ns | ns | ns | ns |
| Signif. Cv | | | ns | ns | ns | * | ns | * | ns | * | ns |
| Signif. Treat | | | ns | ns | * | *** | *** | *** | ns | *** | ns |

(figures in brackets are when comparing means with the same level of Cultivar)

[1] = untreated until 10 Dec 01

[2] = untreated until 05 Feb 02

ns = not significant; * significant at p=0.05; ** significant at p=0.01; *** significant at $p \leq 0.001$

Table 14. Development of phoma leaf spot in untreated plots, Aberdeen, 2001 – 2002.

| | 16 Oct 01<br>1.06 | 29 Oct 01<br>1.06-1.08 | 12 Nov 01<br>1.09-1.10 | 26 Nov 01<br>1.08-1.11 | 10 Dec 01<br>1.08-1.11 | 14 Jan 02<br>1.10-1.12 | 22 Jan 02<br>1.09-1.12 | 04 Feb 02<br>1.10-1.12 | 11 Mar 02<br>3.1 | 18 Apr 02<br>3.5 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | % Plants affected | | | | | |
| Synergy | 0 | 16.0 | 24.0 | 32.0 | 17.5 | 12.0 | 37.5 | 12.0 | 35.0 | 10.0 |
| Apex | 0 | 28.0 | 8.0 | 12.0 | 17.5 | 28.0 | 12.5 | 8.0 | 2.5 | 2.5 |
| Escort | 0 | 8.0 | 0 | 0 | 0 | 4.0 | 5.0 | 0 | 2.5 | 2.5 |
| | | | | | % Leaves affected | | | | | |
| Synergy | 0 | 3.1 | 3.75 | 4.82 | 2.82 | 2.74 | 8.16 | 2.01 | 5.09 | 0.90 |
| Apex | 0 | 4.64 | 1.16 | 2.03 | 3.46 | 7.63 | 2.51 | 1.60 | 0.40 | 0.22 |
| Escort | 0 | 1.55 | 0 | 0 | 0 | 0.88 | 1.06 | 0 | 0.35 | 0.22 |
| | | | | | % Leaf area affected | | | | | |
| Synergy | 0 | 0.01 | 0.06 | 0.16 | 0.32 | 0.06 | 0.12 | 0.06 | 0.10 | 0.02 |
| Apex | 0 | 0.19 | 0.02 | 0.04 | 0.09 | 0.12 | 0.01 | 0.02 | 0.002 | 0.002 |
| Escort | 0 | 0.02 | 0 | 0 | 0 | 0.004 | 0.02 | 0 | 0.002 | 0.002 |
| | | | | | Leaf length (mm) | | | | | |
| Synergy | 96.00 | 164.36 | 182.68 | 191.56 | 185.90 | 180.52 | 171.80 | 157.36 | - | - |
| Apex | 115.48 | 178.52 | 217.12 | 240.88 | 239.50 | 232.64 | 221.10 | 202.80 | - | - |
| Escort | 130.60 | 192.80 | 234.60 | 238.44 | 231.30 | 223.44 | 206.60 | 196.80 | - | - |
| | | | | | Petiole length (mm) | | | | | |
| Synergy | 33.84 | 64.88 | 72.08 | 74.60 | 75.40 | 68.44 | 60.80 | 57.32 | - | - |
| Apex | 41.24 | 74.60 | 105.52 | 117.36 | 126.20 | 115.00 | 109.80 | 92.12 | - | - |
| Escort | 52.52 | 92.46 | 110.96 | 112.28 | 116.00 | 100.68 | 93.00 | 57.32 | - | - |

Table 15. Effect of fungicide on levels of phoma leaf spot, Aberdeen, 2001 – 2002.

| | | % Plants affected | | | | | % Leaves affected | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 29 Oct 01<br>1.06-1.08 | 10 Dec 01<br>1.08-1.11 | 22 Jan 02<br>1.09-1.12 | 11 Mar 02<br>3.1 | 18 Apr 02<br>3.5 | 29 Oct 01<br>1.06-1.08 | 10 Dec 01<br>1.08-1.11 | 22 Jan 02<br>1.09-1.12 | 11 Mar 02<br>3.1 | 18 Apr 02<br>3.5 |
| Synergy | Untreated | 16.0 | 17.5 | 37.5 | 35.0 | 10.0 | 3.1 | 2.82 | 8.16 | 5.09 | 0.90 |
| | Full | - | 2.5 | 0 | 2.5 | 0 | - | 0.43 | 0 | 0.37 | 0 |
| | Autumn | - | 7.5 | 0 | 7.5 | 2.5 | - | 1.33 | 0 | 0.91 | 0.22 |
| | Managed[2] | - | 25.0 | 32.5 | 0 | 2.5 | - | 4.53 | 6.41 | 0 | 0.21 |
| Apex | Untreated | 28.0 | 17.5 | 12.5 | 2.5 | 2.5 | 4.64 | 3.46 | 2.51 | 0.40 | 0.22 |
| | Full | - | 5.0 | 0 | 5.0 | 2.5 | - | 0.95 | 0 | 0.76 | 0.22 |
| | Autumn | - | 2.5 | 0 | 2.5 | 0 | - | 0.45 | 0 | 0.35 | 0 |
| | Managed[1] | - | 5.0 | 5.0 | 0 | 0 | - | 0.93 | 1.00 | 0 | 0 |
| Escort | Untreated | 8.0 | 0 | 5.0 | 2.5 | 2.5 | 1.55 | 0 | 1.06 | 0.35 | 0.22 |
| | Full | - | 0 | 0 | 0 | 0 | - | 0 | 0 | 0 | 0 |
| | Autumn | - | 0 | 2.5 | 0 | 0 | - | 0 | 0.49 | 0 | 0 |
| | Managed[2] | - | 0 | 0 | 0 | 0 | - | 0 | 0 | 0 | 0 |
| SED | | - | 5.37<br>(5.62) | 5.57<br>(4.93) | 5.45<br>(5.15) | 2.70<br>(2.91) | - | 0.924<br>(0.969) | 1.253<br>(1.189) | 0.865<br>(0.824) | 0.239<br>(0.258) |
| df | | - | 27 | 27 | 27 | 27 | - | 27 | 27 | 27 | 27 |
| LSD | | - | 10.92<br>(11.53) | 11.48<br>(10.12) | 11.15<br>(10.56) | 5.50<br>(5.96) | - | 1.880<br>(1.987) | 2.563<br>(2.439) | 1.768<br>(1.691) | 0.487<br>(0.550) |
| Signif. Cv x treat | | - | * | *** | *** | ns | - | * | *** | ** | ns |
| Signif. Cv | | | ** | ** | ** | * | | ** | ** | * | * |
| Signif. Treat | | | * | *** | *** | * | | * | *** | ** | * |

(figures in brackets are when comparing means with the same level of Cultivar)

[1] = untreated until 10 Dec 02

[2] = untreated until 05 Feb 02

ns = not significant; * significant at p=0.05; ** significant at p=0.01; *** significant at $p \leq 0.001$

Table 15 (cont). Effect of fungicide on levels of phoma leaf spot, Aberdeen, 2001 – 2002.

| | | % Leaf area infected | | | | |
|---|---|---|---|---|---|---|
| | | 29 Oct 01<br>1.06-1.08 | 10 Dec 01<br>1.08-1.11 | 22 Jan 02<br>1.09-1.12 | 11 Mar 02<br>3.1 | 18 Apr 02<br>3.5 |
| Synergy | Untreated | 0.10 | 0.32 | 0.12 | 0.10 | 0.02 |
| | Full | - | 0.01 | 0 | 0.002 | 0 |
| | Autumn | - | 0.07 | 0 | 0.01 | 0.002 |
| | Managed[2] | - | 0.21 | 0.12 | 0 | 0.002 |
| Apex | Untreated | 0.19 | 0.09 | 0.01 | 0.002 | 0.002 |
| | Full | - | 0.02 | 0 | 0.02 | 0.002 |
| | Autumn | - | 0.01 | 0 | 0.002 | 0 |
| | Managed[1] | - | 0.04 | 0.005 | 0 | 0 |
| Escort | Untreated | 0.02 | 0 | 0.02 | 0.002 | 0.002 |
| | Full | - | 0 | 0 | 0 | 0 |
| | Autumn | - | 0 | 0.01 | 0 | 0 |
| | Managed[2] | - | 0 | 0 | 0 | 0 |
| SED | | - | 0.105<br>(0.105) | 0.041<br>(0.042) | 0.007<br>(0.007) | 0.005<br>(0.005) |
| df | | - | 27 | 27 | 27 | 27 |
| LSD | | - | 0.214<br>(0.214) | 0.084<br>(0.085) | 0.014<br>(0.015) | 0.010<br>(0.009) |
| Signif. Cv x Treat | | - | ns | ns | *** | ns |
| Signif. Cv | | - | * | ns | *** | ns |
| Signif. Treat | | - | ns | ns | *** | * |

(figures in brackets are when comparing means with the same level of Cultivar)

[1] = untreated until 10 Dec 01 [2] = untreated until 05 Feb 02

ns = not significant; * significant at p=0.05; ** significant at p=0.01; *** significant at p≤0.001

Table 16. Plant counts, Aberdeen, 2001 – 2002.

| Cultivar | Fungicide | Plants/m$^2$ 20 Dec 01 1.08-1.11 | Plants/m$^2$ 19 Aug 02 Post-harvest | Reduction % |
|---|---|---|---|---|
| Synergy | Untreated | 37.4 | 28.8 | 21.9 |
| | Full | 42.6 | 29.2 | 29.5 |
| | Autumn | 33.6 | 29.8 | 11.5 |
| | Managed[2] | 37.0 | 26.4 | 24.3 |
| Apex | Untreated | 66.6 | 52.6 | 19.2 |
| | Full | 71.8 | 62.8 | 12.5 |
| | Autumn | 61.6 | 49.0 | 17.8 |
| | Managed[1] | 65.2 | 58.0 | 10.3 |
| Escort | Untreated | 57.6 | 45.8 | 19.0 |
| | Full | 59.8 | 40.0 | 33.3 |
| | Autumn | 58.6 | 47.0 | 20.8 |
| | Managed[2] | 65.0 | 51.6 | 19.9 |
| SED | | 4.204 | 5.943 | 12.61 |
| | | (4.136) | (4.872) | (12.00) |
| df | | 27 | 27 | 27 |
| LSD | | 8.571 | 12.404 | 25.77 |
| | | (8.486) | (9.996) | (24.63) |
| Signif. Cv x Treat | | ns | ns | ns |
| Signif. Cv | | *** | ** | ns |
| Signif. Treat | | ns | ns | ns |

(figures in brackets are when comparing means with the same level of Cultivar)

[1] = untreated until 10 Dec 01  [2] = untreated until 05 Feb 02

ns = not significant; * significant at p=0.05; ** significant at p=0.01; *** significant at p≤0.001

Table 17. Yield and yield components, Aberdeen, 2001 – 2002.

| | | Fresh weight off combine kg | Dry weight % | Yield t/ha @ 90% DM | Yield benefit t/ha | Yield response % | MOFC £/ha | Economic Benefit £/ha |
|---|---|---|---|---|---|---|---|---|
| Synergy | Untreated | 14.02 | 86.91 | 3.389 | - | - | 515.0 | - |
| | Full | 15.82 | 86.72 | 3.808 | 0.419 | 12.4 | 546.0 | 31.0 |
| | Autumn | 12.85 | 87.27 | 3.115 | -0.274 | -8.1 | 452.0 | -63.0 |
| | Managed[2] | 15.03 | 86.75 | 3.622 | 0.233 | 6.9 | 529.0 | 14.0 |
| Apex | Untreated | 13.87 | 89.28 | 3.441 | - | - | 523.0 | 0 |
| | Full | 16.73 | 89.15 | 4.142 | 0.701 | 20.4 | 597.0 | 74.0 |
| | Autumn | 15.52 | 88.72 | 3.827 | 0.386 | 11.2 | 560.0 | 37.0 |
| | Managed[1] | 15.63 | 89.34 | 3.880 | 0.439 | 12.8 | 568.0 | 45.0 |
| Escort | Untreated | 15.57 | 81.60 | 3.551 | - | - | 540.0 | 0 |
| | Full | 20.66 | 83.82 | 4.816 | 1.265 | 35.6 | 699.0 | 160.0 |
| | Autumn | 19.36 | 83.92 | 4.518 | 0.967 | 27.2 | 665.0 | 125.0 |
| | Managed[2] | 16.93 | 82.87 | 3.901 | 0.350 | 9.8 | 571.0 | 32.0 |
| SED | | 1.375 | 1.039 | 0.356 | | | 54.20 | 89.30 |
| | | (1.285) | (1.123) | (0.338) | | | (51.40) | (51.40) |
| df | | 27 | 27 | 27 | | | 27 | 27 |
| LSD | | 2.817 | 2.116 | 0.729 | | | 110.80 | 198.10 |
| | | (2.636) | (2.304) | (0.694) | | | (105.50) | (105.50) |
| Signif. CV x treat | | ns | ns | ns | | | ns | ns |
| Signif. CV | | ** | *** | * | | | * | ns |
| Signif. Treat | | ** | ns | ** | | | * | * |

(figures in brackets are when comparing means with the same level of Cultivar)

[1] = untreated until 10 Dec 01 [2] = untreated until 05 Feb 02

ns = not significant; * significant at p=0.05; ** significant at p=0.01; *** significant at p≤0.001

MOFC based on fungicide costs of Punch C £26.50/l, Folicur £22.00/l (SAC Farm Management Handbook 2002/03); price of oilseed rape seed @ £152/t (SAC Weekly Economic Summary, Vol 29, No. 35, 05 September 2003)

Table 18. Effect of fungicide on levels of light leaf spot, Aberdeen, 2002 – 2003.

| | | % Plants affected | | | | % Leaves affected | | | |
|---|---|---|---|---|---|---|---|---|---|
| Date<br>GS | | 05 Nov 02<br>1.08 | 03 Dec 02<br>1.10-1.11 | 24 Feb 03<br>3.1 | 22 Apr 03<br>4.1 | 05 Nov 02<br>1.08 | 03 Dec 02<br>1.10-1.11 | 24 Feb 03<br>3.1 | 22 Apr 03<br>4.1 |
| Synergy | Untreated | 0 | 0 | 90.0 | 100.0 | 0 | 0 | 28.3 | 54.3 |
| | Full | - | 0 | 42.5 | 90.0 | - | 0 | 8.5 | 24.9 |
| | Autumn | - | 0 | 50.0 | 100.0 | - | 0 | 8.9 | 42.6 |
| | Managed[1] | - | 0 | 45.0 | 100.0 | - | 0 | 9.2 | 45.2 |
| Apex | Untreated | 0 | 0 | 90.0 | 100.0 | 0 | 0 | 36.0 | 45.5 |
| | Full | - | 0 | 60.0 | 90.0 | - | 0 | 16.4 | 23.3 |
| | Autumn | - | 0 | 62.5 | 100.0 | - | 0 | 15.0 | 33.7 |
| | Managed[1] | - | 0 | 50.0 | 100.0 | - | 0 | 11.6 | 36.2 |
| Escort | Untreated | 0 | 0 | 72.5 | 100.0 | 0 | 0 | 16.0 | 38.3 |
| | Full | - | 0 | 10.0 | 60.0 | - | 0 | 1.5 | 8.5 |
| | Autumn | - | 0 | 17.5 | 75.0 | - | 0 | 2.6 | 20.3 |
| | Managed[1] | - | 0 | 30.0 | 87.5 | - | 0 | 6.0 | 22.8 |
| SED | | - | - | 11.56<br>(11.02) | 7.66<br>(7.52) | - | - | 3.78<br>(4.00) | 5.23<br>(5.19) |
| df | | - | - | 27 | 27 | - | - | 27 | 27 |
| LSD | | - | - | 23.63<br>(22.62) | 15.62<br>(15.44) | - | - | 7.69<br>(8.20) | 10.66<br>(10.66) |
| Signif. Cv x Treat | | - | - | ns | ns | - | - | ns | ns |
| Signif. Cv | | | - | ** | * | | - | *** | *** |
| Signif. Treat | | | - | *** | *** | | - | *** | *** |

(figures in brackets are when comparing means with the same level of Cultivar) [1] = untreated until 16 Jan 03
ns = not significant; * significant at p=0.05; ** significant at p=0.01; *** significant at $p \leq 0.001$

Table 19. Effect of fungicide on levels of light leaf spot, Aberdeen , 2002 – 2003.

| | | % Leaf area infected | | | | % plants with stems affected | % stem area affected | % plants with pods affected | % pod area affected |
|---|---|---|---|---|---|---|---|---|---|
| Date | | 05 Nov 02 | 03 Dec 02 | 24 Feb 03 | 22 Apr 03 | 17 Jul 02 | 17 Jul 02 | 17 Jul 02 | 17 Jul 02 |
| GS | | 1.08 | 1.10-1.11 | 3.1 | 4.1 | 6.3 | 6.3 | 6.3 | 6.3 |
| Synergy | Untreated | 0 | 0 | 13.06 | 20.90 | 100.0 | 3.27 | 92.5 | 3.89 |
| | Full | - | 0 | 0.72 | 4.14 | 87.5 | 1.16 | 97.5 | 11.46 |
| | Autumn | - | 0 | 0.61 | 12.35 | 92.5 | 2.87 | 100.0 | 2.67 |
| | Managed[1] | - | 0 | 0.66 | 15.16 | 92.5 | 3.34 | 100.0 | 2.83 |
| Apex | Untreated | 0 | 0 | 13.01 | 16.43 | 100.0 | 6.45 | 100.0 | 10.02 |
| | Full | - | 0 | 2.92 | 6.18 | 100.0 | 5.32 | 100.0 | 16.95 |
| | Autumn | - | 0 | 3.38 | 10.55 | 100.0 | 5.65 | 100.0 | 14.17 |
| | Managed[1] | - | 0 | 1.00 | 15.35 | 100.0 | 6.75 | 97.5 | 18.47 |
| Escort | Untreated | 0 | 0 | 1.17 | 9.90 | 97.5 | 4.17 | 90.0 | 3.02 |
| | Full | - | 0 | 0.14 | 1.15 | 80.0 | 1.46 | 67.5 | 1.06 |
| | Autumn | - | 0 | 0.10 | 4.94 | 90.0 | 2.25 | 80.0 | 2.29 |
| | Managed[1] | - | 0 | 0.49 | 5.20 | 90.0 | 3.11 | 85.0 | 3.47 |
| SED | | - | - | 2.022 | 2.737 | 6.97 | 0.987 | 7.16 | 4.438 |
| | | | | (2.042) | (2.729) | (5.02) | (0.708) | (4.74) | (4.315) |
| df | | - | - | 27 | 27 | 27 | 27 | 27 | 27 |
| LSD | | - | - | 4.117 | 5.576 | 14.87 | 2.109 | 15.52 | 9.056 |
| | | | | (4.189) | (5.600) | (10.31) | (1.452) | (9.72) | (8.854) |
| Signif. Cv x Treat | | - | - | ** | ns | ns | ns | ** | ns |
| Signif. Cv | | | - | ** | ** | ns | ** | * | ** |
| Signif. Treat | | | - | *** | *** | * | *** | ns | ns |

(figures in brackets are when comparing means with the same level of Cultivar)
[1] = untreated until 16 Jan 03
ns = not significant; * significant at p=0.05; ** significant at p=0.01; *** significant at p≤0.001

Table 20. Development of phoma leaf spot in untreated plots, Aberdeen, 2002 – 2003.

| | 05 Nov 02<br>1.08 | 18 Nov 02<br>1.08-1.09 | 03 Dec 02<br>1.10-1.11 | 16 Dec 02<br>1.10-1.11 | 13 Jan 03<br>1.11-1.12 | 28 Jan 03<br>1.11-1.12 | 10 Feb 03<br>1.12 | 24 Feb 03<br>3.1 | 10 Mar 03<br>3.1 | 24 Mar 03<br>3.3 | 22 Apr 03<br>4.1 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | % Plants affected | | | | | | | | | | |
| Synergy | 0 | 0 | 0 | 8 | 4 | 0 | 8 | 0 | 4 | 0 | 0 |
| Apex | 0 | 0 | 0 | 0 | 4 | 8 | 0 | 0 | 0 | 0 | 0 |
| Escort | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | % Leaves affected | | | | | | | | | | |
| Synergy | 0 | 0 | 0 | 1.3 | 0.7 | 0 | 1.2 | 0 | 0.5 | 0 | 0 |
| Apex | 0 | 0 | 0 | 0 | 0.7 | 1.4 | 0 | 0 | 0 | 0 | 0 |
| Escort | 0 | 0 | 0 | 0.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | % Leaf area affected | | | | | | | | | | |
| Synergy | 0 | 0 | 0 | 0.01 | 0.08 | 0 | 0.08 | 0 | 0.02 | 0 | 0 |
| Apex | 0 | 0 | 0 | 0 | 0.02 | 0.01 | 0 | 0 | 0 | 0 | 0 |
| Escort | 0 | 0 | 0 | 0.004 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Leaf length (mm) | | | | | | | | | | |
| Synergy | 154.4 | 147.5 | 124.6 | 105.84 | 105.12 | 120.76 | 118.10 | 100.20 | 111.80 | 125.90 | - |
| Apex | 188.0 | 167.1 | 162.8 | 141.36 | 131.24 | 131.52 | 128.40 | 114.88 | 117.90 | 124.30 | - |
| Escort | 215.7 | 169.0 | 145.3 | 133.00 | 136.64 | 123.44 | 124.60 | 118.45 | 130.10 | 128.600 | - |
| | Petiole length (mm) | | | | | | | | | | |
| Synergy | 62.1 | 50.7 | 68.3 | 36.56 | 40.52 | 50.56 | 49.60 | 37.35 | 44.80 | 45.00 | - |
| Apex | 78.2 | 63.5 | 45.0 | 55.96 | 53.68 | 53.60 | 56.40 | 49.10 | 47.40 | 52.10 | - |
| Escort | 107.9 | 72.2 | 59.7 | 50.52 | 53.40 | 52.28 | 44.10 | 45.32 | 59.00 | 51.20 | - |

Note: There was no phoma leaf spot present on full assessment dates, so no fungicide data.

Table 21. Plant counts, Aberdeen, 2002 – 2003.

| Cultivar | Fungicide | Plants/m² 17 Dec 02 1.11-1.11 | Plants/m² 08 Aug 02 Post-harvest | Reduction % |
|---|---|---|---|---|
| Synergy | Untreated | 55.8 | 44.8 | 18.1 |
| | Full | 57.4 | 51.6 | 6.7 |
| | Autumn | 60.2 | 51.0 | 13.5 |
| | Managed[1] | 60.2 | 49.8 | 16.3 |
| Apex | Untreated | 91.6 | 81.2 | 10.6 |
| | Full | 98.4 | 91.2 | 7.0 |
| | Autumn | 98.0 | 63.0 | 2.2 |
| | Managed[1] | 94.6 | 86.6 | 5.8 |
| Escort | Untreated | 84.8 | 83.4 | 1.0 |
| | Full | 81.6 | 81.8 | -0.1 |
| | Autumn | 90.6 | 75.0 | 18.7 |
| | Managed[1] | 87.0 | 76.6 | 14.8 |
| SED | | 8.69<br>(6.75) | 9.57<br>(7.05) | 13.16<br>(11.28) |
| df | | 27 | 27 | 27 |
| LSD | | 18.30<br>(13.85) | 20.36<br>(14.47) | 27.28<br>(23.14) |
| Signif. Cv x Treat | | ns | ns | ns |
| Signif. Cv | | ** | ** | ns |
| Signif. Treat | | ns | ns | ns |

(figures in brackets are when comparing means with the same level of Cultivar)
[1] = untreated until 10 Jan 0 ns = not significant; * significant at p=0.05; ** significant at p=0.01; *** significant at p≤0.001

Table 22. Yield and yield components, Aberdeen, 2002 – 2003.

| | | Fresh weight off combine kg | Dry weight % | Yield t/ha @ 90% DM | Yield benefit t/ha | Yield response % | MOFC £/ha | Economic Benefit £/ha |
|---|---|---|---|---|---|---|---|---|
| Synergy | Untreated | 14.78 | 90.65 | 3.723 | - | - | 565.8 | - |
| | Full | 15.11 | 90.32 | 3.790 | 0.070 | -1.88 | 543.4 | -22.4 |
| | Autumn | 16.13 | 90.55 | 4.058 | 0.335 | 9.00 | 595.2 | 29.4 |
| | Managed[2] | 15.52 | 90.70 | 3.910 | 0.187 | 5.02 | 572.8 | 7.0 |
| Apex | Untreated | 13.17 | 92.25 | 3.378 | - | - | 513.4 | - |
| | Full | 13.97 | 92.45 | 3.588 | 0.210 | 6.22 | 512.7 | -0.7 |
| | Autumn | 14.02 | 92.30 | 3.595 | 0.217 | 6.42 | 524.9 | 11.5 |
| | Managed[1] | 13.55 | 92.45 | 3.480 | 0.102 | 3.02 | 507.3 | -6.1 |
| Escort | Untreated | 14.35 | 91.82 | 3.661 | - | - | 556.4 | - |
| | Full | 14.30 | 91.55 | 3.634 | -0.027 | -0.74 | 519.7 | -33.7 |
| | Autumn | 14.47 | 91.40 | 3.680 | 0.019 | 0.52 | 537.8 | -18.6 |
| | Managed[2] | 14.24 | 91.35 | 3.614 | -0.047 | -1.28 | 527.7 | -28.7 |
| SED | | 1.115 | 0.428 | 0.286 | | | 43.46 | 38.81 |
| | | (0.833) | (0.310) | (0.214) | | | (32.54) | (32.53) |
| df | | 27 | 27 | 27 | | | 27 | 27 |
| LSD | | 2.364 | 0.913 | 0.600 | | | 92.14 | 80.70 |
| | | (1.710) | (0.635) | (0.434) | | | (66.76) | (66.74) |
| Signif. CV x Treat | | ns | ns | ns | | | ns | ns |
| Signif. CV | | ns | ** | ns | | | ns | ns |
| Signif. Treat | | ns | ns | ns | | | ns | ns |

(figures in brackets are when comparing means with the same level of Cultivar)

[1] = untreated until 16 Jan 03

ns = not significant; * significant at p=0.05; ** significant at p=0.01; *** significant at p≤0.001

MOFC based on fungicide costs of £22.00/ha (SAC Farm Management Handbook); price of oilseed rape seed @ £152/t (SAC Weekly Economic Summary, Vol 29, No. 35, 05 September 2003).

**Appendix 3. Fungicide spray timing experiments, Rothamsted Research 2000-2003**

Table 23. Site details for field experiments at Rothamsted Research.

| | 2000/01 | 2001/02 | 2002/03 |
|---|---|---|---|
| Field name | Meadow | Highfield IV | Bones Close |
| Grid ref. | TL 512 213 | TL 513 212 | TL 512 213 |
| Soil type | Flinty silt loam, well drained | Flinty silty clay loam, moderately well drained | Flinty silty clay loam, moderately well drained |
| Soil series | Charity-Hamble | Batcombe | Batcombe |
| Previous cropping | 1998/99 w. beans, lupins<br>1997/98 w. wheat, w. barley | 1999/2000 lupins<br>2000/01 w. barley | 2000/01 w. wheat<br>2001/02 w. wheat |
| Cultivation | Ploughed 21/8/00, drilled and rolled 23/8/01 | Sub-soiled and ploughed 4/8/01, drilled and rolled 13/8.01 | Ploughed and power harrowed 16/8/02, drilled and rolled 20/8/02 |
| Sowing date | 23/8/00 | 13/8/01 | 20/8/02 |
| Cultivar | Apex | Apex | Apex |
| Seed treatment | Carboxin + gamma HCH + thiram | Beta-cyfluthrin + imidacloprid + thiram | Beta-cyfluthrin + imidacloprid + thiram |
| Seeds/m$^2$ | 90 | 80 | 80 |
| Fertiliser | 29/9/00 Sulphur Gold 100kg/ha<br>15/2/01 Sulphur Gold 266 kg/ha<br>2/4/01 Sulphur Gold 400kg/ha | 19/2/02 Sulphur Gold 30% N, 7.6% S at 333 kg/ha<br>22/3/02 Sulphur Gold 267 kg/ha | 26/9/02 Sulphur Gold 30% N, 7.6% S at 100 kg/ha<br>17/2/03 Sulphur Gold 267 kg/ha<br>26/3/03 Sulphur Gold 333 kg/ha |
| Herbicides | 13/9/00 Katamaran ( 2 l/ha)<br>14/2/01 Laser 0.75l/ha | 17/8/01 Katamaran ( 2 l/ha) + Treflan (2 l/ha) | 21/8/02 Katamaran ( 2 l/ha)<br>28 Oct. Kerb 50 W (1.7kg/ha) |
| Molluscicides | 26/8/00 Genesis (5kg/ha)<br>14/10/00 Judge (5kg/ha) | | |
| Insecticides | 12/10/00 Hallmark Zeon (50ml/ha) | | 28/10/02 and 15/4/03 Hallmark (50ml/ha) |
| Desiccant | 14/7/01 Diquat (Reglone) 3.0 l/ha in 400l water/ha | 11/7/01 Diquat (Reglone) 3.0 l/ha in 400 l water/ha | 10/7/01 Diquat (Reglone) + adjuvant 3.0 l/ha in 400 l water/ha |
| Harvest date | 23/7/01 | 18/7/02 | 14/7/03 |

Table 24.Spray conditions and application details, Rothamsted 2000-2003.

a) 2000/01

| Date treated | Air temp on day of spraying (max º C) | Air temp on day of spraying (min º C) | Wind speed (kph) and direction at time of spraying | Application details |
|---|---|---|---|---|
| 9 Oct 00 | 11.2 | 4.2 | 2 –6 SW | 220 l/ha water at 2 bar pressure with 3m boom, nozzles spaced at 0.5m, propelled by battery operated compressor at 3.7 kph |
| 6 Nov 00 | 9.6 | 4.4 | 3 –6 NE | |
| 14 Dec 00 | 7.9 | 2.7 | 0 –3 S | |
| 30 Jan 01 | 3.7 | -0.7 | 0 –3 S | |
| 26 Feb 01 | 6.3 | -0.6 | <2 | |
| 3 April 01 | 11.8 | 5.7 | 3 –6 SW | |

b) 2001/02

| Date treated | Air temp (ºC)on day of spraying (max) | Air temp (ºC) on day of spraying (min) | Wind speed (knots) and direction at time of spraying | Application details |
|---|---|---|---|---|
| 22 Oct 01 | 15.6 | 9.6 | 4 (SW) | 220 l/ha water at 2 bar pressure propelled by battery operated compressor, using Lurmark 02-110-LD nozzles, spaced at 0.5 m on a 3.0 m boom, at 3.7 k.p.h. |
| 19 Nov 01 | 7.6 | 5.1 | 4 (NE) | |
| 8 Jan 02 | 5.0 | 2.1 | 2 (NE) | |
| 5 March 02 | 10.4 | 3.0 | 1 (NW) | |
| 5 April 02 | 15.5 | 3.8 | 6 (NE) | |

c) 2002/03

| Date and time treated | Air temp (ºC) at time of application[1] | Max. air temp (ºC)on day of spraying [1] | Min. air temp (ºC) on day of spraying [1] | Wind speed (k/hr) at time of spraying | Application details |
|---|---|---|---|---|---|
| 4 Nov, 8:40 | 7 | 12 | 5.5 | 2 | 220 l/ha water at 2 bar pressure, using Lurmark 02-110-LD or 02 Pnuejet nozzles, spaced at 50 cm on a 3.0 m boom, at 3.7 k/hr |
| 18 Dec, 14:40 | 5.2 | 5.2 | 1.2 | 2 | |
| 16 Jan, 8:40 | 2.8 | 8 | 2.3 | 1.5 | |
| 14 Feb, 8:20 | * | * | * | 4 | |

[1] From on-site met. station * met. station not operating

## Appendix 2

**List of publications and technology transfer activities relating to PASSWORD project (LK0917)**

### Refereed papers

Evans, N., Baierl, A., Brain, P., Welham, S.J.& Fitt, B.D.L. (2003). Spatial aspects of light leaf spot (*Pyrenopeziza brassicae*) epidemic development on winter oilseed rape (*Brassica napus*) in the United Kingdom. *Phytopathology* **93**: 657-665.

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Spray early and spray twice. Arable Farming 22 October 2002 p. 8 &10

Let autumn downpours dictate phoma tactics. Farmers Weekly 25 October 2002 p.56.

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Keep watch for light leaf spot. Farmers Weekly 21 February 2003, p.52

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Phoma set to be a serious problem. Farmers Weekly 10 October 2003, 139 (15), p.50

Forecasting at your fingertips. Crops 18 October 2003, p. 10

What's the forecast? Crops, 20 September 2003, p. 8.

**Crop notes**

Both ADAS and SAC use information from forecasts in advisory publications and websites for farmers. Technical updates for advisers are given to advisers formally and informally.

E,g . SAC reports (300 copies each edition to farmers/advisers/trade):

Crop Protection Report, North Edition, 27 September 2001

Crop Protection Report, North Edition, 18 October 2001

Crop Protection Report, North Edition, 28 February 2002

**Project groups**

Farmer user focus group workshops 2001– CSL York (13 February) and Boxworth, Cambs (14 February)

**Web sites**

The project has its own closed web site. Free access to disease forecasts and other information is also available via Rothamsted Research, CSL and HGCA websites. DuPont and Syngenta have provided technical support on pest and disease control in oilseed rape via their websites.