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New fungicides for oilseed rape: defining dose-response activity

by

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Contents

1. ABSTRACT

Fungicides are used on over 90% of winter oilseed rape crops at a total annual cost to farmers of around £12 million. Diseases cause estimated losses of up to £80 million per annum and effective management requires integration of resistant cultivars with agronomic factors and fungicides. Cultivar resistance alone has not provided adequate control of the three most important diseases: stem canker (*Leptosphaeria maculans*), light leaf spot (*Pyrenopeziza brassicae*) and sclerotinia stem rot (*Sclerotinia sclerotiorum*). The overall aim of the project was to determine the dose-response activity of new and standard fungicides against the major diseases of oilseed rape.

Replicated field experiments with disease and yield assessments were done in farm crops of susceptible cultivars in harvest years 2006 2007 and 2008 against phoma stem canker (6 sites), light leaf spot (4 sites) and sclerotinia stem rot (6 sites). The seven or eight test fungicides were applied at 0.25. 0.50, 0.75 and 1.00 (full label) doses were applied in 200 litres water/ha by OPS knapsack sprayer to plots (40-60m^2) when phoma experiments had 10-20% plants affected and 6-8 weeks later, in November and March/April for light leaf spot and at early to mid-flowering for sclerotinia stem rot control.

Disease data was obtained from all experiments and disease severity was moderate to high in 14 experiments. Yield data was obtained from 15 experiments and significant responses to the fungicide treatments were recorded at 10 sites. The response to fungicide treatments was generally related to disease severity, with largest responses (c. 2 t/ha) being obtained where sclerotinia stem rot was very severe (80-82% plants affected). When data for three years was combined, disease control and yield responses to fungicide products and dose were all highly significant for each disease.

Prothioconazole (Proline) performed well against light leaf spot and in mixture with tebuconazole (Prosaro) gave the highest yield at phoma stem canker sites. Filan, Compass and Proline were most effective against sclerotinia, though differences between products were most evident under high disease pressure. Whilst products can perform very well at 0.5 full label dose, higher doses are required to optimise economic performance under high disease pressure. Plant growth regulatory effects contributed to yield responses and both positive and negative effects were detected. Careful interpretation of the yield data is required when using it to guide fungicide inputs on farms.

2. SUMMARY

2.1 Introduction

Fungicides are used on over 90% of winter oilseed rape crops and total expenditure by farmers is about £12 million per annum. Diseases are estimated to cause losses of up to £80 million per annum (Fitt *et al*., 1997) and effective management requires integration of resistant cultivars with agronomic factors and fungicides. Cultivar resistance alone has not provided adequate control of stem canker (*Leptosphaeria maculans*) and light leaf spot (*Pyrenopeziza brassicae*) (Gladders *et al*., 1998a) and fungicides are required in most years to prevent significant loss of yield. In addition, cultivar resistance has not been durable on widely-grown cultivars. There is no cultivar resistance to sclerotinia stem rot (*Sclerotinia sclerotiorum*) and fungicide use against it is likely to increase in 2009 after the 2007 and 2008 epidemics in England (Gladders *et al*., 2008). Fungicides are therefore an important part of disease management and are very cost-effective if their use is optimised for product, dose and timing.

Opportunities to reduce fungicide dose will depend on careful characterisation of activity against individual diseases and the ability to define requirements from a full dose-response curve. Fungicides on oilseed rape also have physiological effects on crop growth and this can result in positive or negative effects on yield. Provision of yield data is therefore an important part of the project. It is important that farmers have up-to-date information on new and existing fungicide products. This project is the first systematic study of fungicide performance in relation to products and dose.

2.2 Objectives

The overall aim of the project was to determine the dose-response activity of new and standard fungicides against the major diseases of oilseed rape.

To determine the most appropriate fungicide dose for disease control and yield response for situations with: i) Phoma leaf spot and stem canker, ii) Light leaf spot and iii) Sclerotinia stem rot.

2.3 Materials & Methods

Field experiments were done in farm crops of susceptible cultivars against phoma stem canker, light leaf spot and sclerotinia stem rot in three harvest years 2006 2007 and 2008 (Tables 2.1 and 2.2). The test fungicides were applied at 0.25. 0.50, 0.75 and 1.00 (full label). Doses were applied in 200 litres water/ha by OPS knapsack sprayer to plots (40-60m^2) when phoma experiments had 10-20% plants affected and 6-8 weeks later, in November and March/April for light leaf spot and at early to mid-flowering for sclerotinia stem rot control. There was three-fold replication of seven different fungicides (eight products were tested at light leaf spot sites) and a double untreated control. Unregistered fungicides in these experiments have been included under an HGCA code, though details will be disclosed in future when products are registered for use on oilseed rape.

Foliar diseases were assessed on 10 plants per plot 6-8 weeks after treatments and pre-harvest on 25 plants/plot (phoma sites), 100 plants/plot (stem rot sites) or using whole plot methods (light leaf spot site). At least three assessments were made on light leaf spot experiments. Disease control was evaluated using incidence (% of plants affected), % leaf area affected and stem disease index (0-100 where individual plants are scored on a 0-4 index: 0 = no disease and 4 = dead) data. Plots were combine harvested and yields adjusted to 91% dry matter.

Statistical analyses were done using Genstat with curve fitting using a negative exponential function (Paveley *et al.,* 2003). Curves for individual products show the unfitted data points and the fitted line. On occasion, a satisfactory line could not be fitted and only unfitted values are shown. Significant differences between treatments in statistical analyses are indicated by asterisks (*) using the following notation: $P<0.001$ =***, $P<0.01$ = **, $P<0.05$ = *. ns = not significant.

2.4 Results

A total of 16 experiments were completed in this project during harvest years 2006 to 2008. Disease data was obtained from all experiments and disease severity was moderate to high in 14 experiments. Yield data was obtained from all experiments except the light leaf spot experiment in Aberdeen in 2008, and significant yield responses to the fungicide treatments were recorded at 10 sites. The response to fungicide treatments was generally related to disease severity, with the largest responses (c. 2 t/ha) being obtained where sclerotinia stem rot was very severe. When data for three years was combined, disease control and yield responses to fungicide treatment were all highly significant for each disease (Table 2.3).

Product differences were evident in all experiments except for the sclerotinia experiment in Kent in 2006 and the phoma experiments at Boxworth and Terrington in 2008. Dose effects were significant in all experiments except for the light leaf spot sites at Aberdeen in 2007 and High Mowthorpe in 2008. The interaction of product x dose was only significant for yield in the light leaf spot experiment in 2006 and sclerotinia experiments in Hereford in 2006 and 2008 and disease control in Kent in 2008.

Table 2.1: Fungicide products, full doses and active ingredients used in experiments for phoma and light leaf spot 2006-2008 (P =phoma sites, L = light leaf spot sites).

Fungicide product	Full dose	Active ingredient	Experiments (2006-2008 unless indicated otherwise)
Caramba	1.2 l/ha	Metconazole (60g L^{-1})	P+L
Charisma	1.5 l/ha	Famoxadone+ flusilazole (100+106.7g L^{-1})	P+L
Folicur	1.0 l/ha	Tebuconazole (250g L^{-1})	L
Plover	0.5 l/ha	Difenoconazole (250g L^{-1})	P
Proline	0.7 l/ha	Prothioconazole (250g L^{-1})	P+L
Prosaro	1.0 l/ha	Prothioconazole+ tebuconazole (125+125g L^{-1})	P+L
Punch C (or Contrast)	0.8 l/ha	Carbendazim + flusilazole (125+250g L^{-1})	P+L

Table 2.2: Fungicide products, full doses and active ingredients used in experiments for sclerotinia 2006-2008.

Fungicide product	Full dose	Active ingredient
Amistar	1.0 l/ha	Azoxystrobin (250g L^{-1})
Compass	3.0 l/ha	Iprodione + thiophanate methyl (167+167g L^{-1})
Filan	0.5 kg/ha	Boscalid (500g kg^{-1})
Folicur	1.0 l/ha	Tebuconazole (250g L^{-1})
Proline	0.7 l/ha	Prothioconazole (250g L^{-1})
Priori Xtra	1.0 l/ha	Azoxystrobin + cyproconazole (200+80g L^{-1})
HGCAOSR2	0.5 l/ha	Not disclosed

Table 2.3: Disease severity and yield for untreated controls and mean of all fungicide treatments for cross site and year analyses in 2006-2008.

Year	Target disease	Location	Disease Severity[1]		Yield (t/ha)	
			Untreated	Treated	Untreated	Treated
2006-2008 6 sites	Phoma stem canker	Boxworth, Cambs and Terrington, Norfolk	44.03	19.98***	3.49	3.84***
2006-2008 3 sites (no yield in 2008)	Light leaf spot	Aberdeen	11.20	5.33***	3.45	3.67***
2006-2008 6 sites	Sclerotinia stem rot	Herefordshire and Kent	33.97	13.16***	3.69	4.34***
2006-2008 3 sites	Sclerotinia stem rot	Herefordshire	46.68	18.41***	2.56	4.07***
2006-2008 3 sites	Sclerotinia stem rot	Romney Marsh, Kent	19.26	7.92***	3.32	3.71***

[1] Disease index (0-100) for stem canker and sclerotinia stem rot pre-harvest; % leaf area affected for light leaf spot (mean of three assessments per year in Scotland) $P<0.001$ =***

2.4.1 Phoma (Figures 2.1, 2.2)

The severity of phoma A leaf spotting about 6 weeks after the first fungicide treatments showed significant differences between years, sites, fungicides, dose and year x dose, but no treatment x dose interaction. Disease severity was greatest in 2007. Proline and Prosaro had less severe spotting than Charisma and Punch C, whilst Plover and Caramba did not differ from other products. Stem canker severity showed significant differences between years, sites, fungicides treatments dose and year x dose but no treatment x dose interaction. The annual mean canker indices for 2006, 2007 and 2008 were 24.1, 31.3 and 10.2 respectively. Proline, Plover and Prosaro were the most effective products. Caramba had more severe canker (index 24.0) than all the other products (index range 17.5-21.4; untreated index 44.0) but still gave acceptable stem canker control. The differences between each dose were significant and canker index decreased from 24.5 at 0.25 dose to 16.3 at full dose.

Yields showed significant differences between fungicide treatments, dose and year x dose, but not for sites or treatment x dose interactions. The annual mean yields for

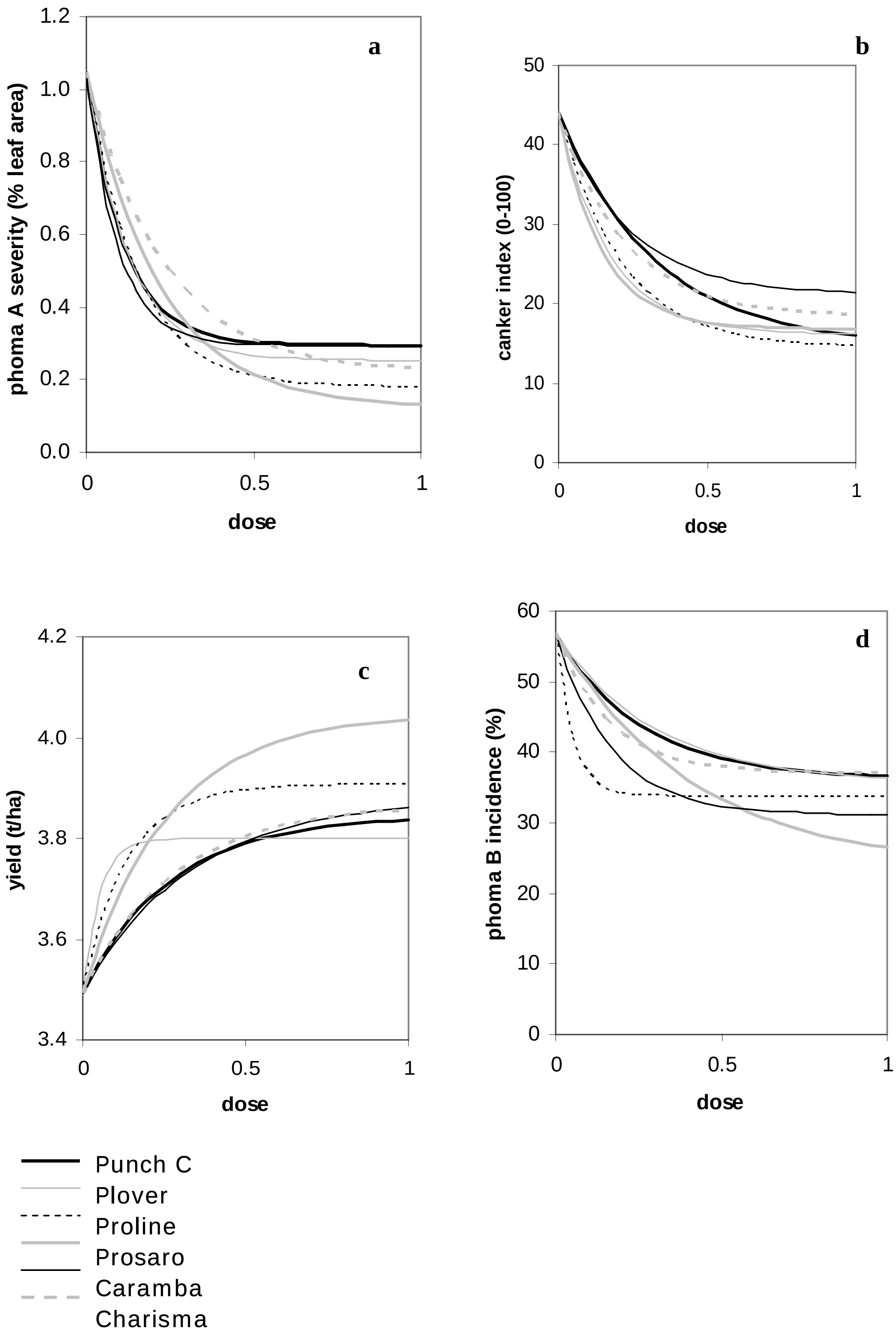


Figure 2.1: Mean data from phoma trials across three years (2006-2008) and two sites (ADAS Boxworth and ADAS Terrington): (a) phoma A leaf spot severity at first assessment; (b) canker index at final assessment; (c) yield; (d) phoma B incidence at first assessment**.**

2006, 2007 and 2008 were 4.03, 3.34 and 4.08 t/ha respectively. Boxworth and Terrington had similar yields at 3.78 and 3.85 t/ha respectively. All the products increased yields, with Prosaro giving a greater yield (3.97 t/ha) than all the other products (range 3.79-3.80 t/ha) except Proline (3.89 t/ha). All doses increased yield but there was no significant increase above 0.50 dose. The greatest yield was 3.90 t/ha at 0.75 dose.

Phoma B leaf spot incidence (Fig. 2.1d) at the first assessment in late November or early December showed significant effects for control, year, fungicide, dose, but no fungicide x dose interactions. Its incidence was greater in harvest year 2007 (75% plant affected) than in 2006 (34% plants affected) and 2008 (4% plants affected). Treatments decreased incidence from 57% plants affected to 36%. Prosaro, Proline and Caramba gave better control than Charisma, Punch C and Plover, though differences were small (range of incidence 33% to39% plants affected). Control improved as dose increased, with incidence decreased from 39% plants affected at 0.25 dose to 31% at full dose. Full dose was more effective than all the other doses. Phoma B severity was very low (0.01% leaf area affected) and no product differences were found.

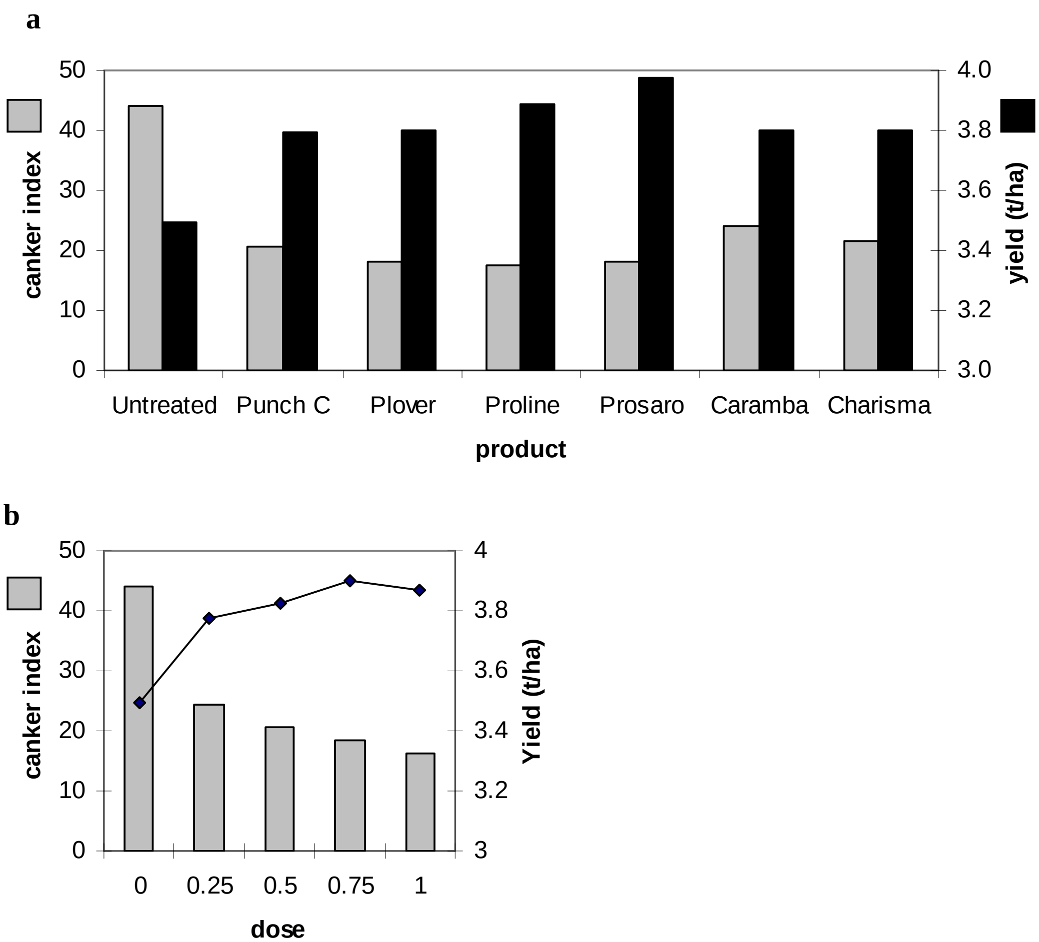


Figure 2.2: Mean data from phoma trials across three years (2006-2008) and two sites (ADAS Boxworth and ADAS Terrington), showing canker index (0-100) and yield (t/ha): (a) data averaged across doses for each product; (b) data averaged across products for each dose.

2.4.2 Light leaf spot (Figures 2.3, 2.4)

Only the data from the Aberdeen sites was included in the three year analyses and yield data were only available for 2006 and 2007. The severity of light leaf spot averaged over three assessments in spring each year showed significant differences between years, fungicides, dose and year x fungicide, but no treatment x dose interaction. Mean severity was 6.8% leaf area affected in 2006, 6.6% in 2007 and 5.2% in 2008, whilst untreated means were 12.3%, 13.0% and 8.3% respectively. Proline gave better control of light leaf spot than all the other treatments and Prosaro was better than all the remaining products except Folicur. Overall, untreated levels were 11.2% leaf area affected and treated severity 5.3%. Disease severity was decreased progressively as dose increased from 6.1% area affected at 0.25 dose to 4.6% at full dose. Full dose was significantly more effective than half dose. Yields showed significant differences between control in the two years, fungicide treatments, and for control x treatment x dose interactions, but not for dose. Mean yields were 3.49 t/ha in 2006 and 3.79 t/ha in 2007. Untreated yield averaged 3.45 t/ha compared with 3.67 t/ha for all treatments. Dose trends between 0.25 and full dose were from 3.64 to 3.71 t/ha. Proline (3.92 t/ha, a response of 0.47 t/ha) gave a significantly higher yield than all the other products except Prosaro (3.82 t/ha). At High Mowthorpe in 2008, light leaf spot severity was low and there were no significant differences between products or doses for disease control. Fungicides increased plant height in spring. Folicur, Caramba and Prosaro gave the highest yields, though these were not significantly different from Proline.

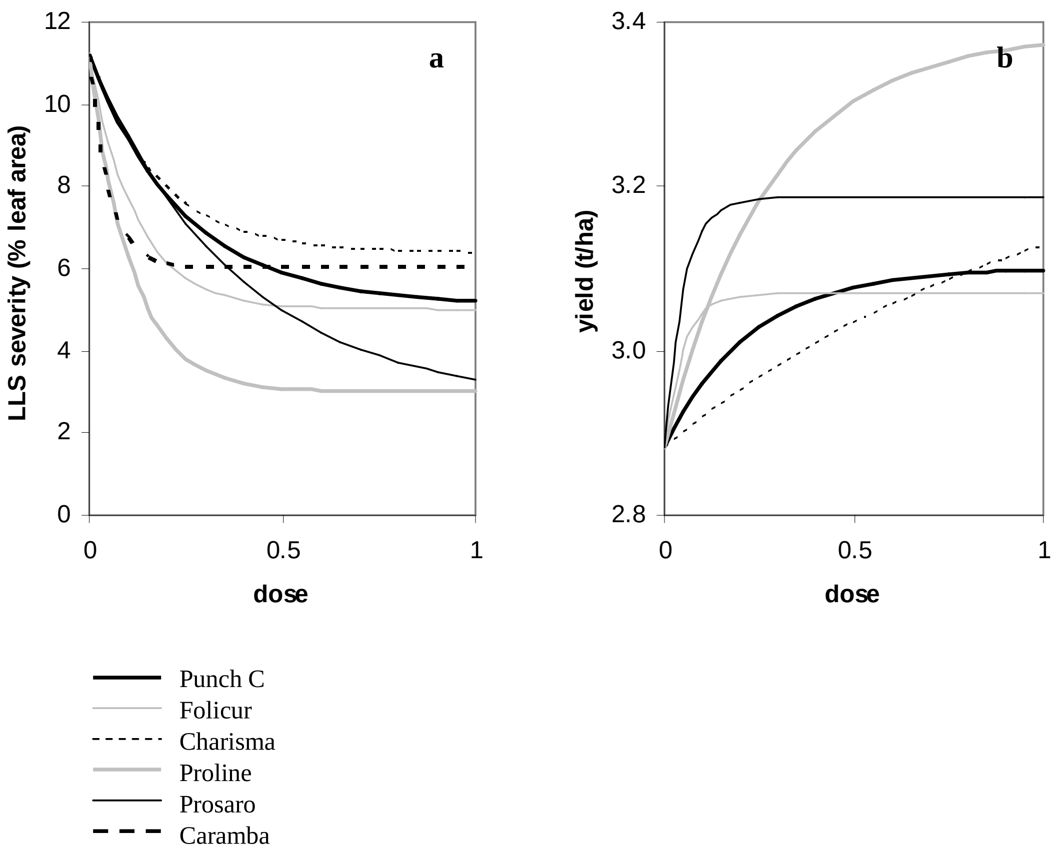


Figure 2.3: Mean data from light leaf spot trials across three years (2006-2008) at SAC, Aberdeenshire: (a) light leaf spot severity; (b) yield [curve fitting was not possible for Caramba yield].

2.4.3 Sclerotinia (Figures 2.5, 2.6)

The combined data on sclerotinia incidence from all six experiments showed highly significant effects from year, site, fungicide, dose and their interactions except for fungicide x dose interactions. Overall fungicides decreased incidence from 44% to 22%. Products were ranked in order of efficacy: Filan, Proline>Compass>Amistar, Folicur, Priori Xtra. Each increase in dose gave a significant improvement in control with incidence decreasing from 27% at 0.25 dose to 17% at full dose.

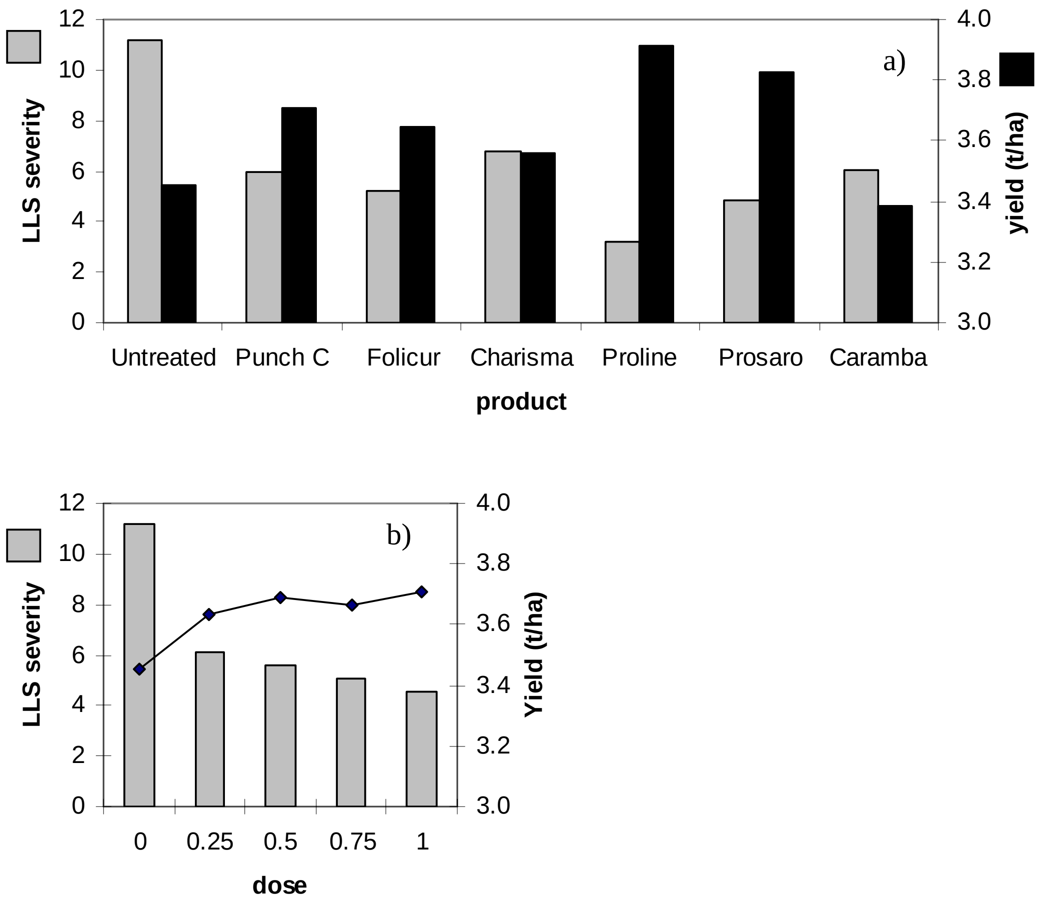


Figure 2.4: Mean data from light leaf spot trials across three years (2006-2008) at SAC, Aberdeenshire, showing light leaf spot severity (% leaf area) and yield (t/ha) (yield for 2006 and 2007 only: (a) data averaged across doses for each product; (b) data averaged across products for each dose.

The combined data on sclerotinia severity index from all six experiments showed highly significant effects from year, site, fungicide, dose and their interactions except for fungicide x dose interactions. The Hereford sites averaged 20.4 sclerotinia compared with 8.3 in Kent. Overall fungicides decreased incidence from 33.7 to 13.0.

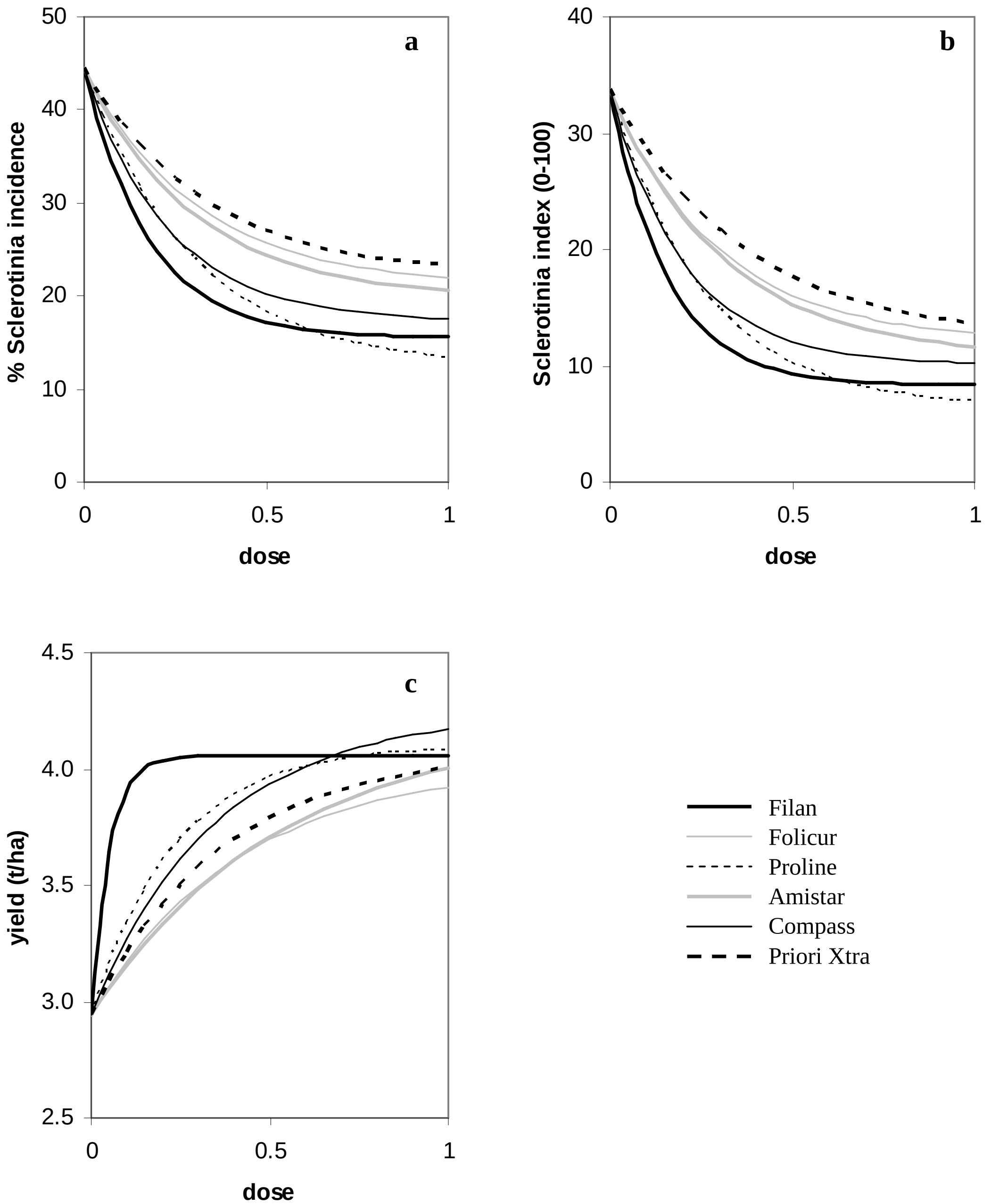


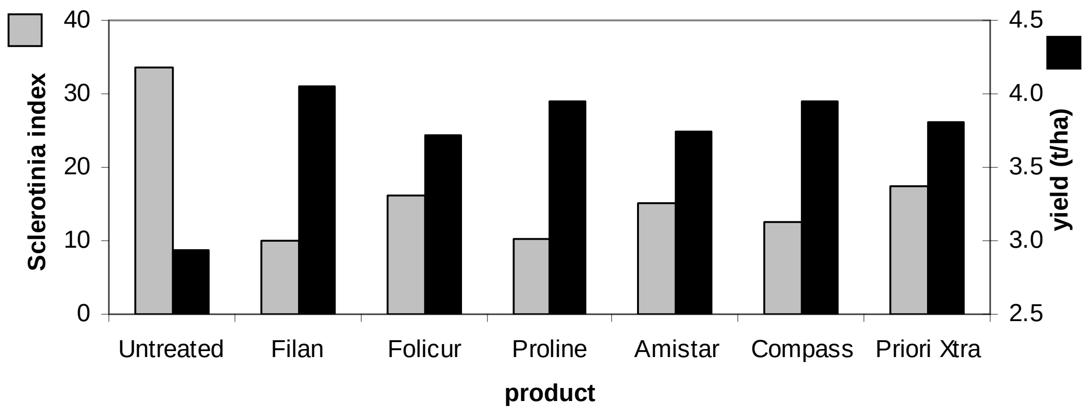
Figure 2.5: Mean data from Sclerotinia trials across three years (2006-2008) and two sites (Romney Marsh and ADAS Rosemaund): (a) Sclerotinia incidence at final assessment; (b) Sclerotinia index at final assessment; (c) yield.

Products were ranked in order of efficacy as Filan (index 9.9), Proline>Compass>Amistar, Folicur, Priori Xtra (index 17.3) – identical to the incidence data. Each increase in dose gave a significant improvement in control with index decreasing from 17.5 at 0.25 dose to 9.4 at full dose.

The yield from Hereford sites averaged 3.97 t/ha compared with 3.68 t/ha in Kent. Products were ranked in order of yield as Filan, Compass, Proline> Priori Xtra, Amistar, Folicur Each increase in dose gave a significant improvement in control up to 0.75 dose with no additional benefit at full dose. Untreated yield at the Hereford sites was 2.56 t/ha and the mean treated yield 4.07 t/ha, a response of 1.51 t/ha. Products were ranked in the order: Filan (4.36 t/ha)> Proline, Compass> Priori Xtra, Amistar> Folicur (3.69 t/ha). There were significantly increased yields with dose up to 0.75 dose and then no further increase at full dose. The responses ranged from 1.11 t/ha at 0.25 dose up to 1.74 t/ha at 0.75 dose.

There was a significant yield response overall in Kent where untreated yield averaged 3.32 t/ha and treated yield was 3.71 t/ha. There were no significant yield differences between products (range 3.64-3.76 t/ha) or doses (range 3.63-3.74 t/ha). Clearly, products performed quite differently at the Hereford site.

a



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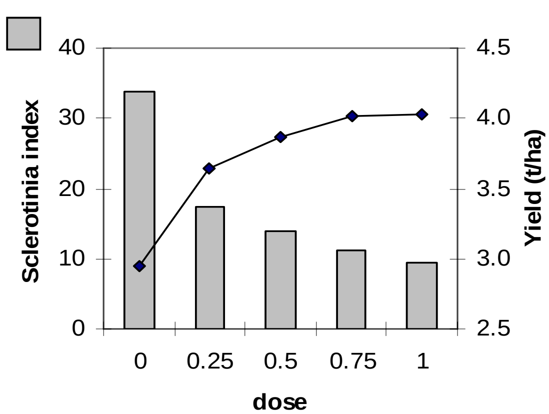


Figure 2.6: Mean data from Sclerotinia trials across three years (2006-2008) and two sites (Romney Marsh and ADAS Rosemaund), showing Sclerotinia index (0-100) and yield (t/ha): (a) data averaged across doses for each product; (b) data averaged across products for each dose.

2.5 Discussion

Products have been exposed to testing disease pressure and the project has therefore provided detailed new information on fungicide efficacy and impact on yield. There has been previous work comparing full and half doses, but no systematic study of products for a range of doses. The oilseed rape protocols with one or two fungicide applications provide valuable yield response data as other diseases are kept at low levels by site selection or oversprays. The yield effects are important as it is clear that responses relate to both disease control and physiological effects on the plant. The latter may have positive or negative effects and influence the economic benefits of treatments.

The number of experiments completed for each disease is still small and careful interpretation of yield benefits from treatments is required before selecting appropriate doses and products for use on farms. For example, the benefits from metconazole in stem canker trials were associated with stem canker control and plant growth regulatory effects on medium to large plants in autumn and these may not occur in crops where plants are small. Similarly the benefits may be larger in dry summers if treatments lead to improved rooting at depth.

Generally, a dose at 0.5 rate is robust for phoma control and this rate is widely used on farms (Garthwaite *et al.,* 2007). The data from 2006/07 provides support for use of products at 0.75 dose where crops have early infection (including cotyledons) and have disease levels well above threshold. Data for light leaf spot control are more limited, but doses of Proline should be kept about 0.5 dose for yield response. Site and variety may also be important for the economic performance of products, though the effects of these factors are often smaller than seasonal variation which is both large and difficult to predict (see PASSWORD project, Gladders *et al*., 2006).

The sclerotinia products had similar rankings for disease control under different disease pressures at the sites in Kent and Hereford. However there were differences between these sites in dose responses for yield. If products are applied under ideal conditions or low disease pressure then it may not be possible to statistically separate commercial products.

2.6 Conclusions and implications for levy payers

- Independent data are now available for disease control and yield response for the three most important diseases of winter oilseed rape: phoma stem canker, light leaf spot and sclerotinia stem rot.

- Under moderate or severe disease pressure, significant differences in product performance were evident for disease control and yield response. However, these differences were usually small. Under low disease pressure, there were no significant differences between product and no dose effects.

- The yield response data should be interpreted carefully in relation to disease development, disease severity, location, crop and environmental factors.

- Prothioconazole was identified as a significant new fungicide with strong performance against all three target diseases. It performed better than established products for light leaf spot control and yield in the Aberdeen area.

- All products gave good control of phoma leaf spot and stem canker. Caramba gave weaker control of stem canker than other products, but performed as well as established products on yield. Prosaro gave a higher yield than all other products except Proline and this was associated with pant growth regulatory effects as well as disease control.

- Whilst 0.5 dose was robust for phoma control, higher doses (0.75 dose) were beneficial against early and severe leaf spotting.

- Light leaf spot was difficult to control with autumn + late winter programmes. Yield was decreased by high doses of some products with plant growth regulatory activity in Scotland. Further data is required to define product and dose effects in England.

- Control of very severe sclerotinia stem rot gave yield responses of >2 t/ha, with 0.75-full dose being optimal for yield. Control of moderate epidemics resulted in smaller responses (c. 0.5 t/ha) and dose effects were not significant. The economics of these treatments should also consider disease control efficacy as this affects sclerotial returns and hence future disease risk.

- Fungicides applied for sclerotinia control at early to mid-flowering did not protect crops against infection at the end of flowering. Two sprays for sclerotinia control may be required to achieve good control of sclerotinia at high risk sites.

- Up-to-date information on new products should enable strategies to protect products against the development of fungicide resistant strains to be deployed more effectively. Base-line data will enable shifts in product performance or fungicide sensitivity to be detected more readily.

- The various dose-response curves can be exploited to improve selection of fungicide treatments and improve margins over input costs.

3. TECHNICAL DETAIL

3.1 Introduction

Fungicides are used on over 90% of winter oilseed rape crops and total expenditure by farmers is about £12 million per annum. Diseases are estimated to cause losses of up to £80 million per annum (Fitt *et al*., 1997) and effective management requires integration of resistant cultivars, agronomic factors and fungicides. Cultivar resistance alone has not provided adequate control of stem canker (*Leptosphaeria maculans*) and light leaf spot (*Pyrenopeziza brassicae*) (Gladders *et al*., 1998a) and fungicides are required in most years to prevent significant loss of yield. In addition, cultivar resistance has not been durable on widely-grown cultivars. There is no cultivar resistance to sclerotinia stem rot (*Sclerotinia sclerotiorum)* and fungicide use against it has increased after the 2007 epidemic (Gladders *et al*., 2008). Cultivar resistance alone has not provided adequate control of stem canker and light leaf spot (Gladders *et al*., 1998a) and fungicides are required in most years to prevent significant loss of yield. In addition, cultivar resistance has not been durable on widely grown cultivars. Resistance to stem canker based on a single major gene has been overcome within three years of commercial production in both France and Australia (Sprague *et al*., 2005). Fungicides are therefore an important part of disease management when disease pressure is high. Their contribution and value is expected to increase if minimum tillage and more intensive rotations (e.g. alternating first wheat crops and winter oilseed rape) are more widely adopted. Fungicide treatments are very cost-effective if their use is optimised for product, dose and timing (Gladders *et al*., 1998a; 1998b; 2004).

Phoma stem canker (*Leptosphaeria maculans*), light leaf spot (*Pyrenopeziza brassicae*) and stem rot (*Sclerotinia sclerotiorum*) are the most damaging diseases of oilseed rape in the UK (Fitt *et al.,* 1997 and see disease surveys at www.cropmonitor.co.uk). Cultivars with good resistance to stem canker and light leaf spot are available, but there are no cultivars available with resistance to stem rot. Fungicides are widely used to control these diseases. In 2006, 94% of oilseed crops were sprayed with fungicide and treated crops received an average of 2.1 spray applications and 3.0 active ingredients (Garthwaite *et al*., 2007). The annual cost of fungicides applied to oilseed rape in the UK is now at least £15 million. Understanding the effectiveness of fungicide products for disease control and effects on yield is important for decision making. This is particularly important for new products as they are taken up quickly by farmers (Hardwick *et al*., 2002). This paper reviews fungicide performance studies of the main commercial products against stem canker, light leaf spot and stem rot from the second year of a three year study of products used on oilseed rape.

Recent research has focussed on timing of treatments at half dose and this has identified the importance of autumn sprays for control of phoma leaf spot (and hence the canker phase) and early control of light leaf spot (Gladders *et al*., 2004). For light leaf spot, fungicides applied in spring can produce benefits of >1 t/ha. Fungicides are used on about 40% of crops for sclerotinia control, but many treatments are not directly cost-effective because yield responses are small. There is strong interest from farmers to use low doses of fungicide, but no recent independent data to confirm their effectiveness. The Defra Pesticide Usage survey of 2002 showed that the major fungicides in oilseed rape were used at 0.51 to 0.60 of full label dose (Garthwaite *et al*., 2003), though doses above 0.5 are often associated with plant growth regulation or severe light leaf spot. Cereal fungicides are assessed prior to commercial use in the Appropriate Fungicide Doses Network (HGCA Project 2496) with dose response curves widely promoted to the industry. There is no comparable data for oilseed rape fungicides in England (and only for two fungicides against light leaf spot in Scotland from OS63).

A number of new fungicides have recently been launched or are under development for oilseed rape and independent appraisal is now timely. There is concern that existing fungicides are likely to be affected by fungicide resistant strains (e.g. light leaf spot and triazoles in Scotland (Burnett, 2003); mbc resistance is widespread in sclerotinia in France (Penaud et al., 2003) and therefore new fungicide chemistry is required for effective resistance management strategies. There are potential benefits from fungicides affecting the physiology of the crop through plant growth regulation, improved rooting and canopy greening effects. Such effects may affect the profitability of treatments and independent information is required to guide farmers on the likely occurrence of these benefits.

There have been some previous studies to compare fungicides, though some of these were done over 10 years ago. Previous projects funded by HGCA have comparisons of fungicides mainly at full and half dose (e.g. Project Report OS28: Roles of varieties and fungicides in managing light leaf spot and canker in winter oilseed rape (reported in 1998); Project Report OS63: Light leaf spot (*Pyrenopeziza brassicae*) in oilseed rape: extent of triazole resistance in Scotland; fungicide strategies (reported in 2003) (light leaf spot data is from Scotland only). Defra-funded studies on dose and number of applications targeted stem canker during 1993-1997 (Gladders *et al*., 1998b). Agrochemical manufacturers have sponsored some experiments with new fungicides, but commercial comparisons are usually at full dose. The project will be supported by manufacturers providing new products for inclusion against individual pathogens. New fungicide products to evaluate in this project include Amistar, Caramba (for phoma and light leaf spot), Charisma, Filan, Proline, Prosaro and numbered products awaiting approval. Standard products included Folicur, Plover and Punch C.

Guidance on disease management and use of fungicides has been developed in the PASSWORD decision support system. Users have identified fungicide product and dose information as an important additional requirement (Gladders *et al*., 2004) Datasets available for fungicides are limited to only two or three products per disease and these do not have dose-response curves. Opportunities to reduce fungicide dose will depend on careful characterisation of curative and protectant activity against individual diseases and the ability to define requirements from a full dose-response curve. Fungicides on oilseed rape also have physiological effects on crop growth and this can result in positive or negative effects on yield. Provision of yield data is therefore an important part of the project. It is important that farmers have up-to-date information on new and existing fungicide products. This project is the first systematic study of fungicide performance in relation to products and dose.

3.1.1 Objectives

The overall aim of the project was to determine the dose-response activity of new and standard fungicides against the major diseases of oilseed rape.

To determine the most appropriate fungicide dose for disease control and yield response for situations with: i) Phoma leaf spot and stem canker, ii) Light leaf spot and iii) Sclerotinia stem rot.

3.2 Materials & Methods

Field experiments were done in farm crops of susceptible cultivars against phoma stem canker, light leaf spot and sclerotinia stem rot in three harvest years 2006 2007 and 2008 (Table 1). The test fungicides (see Tables 2 and 3) were applied at 0.25, 0.50, 0.75 and 1.00 (full label), doses were applied in 200 litres water/ha by OPS knapsack sprayer to plots (40-60m^2) when phoma experiments had 10-20% plants affected or by appropriate growth stage for other diseases (Table 1). There was three-fold replication of seven different fungicides (eight products were tested at light leaf spot sites) and a double untreated control. Unregistered fungicides in these experiments have been included under an HGCA code, though details will be disclosed in future when products are registered for use on oilseed rape.

Foliar diseases were assessed on 10 plants per plot 6-8 weeks after treatments and pre-harvest on 25 plants/plot (phoma sites), 100 plants/plot (stem rot sites) or using whole plot methods (light leaf spot site). At least three assessments were made on light leaf spot experiments. Disease control was evaluated using incidence (% of plants affected), % leaf area affected and stem disease index (0-100 where individual plants are scored on a 0-4 index: 0 = no disease and 4 = dead) data. Plots were combine harvested and yields adjusted to 91% dry matter.

Statistical analyses were done using Genstat with curve fitting using a negative exponential function (Paveley *et al.,* 2003). Curves for individual products show the unfitted data points and the fitted line. On occasion, a satisfactory line could not be fitted and only unfitted values are shown. Significant differences between treatments in statistical analyses are indicated by asterisks (*) using the following notation: $P<0.001$ =***, $P<0.01$ = **, $P<0.05$ = *. ns = not significant.

Table 1: Sites, cultivars and treatment dates for fungicide experiments in 2006-2008.

Year	Target disease	Location	Date sown; harvested	Cultivar	Application date (growth stage)
2006	Phoma stem canker	Boxworth, Cambs	27 August 2005; 20 July 2006	Labrador	18 October, GS 1,5-1,6 13 December, GS 1,14
2006	Phoma stem canker	Terrington, Norfolk	7 September 2005; 18 July 2006	Winner	1 November, GS 1,5-1,6 19 December, GS 1,12
2006	Light leaf spot	Inverurie, Aberdeen	1 September 2006; 10 August 2007	Castille	9 November, GS 1,4-1,8 20 April, GS 3,3
2006	Sclerotinia stem rot	Ocle Pychard, Herefordshire	1 September 2005; 21 July 2006	Lioness	6 May (4,5)
2006	Sclerotinia stem rot	Romney Marsh, Kent	31 August 2005; 26 July 2006	Es Astrid	11 April (4,2)
2007	Phoma stem canker	Boxworth, Cambs	4 September 2006; 17 July 2007	Winner	12 October, GS 1,5-1,6 18 December, GS 1,14
2007	Phoma stem canker	Terrington, Norfolk	10 September 2006; 27 July 2007	Winner	13 October, GS 1,5-1,6 20 November, GS 1,8
2007	Light leaf spot	Blackburn, Aberdeen	1 September 2006; 10 August 2007	Castille	7 November, GS 1,6-1,8 7 March, GS 2,1
2007	Sclerotinia stem rot	Weobley, Herefordshire	1 September 2006; 3 August 2007	Catalina	11 April (4,3)
2007	Sclerotinia stem rot	Romney Marsh, Kent	1 September 2006; 24 July 2007	Castille	11 April (4,2)
2008	Phoma stem canker	Boxworth, Cambs	20 August 2007; 29 July 2008	Winner	24 October, GS 1,7 12 December, GS 1,10-1,15
2008	Phoma stem canker	Terrington, Norfolk	28 August 2007; 1 August 2008	Winner	1 November, GS 1,8 13 December, GS 1,11
2008	Light leaf spot	Ellon, Aberdeen	1 September 2006; 10 August 2007	Castille	14 November, GS 1,6-1,8 3 March, GS 2,1
2008	Light leaf spot	High Mowthorpe Malton, N. Yorks	6 September 2007; 16 September 2008	Castille	26 November, GS 1,3 27 March, GS 2,0
2008	Sclerotinia stem rot	Weobley, Herefordshire	4 September 2007; 14 August 2008	Castille	1 May (4,5)
2008	Sclerotinia stem rot	Romney Marsh, Kent	7 September 2007; 24 July 2008	Es Astrid	25 April (4,4)

Table 2: Fungicide products, full doses and active ingredients used in experiments for phoma and light leaf spot 2006-2008.

Fungicide product (designation in reports)	Full dose	Active ingredient	Experiments (2006-2008 unless indicated otherwise) P= phoma sites L = light leaf spot sites
Caramba	1.2 l/ha	Metconazole (60g L^{-1})	P+L
Charisma	1.5 l/ha	Famoxadone+ flusilazole (100+106.7g L^{-1})	P+L
Folicur	1.0 l/ha	Tebuconazole (250g L^{-1})	L
Plover	0.5 l/ha	Difenoconazole (250g L^{-1})	P
Proline	0.7 l/ha	Prothioconazole (250g L^{-1})	P+L
Prosaro	1.0 l/ha	Prothioconazole + tebuconazole (125+125g L^{-1})	P+L
Punch C (or Contrast)	0.8 l/ha	Carbendazim + flusilazole (125+250g L^{-1})	P+L
HGCAOSR1	2.0 l/ha	Not disclosed	P 2006
HGCAOSR2	0.5 l/ha	Not disclosed	L 2006 and 2007
HGCAOSR4	0.5 l/ha	Not disclosed	P+L 2007and 2008
HGCAOSR5	1.25 l/ha	Not disclosed	L 2008 only

Table 3: Fungicide products, full doses and active ingredients used in experiments for sclerotinia 2006-2008.

Fungicide product (designation in trial plans and reports)	Full dose	Active ingredient
Amistar	1.0 l/ha	Azoxystrobin (250g L^{-1})
Compass	3.0 l/ha	Iprodione + thiophanate methyl (167+167g L^{-1})
Filan	0.5 kg/ha	Boscalid (500g kg^{-1})
Folicur	1.0 l/ha	Tebuconazole (250g L^{-1})
Proline	0.7 l/ha	Prothioconazole (250g L^{-1})
Priori Xtra	1.0 l/ha	Azoxystrobin + cyproconazole (200+80g L^{-1})
HGCAOSR2	0.5 l/ha	Not disclosed

3.3 Results

A total of 16 experiments were completed in this project during harvest years 2006 to 2008. Disease data was obtained from all experiments and disease severity was moderate to high in 14 experiments (Table 4). Yield data was obtained from 15 experiments and significant responses to the fungicide treatments were recorded at 10 sites (Table 5). The response to fungicide treatments was generally related to disease severity, with the largest responses (c. 2 t/ha) being obtained where sclerotinia stem rot was very severe. When data for three years was combined, disease control and yield responses to fungicide treatment were all highly significant for each disease (Table 6).

Product, dose and the interaction of product x dose effects are summarised in Table 7. Replication of treatments usually differed from that of the untreated control and different standard errors apply for untreated v product or dose comparisons and where products or doses are compared. Product differences were evident in all experiments except for the sclerotinia experiment in Kent in 2006 and the phoma experiments at Boxworth and Terrington in 2008. Dose effects were significant in all experiments except for the light leaf spot sites at Aberdeen in 2007 and High Mowthorpe in 2008. The interaction of product x dose was only significant for yield in the light leaf spot experiment in 2006 and sclerotinia experiments in Hereford in 2006 and 2008 (Table 7) and disease control in Kent in 2008 (Table 6).

The cross-site analyses for each disease identified highly significant differences between products and doses (Table 8). There were significant differences in yield responses between products for all diseases though no differences were found in sub-set of sclerotinia experiments on the Romney Marsh (Table 9). There were significant effects of dose on yield at phoma and sclerotinia sites, but no dose effects against light leaf spot. The light leaf spot yields are based only two years data and are too limited to draw firm conclusions about dose effects. Fungicide x dose interactions were significant for yield and sclerotinia in the overall six site analysis and at the Hereford site (Table 9).

Table 4: Disease severity and yield for untreated controls and mean of all fungicide treatments for individual fungicide experiments in 2006-2008.

Year	Target disease	Location	Disease Severity[1]		Yield (t/ha)	
			Untreated	Treated	Untreated	Treated
2006	Phoma stem canker	Boxworth, Cambs	40.83	17.71***	4.06	4.28ns
2006	Phoma stem canker	Terrington, Norfolk	55.67	26.36***	3.38	3.83***
2006	Light leaf spot	Inverurie, Aberdeen	12.32	6.10***	3.18	3.54***
2006	Sclerotinia stem rot	Ocle Pychard, Herefordshire	18.46	4.10***	3.69	4.34***
2006	Sclerotinia stem rot	Romney Marsh, Kent	2.10	1.32ns	3.47	3.59ns
2007	Phoma stem canker	Boxworth, Cambs	60.50	34.36***	2.90	3.36***
2007	Phoma stem canker	Terrington, Norfolk	49.33	24.26***	3.04	3.39*
2007	Light leaf spot	Blackburn, Aberdeen	13.02	5.74***	3.73	3.80ns
2007	Sclerotinia stem rot	Weobley, Herefordshire	81.75	32.21***	2.18	4.16***
2007	Sclerotinia stem rot	Romney Marsh, Kent	29.58	6.01***	2.79	3.37*
2008	Phoma stem canker	Boxworth, Cambs	25.00	13.18***	3.50	3.79ns
2008	Phoma stem canker	Terrington, Norfolk	32.83	4.03***	4.09	4.41***
2008	Light leaf spot	Ellon, Aberdeen	8.25	4.74***	No yield data	
2008	Light leaf spot	High Mowthorpe Malton, N. Yorks	1.22	0.46**	2.57	2.72 ns
2008	Sclerotinia stem rot	Weobley, Herefordshire	45.83	18.91***	1.82	3.72***
2008	Sclerotinia stem rot	Romney Marsh, Kent	26.08	16.44***	3.71	4.17**

[1] Disease index (0-100) for stem canker and sclerotinia stem rot pre-harvest; % leaf area affected for light leaf spot (mean of three assessments per year in Scotland)

$P<0.001$ =***, $P<0.01$ = **, $P<0.05$ = *. ns = not significant

Table 5: Disease severity and yield for untreated controls and mean of all fungicide treatments for cross site and year analyses in 2006-2008.

Year	Target disease	Location	Disease Severity[1]		Yield (t/ha)	
			Untreated	Treated	Untreated	Treated
2006-2008 6 sites	Phoma stem canker	Boxworth, Cambs and Terrington, Norfolk	44.03	19.98***	3.49	3.84***
2006-2008 3 sites (no yield in 2008)	Light leaf spot	Aberdeen	11.20	5.33***	3.45	3.67***
2006-2008 6 sites	Sclerotinia stem rot	Herefordshire and Kent	33.97	13.16***	3.69	4.34***
2006-2008 3 sites	Sclerotinia stem rot	Herefordshire	46.68	18.41***	2.56	4.07***
2006-2008 3 sites	Sclerotinia stem rot	Romney Marsh, Kent	19.26	7.92***	3.32	3.71***

[1] Disease index (0-100) for stem canker and sclerotinia stem rot pre-harvest; % leaf area affected for light leaf spot (mean of three assessments per year in Scotland)

$P<0.001$ =***

Table 6: Summary of the main effects of product, dose and product x dose interactions for disease control in individual fungicide experiments in 2006-2008.

Year	Target disease	Location	SED				
			Untreated v. product	Between products	Untreated v. dose	Between doses	Inter-action[a]
2006	Phoma stem canker	Boxworth, Cambs	2.439*	1.991*	2.258***	1.505**	3.983ns
2006	Phoma stem canker	Terrington, Norfolk	3.317***	2.708***	3.071**	2.047**	5.416ns
2006	Light leaf spot	Inverurie, Aberdeen	0.717***	0.717***	0.621**	0.507**	1.434ns
2006	Sclerotinia stem rot	Ocle Pychard, Herefordshire	1.519***	1.241***	1.407*	0.938*	2.481ns
2006	Sclerotinia stem rot	Romney Marsh, Kent	0.527ns	0.430ns	0.488*	0.325*	0.861ns
2007	Phoma stem canker	Boxworth, Cambs	3.434***	2.804**	3.179***	2.119***	5.607ns
2007	Phoma stem canker	Terrington, Norfolk	3.386*	2.765*	3.135***	2.090***	5.530ns
2007	Light leaf spot	Blackburn, Aberdeen	1.068***	1.068***	0.925ns	0.755ns	2.137ns
2007	Sclerotinia stem rot	Weobley, Herefordshire	3.644***	2.976***	3.374***	2.249***	5.951ns
2007	Sclerotinia stem rot	Romney Marsh, Kent	2.486***	2.030***	2.302***	1.543***	4.059ns
2008	Phoma stem canker	Boxworth, Cambs	1.927ns	1.573ns	1.784***	1.189**	3.147ns
2008	Phoma stem canker	Terrington, Norfolk	1.968ns	1.607ns	1.822**	1.215**	3.214ns
2008	Light leaf spot	Ellon, Aberdeen	0.502***	0.502***	0.435*	0.355*	1.005ns
2008	Light leaf spot	High Mowthorpe Malton, N. Yorks	0.300*	0.245*	0.274ns	0.173ns	0..490ns
2008	Sclerotinia stem rot	Weobley, Herefordshire	1.808**	1.476**	1.674***	1.118***	2.952ns
2008	Sclerotinia stem rot	Romney Marsh, Kent	3.240***	2.646***	3.000***	2.000***	5.291***

[a] – SED is for product comparison

[1] Disease index (0-100) for stem canker and sclerotinia stem rot pre-harvest; % leaf area affected for light leaf spot (mean of three assessments per year in Scotland)

P<0.001 =***, *P*<0.01 = **, *P*<0.05 = *. ns = not significant

Table 7: Summary of the main effects of product, dose and product x dose interactions for yield in individual fungicide experiments in 2006-2008.

Year	Target disease	Location	SED				
			Untreated v. product	Between products	Untreated v. dose	Between doses	Inter-action[a]
2006	Phoma stem canker	Boxworth, Cambs	0.147ns	0.120ns	0.091ns	0.136ns	0.241ns
2006	Phoma stem canker	Terrington, Norfolk	0.122*	0.099*	0.113ns	0.075ns	0.199ns
2006	Light leaf spot	Inverurie, Aberdeen	0.066***	0.066***	0.057**	0.046*	0.131*
2006	Sclerotinia stem rot	Ocle Pychard, Herefordshire	0.159ns	0.130ns	0.148**	0.0.98**	0.260*
2006	Sclerotinia stem rot	Romney Marsh, Kent	0.109ns	0.089ns	0.101ns	0.067ns	0.178ns
2007	Phoma stem canker	Boxworth, Cambs	0.078**	0.064**	0.072***	0.048***	0.128ns
2007	Phoma stem canker	Terrington, Norfolk	0.197*	0.161*	0.183*	0.122*	0.323ns
2007	Light leaf spot	Blackburn, Aberdeen	0.143*	0.143*	0.124ns	0.101ns	0.286ns
2007	Sclerotinia stem rot	Weobley, Herefordshire	0.130***	0.107***	0.121***	0.081***	0.213ns
2007	Sclerotinia stem rot	Romney Marsh, Kent	0.210*	0.171*	0.194ns	0.130ns	0.343ns
2008	Phoma stem canker	Boxworth, Cambs	0.191ns	0.156ns	0.177ns	0.118ns	0.312ns
2008	Phoma stem canker	Terrington, Norfolk	0.099ns	0.081ns	0.092ns	0.061ns	0.161ns
2008	Light leaf spot	Ellon, Aberdeen	No yields				
2008	Light leaf spot	High Mowthorpe Malton, N. Yorks	0.091*	0.074***	0.083ns	0.052ns	0..148ns
2008	Sclerotinia stem rot	Weobley, Herefordshire	0.157***	0.128***	0.145***	0.087***	0.257***
2008	Sclerotinia stem rot	Romney Marsh, Kent	0.261ns	0.213ns	0.242ns	0.163ns	0.427ns

[a] – SED is for product comparison

[1] Disease index (0-100) for stem canker and sclerotinia stem rot pre-harvest; % leaf area affected for light leaf spot (mean of three assessments per year in Scotland)

P<0.001 =***, *P*<0.01 = **, *P*<0.05 = *. ns = not significant

Table 8: Summary of main effects of product, dose and product x dose interactions for disease control in cross site and year analyses in 2006-2008.

Year	Target disease	Location	SED				
			Untreated v. product	Between products	Untreated v. dose	Between doses	Inter-action[a]
2006-2008 6 sites	Phoma stem canker	Boxworth, Cambs and Terrington Norfolk	1.163***	0.950***	1.097***	0.776***	2.499ns
2006-2008 3 sites	Light leaf spot	Aberdeen	0.622***	0.622***	0.568***	0.508**	1.244ns
2006-2008 6 sites	Sclerotinia stem rot	Hereford and Kent	1.606***	1.384***	1.854***	1.422***	1.629ns
2006-2008 3 sites	Sclerotinia stem rot	Hereford	1.448***	1.182***	1.340***	0.893***	2.364ns
2006-2008 3 sites	Sclerotinia stem rot	Romney Marsh, Kent	1.373***	1.121***	1.271***	0.847***	2.242ns

[a] – SED is for product comparison

[1] Disease index (0-100) for stem canker and sclerotinia stem rot pre-harvest; % leaf area affected for light leaf spot (mean of three assessments per year in Scotland)

P<0.001 =***

Table 9: Summary of main effects of product, dose and product x dose interactions control for yield in cross site and year analyses in 2006-2008.

Year	Target disease	Location	SED				
			Untreated v. product	Between products	Untreated v. dose	Between doses	Inter-action[a]
2006-2008 6 sites	Phoma stem canker	Boxworth, Cambs and Terrington, Norfolk	0.062***	0.050***	0.058*	0.041*	0.101ns
2006-2008 3 sites (no yield in 2008)	Light leaf spot	Aberdeen	0.074***	0.074***	0.067ns	0.060ns	0.148ns
2006-2008 6 sites	Sclerotinia stem rot	Hereford and Kent	0.073***	0.060***	0.068***	0.045***	0.119*
2006-2008 3 sites	Sclerotinia stem rot	Hereford	0.086***	0.071***	0.080***	0.053***	0.141***
2006-2008 3 sites	Sclerotinia stem rot	Romney Marsh, Kent	0.118ns	0.096 ns	0.109 ns	0.073 ns	0.193ns

[a] – SED is for product comparison

[1] Disease index (0-100) for stem canker and sclerotinia stem rot pre-harvest; % leaf area affected for light leaf spot (mean of three assessments per year in Scotland)

P<0.001 =***

3.3.1 Harvest year 2006

3.3.1.1 Phoma

The test crops had quite large plants in the autumn and the onset of the phoma epidemic was in early October. The Boxworth site was sprayed on 18 October when 28% plants had phoma leaf spot (GS1, 7) and Terrington was sprayed on 1 November (GS 1, 7) when 64% plants had phoma spotting. Phoma leaf spot continued to increase after treatment, affecting >90% untreated plants later in the autumn. Good control of phoma leaf spot was obtained by all products and at all doses. At Boxworth, phoma leaf spot severity was decreased from 0.66% to 0.10% when averaged over all treatments. There were no significant effects of product or dose on phoma severity on 12 December, but product, dose and product x dose interactions all had significant effects on phoma incidence. Untreated controls had 88% plants with phoma leaf spot and this was decreased to 30% (Proline) – 52% (Plover) by commercial products. At Boxworth, phoma B leaf spots affected 68% of untreated plants and 48% of treated plants, whilst Terrington had 68% of untreated and 14% of treated plants affected, both significant decreases. Product effects were significant at Terrington (range 7.5% with Caramba to 23.3% with Plover) but no dose effects were significant for phoma B at either site.

The second phoma sprays were applied on 13 December at Boxworth and 19 December at Terrington, when plants had 12-14 leaves. At the second foliar disease assessment on 29 March at Boxworth, 75% of untreated plants had phoma leaf spot compared with 24% in treated plots. At Terrington, 53% of untreated plants had phoma spotting compared with 5.8% on treated plants. Dose effects were significant with phoma incidence decreasing from 38% plants affected at 0.25 dose to 11% at full dose at Boxworth and 53% decreased to 11% at 0.25 dose and 3% at full dose at Terrington. Phoma leaf spot severity in March was 0.27% leaf area affected, decreased to 0.03% by treatments at Boxworth and from 0.27% to 0.01% at Terrington. There were no significant product or dose effects on phoma severity at either site. Phoma B spotting had declined to very low levels by this stage and there were no differences between products or doses. There were some indications that 0.25 dose was slightly weaker, but differences were not significant. Good phoma leaf spot control was maintained for 15 weeks after the December sprays in a season where winter activity was limited in cold, dry conditions. There were no significant effects of treatment on plant height in April (when plants averaged 64 cm tall), though all treatments were slightly shorter than the untreated by 0.5-4.0cm at Boxworth, but taller by 1.4-4.8cm at Terrington. Phoma stem canker affected 96% untreated plants (index 40.8) and control was satisfactory (range 53-67% plants affected; index 14.9-20.3), though taking the canker index below 25 generally does not improve yield response (Fig. 2). There was little effect of dose on stem canker control Caramba gave rather weaker stem canker control than Plover, Proline and Prosaro, but this had no significant impact on yield (Fig. 3). At Terrington, canker incidence was decreased from 96% plants affected to 60-81% by product, but was not significantly decreased by higher dose (range 71-64%). However, both product and dose significantly decreased the canker index from 55.7 to 20.3-36.2 and 28.7-21.9 respectively. Phoma stem lesions affected 89% plants at Boxworth and 65% plants at Terrington, but they were not controlled by any of the treatments.

Averaged over all fungicides, there was no significant effect of dose on yield at either site. There were differences in yield responses between sites, averaging 0. 21 t/ha at Boxworth and 0.46 t/ha at Terrington over untreated yields of 4.30 and 3.85 t/ha respectively. There were only significant product differences in yield at Terrington where Punch C gave a lower yield than Caramba, Prosaro and Proline.

3.3.1.2 Light leaf spot

Light leaf spot symptoms were found in the crop at Aberdeen in early December, four weeks after the first spray treatments were applied. Control of light leaf spot was poor with some products and this is attributed to reduced sensitivity to triazole fungicides, high disease pressure and favourable weather for light leaf spot development (which also prevented fungicide applications in winter). Fungicide effects have been examined using the mean of three assessments in March, April and May. Caramba and Punch C were the weakest of the commercial products for light leaf spot control with 7.3% leaf area affected compared with Proline at 3.7% and untreated at 12.3%. Overall, light leaf spot control data showed a significant dose-response with 0.25 dose (7.2% leaf area affected) being significantly less effective than full dose (5.4% leaf area affected). The yield data showed significant differences between products, doses and a product x dose interaction. Untreated yield was 3.18 t/ha. Proline gave the highest yield (3.90 t/ha), significantly above Prosaro (3.71 t/ha), Punch C (3.59 t/ha – note the higher doses of Punch C exceed label recommendations), Folicur (3.41 t/ha) and

Caramba (3.28 t/ha). The dose effects were small but significant showing a response of 0.25 t/ha at 0.25 dose, 0.35 t/ha at 0.50 dose and 0.40 t/ha at full dose.

3.3.1.3 Sclerotinia

There was a high incidence of sclerotinia in untreated control plots (25% plants affected; index 18.5) pre-harvest at Hereford. Most lesions were severe and caused premature ripening. In Kent, there was a low incidence (c. 0.5% plants affected) of sclerotinia and this comprised both pre-flowering infection at the stem base as well as flowering infection at the mid-plant level.

Control of sclerotinia was obtained by all products at the Hereford site (meaned for all doses). Four products gave good control (>80%). Compass and Folicur were significantly weaker than all the other products except Priori Xtra. Whilst there was significant control compared with the untreated control at all doses (meaned across fungicides), the only significant difference between individual doses was for 0.25 (8.4% sclerotinia) versus full dose (4.5% sclerotinia). The fungicide x dose interaction was not statistically significant for disease control.

At the Kent site, with low disease, there was significant control (47-59%) of mid-stem and stem base sclerotinia lesions at 0.75 and full dose, with full dose also giving better control than 0.25 and 0.50 dose. Filan and Proline gave control (70%) of mid-stem lesions, which approached significance (P=0.07). There was no control of lesions on the smaller branches.

At the Hereford site (see Figs 3.18, 3.19, 3.20, 3.21), there were significant yield differences in relation to fungicide x dose interactions and mean fungicide dose, but no differences between products averaged over all doses. The higher doses (0.75 and full dose) gave 4.94 and 4.43 t/ha respectively, 0.2-0.3 t/ha higher yield than 0.25 and 0.50 doses and were therefore cost-effective. There were large responses of up to 1.0 t/ha with individual fungicide treatments and mean responses of >0.70 t/ha for three of the products (untreated 3.69 t/ha). This is almost double the 0.46 t/ha expected if sclerotinia reduced yield by 50% on affected plants and reflected, in part, the premature ripening it caused. There were no significant effects on yield at the Kent site, though treated plots averaged 0.12 t/ha more than untreated controls.

3.3.2 Harvest year 2007

3.3.2.1 Phoma

The first fungicide treatments were applied on 12 October (32% plants with phoma leaf spot, GS 1,4-1,5)) at Boxworth and on 13 October at Terrington (55% plants with phoma leaf spot, GS 1,3-1,5). At Terrington, there was some phoma spotting on the cotyledons and very small numbers of plants developed cankers and died in the autumn.

Control of phoma leaf spot was less effective 6-9 weeks after the first spray than in the first year of the project. Plants grew rapidly in autumn 2006 in mild and wet conditions and phoma leaf spot started to re-infect fungicide treated plants after about 3 weeks. Control was obtained by all products and at all doses. There was significantly improved control at higher doses indicating that they gave better persistence in leaves (Fig. 1). At Boxworth the first assessment was done on plants samples on 17 November (5 weeks after treatment) when 100% of untreated plants had phoma leaf spot compared with 81-96% plants affected for individual fungicide products. There were significant decreases in the % leaf area affected from 2.83% in the untreated to 0.90% after fungicide treatment though product differences were not significant, ranging from 0.73% (Prosaro) to 1.1% (Caramba). Higher doses were most effective and severity decreased from 1.18% at 0.25 dose to 0.70% at full dose. Phoma B incidence was significantly decreased by fungicides from 93% to 79% with significant product, dose and product x dose effects also being identified.

The leaves became darker green within a few days of treatment application with most fungicides. The effects were most pronounced with metconazole, which also reduced the size of developing leaves.

The second fungicide treatments were applied on 18 December at Boxworth (GS 1,12, 92% of plants with phoma A, 33% plants with phoma B) and 20 November at Terrington (GS 1,08, 100% plants with phoma A). Disease progress in relation to spray timing at Boxworth is shown in Fig. 3.1.

At Boxworth, the assessment on 7 February (6 weeks after the second spray) showed 100% of untreated plants had phoma A leaf spot, but phoma B had declined and only affected 28% untreated plants. Product and dose effects were significant for both incidence (25% decrease) and severity (untreated 0.72%, treated 0.23% area affected) of phoma A. Phoma B control was significant or close to significance for the decrease in severity of leaf spotting, but not for product or dose on its incidence.

Terrington was assessed on 29 January, when phoma A affected 100% of untreated plants (1.1% leaf area affected) and phoma B 62% plants (0.01% area); these were decreased by fungicides to 55% (0.2% area) and 22% (0.003% area) respectively. There were significant effects of dose on phoma A incidence ranging from 72% at 0.25 dose to 31.4% at full dose and comparable effects on phoma B 28% at 0.25 dose to 13% at full dose. Product differences were significant only for phoma A incidence: ranging from 38% plants affected with Proline to 66% plants affected with Plover.

Control of phoma stem canker was rather weaker than in 2006 and required higher doses to decrease the canker index below 25. At Boxworth, 98% of untreated plants had stem canker (index 60.5) compared with an average of 85% after fungicide treatment (index 34.0). The improvement in stem canker control by increasing dose from 0.25 (index 43.0) to 0.50 (index 33.4) and from 0.50 to 1.00 (index 28.8) was highly significant at Boxworth. Caramba (index 38.7) gave rather weaker stem canker control than Plover (index 32.0), Proline (index 31.4) and Prosaro (index 27.7). Sclerotinia affected 8.0 % of plants in untreated plots and 2.4% on average in all fungicide treated plots, a significant difference. There were no differences between treatments against powdery mildew on stems and pods.

There were site differences with responses averaging 0.46 t/ha at Boxworth and 0.35 t/ha at Terrington over untreated yields of 2.90 and 3.04 t/ha respectively. Yield responses were slightly larger than in 2006 and averaged 0.46 t/ha over all fungicides at Boxworth and 0.35 t/ha at Terrington. The best treatments gave yield responses of 0.7 t/ha and were very profitable. All products gave significant yield increases at Boxworth (range 0.33-0.58 t/ha) and the mean yields of Proline and Prosaro were 0.13-0.14 t/ha greater than other products. There was a significant effect of dose on yield, with responses averaging 0.32 t/ha at 0.25 dose to 0.57 t/ha at full (1.00) dose at Boxworth compared with 0.13 t/ha and 0.45 t/ha respectively at Terrington. Product differences for yield narrowly missed significance at Terrington (P=0.051).

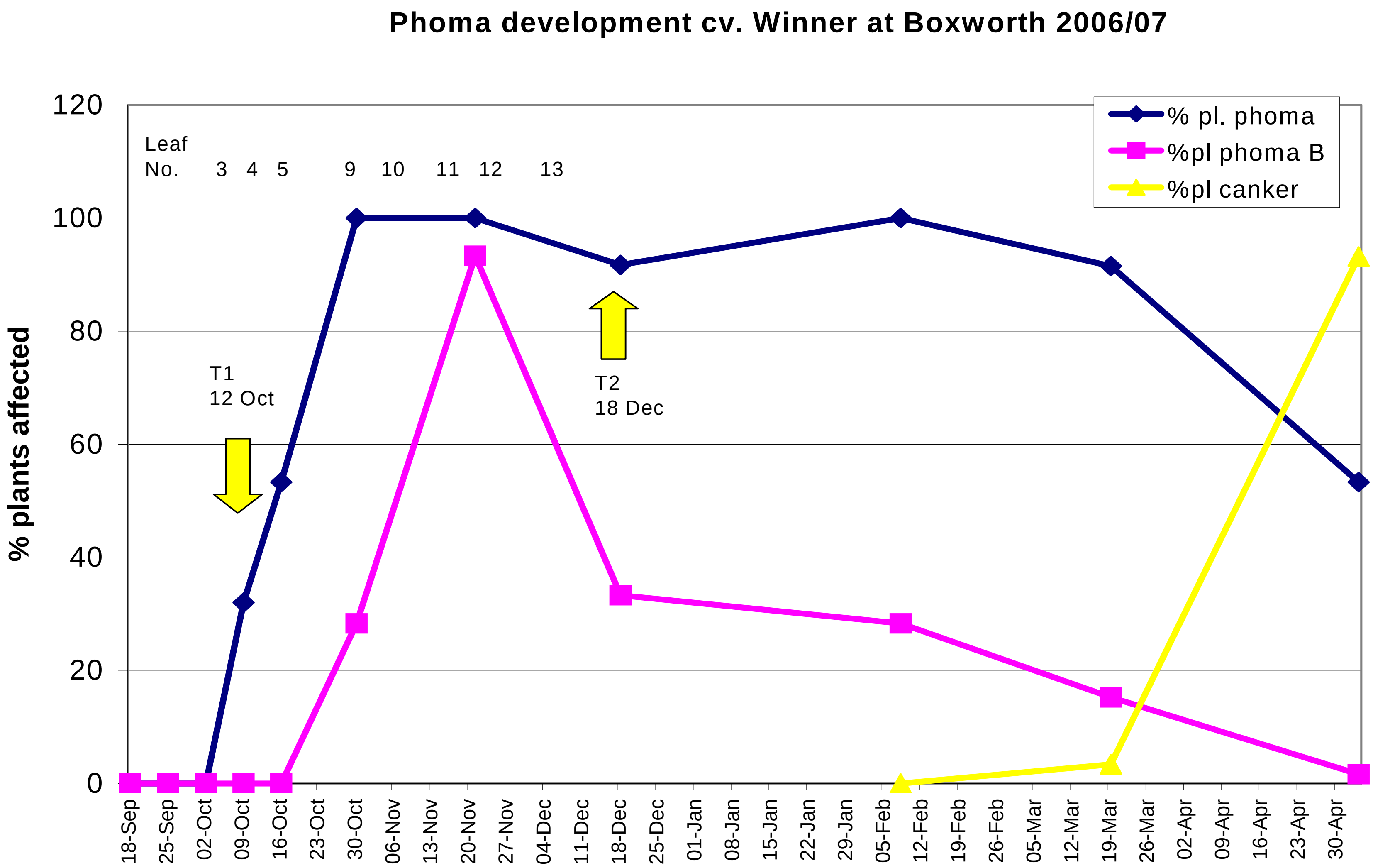


Fig. 3.1: Disease progress for phoma A and phoma B on leaves and early stem canker on stems, Boxworth 2006/07.

3.3.2.2 Light leaf spot

Light leaf spot symptoms were found in the crop at Aberdeen in mid-January and increased quite rapidly over the next month to affect 4.6% leaf area in untreated plots in late February and 19.6% leaf area affected in March when the spring sprays were applied. The disease remained active during stem extension, affecting 14.9% leaf area in control plots and 6.7% in treated plots on 25 April, six weeks after the spring treatments were applied. Significant control of light leaf spot was evident with all products in February, March and April. Proline gave the lowest light leaf spot severity on all three assessments. Caramba gave rather better control of light leaf spot than in 2006. Overall, light leaf spot control data showed a trend for control to improve with increasing dose, but this was only a significant effect in February. There was no effect of increasing dose on yield. The yield data showed significant differences between products, but the effects were negative for growth regulatory products. Caramba gave significantly lower yield (3.49 t/ha) than all the other commercial fungicides (range 3.83-3.94 t/ha) except Charisma (3.74 t/ha) due to negative effects of growth regulation at high doses. However, the yield with Caramba did not differ significantly from the untreated control. Clearly the use of fungicides with growth regulatory effects should be cautious in autumn and winter in Scotland.

3.3.2.3 Sclerotinia

Unusually severe sclerotinia stem rot developed at the Hereford site following favourable conditions for infection on 22 April, 12 and 16 May. In the untreated controls, almost all the 82% plants affected (index 81.8) were dead pre-harvest, as were the 36% of plants affected (index 32.2) in treated plots. The incidence of stem rot by product ranged from 28.3% for Proline to 48.3% for Priori Xtra, with similar differences on the stem rot index. Disease control improved as dose increased from 0.25 dose (48.2% sclerotinia) to full dose (26.2% sclerotinia). At the Hereford site, treatments gave an average response of 2.00 t/ha, so that treated yield was almost double that of the untreated yield of 2.20 t/ha. All fungicides gave significant decreases in stem rot, but Proline, Filan and Compass gave significantly better control and higher yields than the other treatments. There was also a highly significant effect of dose with yield increasing from 3.73 t/ha at 0.25 dose to 4.15 t/ha at 0.50 dose, 4.34 t/ha at 0.75 dose and 4.41 t/ha at full dose. The difference in yield between 0.75 and full dose was not significant.

The stem rot experiment on Romney Marsh, Kent had 41% plants affected (30% with main stem lesions, 11% with secondary branches affected) in untreated controls pre-harvest. Very little stem rot was present at the end of flowering and infection almost certainly occurred during mid to late May. Overall control, product and dose effects were highly significant for both main stem and lateral stem lesions. Compass (92% control) and Filan (87% control) gave the most effective control on the main stem and with Proline, these three fungicides were the most effective for control of both main stem and secondary branch lesions (data not presented). Control on lateral stem was poor and only three Compass treatments and one Proline treatment gave more than a 50% decrease in lateral stem lesions. Stem rot control was not improved above 0.50 dose at the site in Kent. Yield responses averaged 0.59 t/ha in Kent (2.82 t/ha untreated) and overall fungicides significantly increased yield. Compass, Proline and Priori Xtra gave significantly higher yield than azoxystrobin (Fig. 3d). There were no significant effects of dose on yield.

3.3.3 Harvest year 2008

3.3.3.1 Phoma

The first fungicide treatments were applied on 24 October (12% plants with phoma leaf spot, GS 1,6) at Boxworth and on 1 November at Terrington (55% plants with phoma leaf spot, GS 1,8). At both sites crops had been established in wide rows (50cm spacing) using a seeder behind subsoil tines. Growth was more vigorous in the autumn at these sites than in many other crops established by more conventional methods.

Control of phoma leaf spot was very effective at the first assessment on 10 December at Boxworth (GS 1,10-12) and 17 December (GS 1,11) 7 weeks after the first spray. Plants grew quite rapidly in autumn 2007, though the number of phoma leaf spots per plant was lower than usual and the main epidemic developed from late December until February. Control by reducing disease incidence was obtained by all products and at all dose rates at Boxworth (68% of untreated plants affected, 10% of treated plants), but only the untreated v. treated comparison (38% of untreated plants affected, 10% of treated plants) was significant at Terrington. There was significantly improved control at higher doses from 21% plants affected at 0.25 dose to 5% plants affected at 0.75 or full dose at Boxworth. There were no significant product and dose differences for phoma severity at either site but there was a significant decrease in severity averaged over all treatments.

The second fungicide treatments were applied on 12 December at Boxworth (GS 1,10-15, 68% of plants with phoma A, 18% plants with phoma B) and 13 December at Terrington (GS 1,11, 38% plants with phoma A).
At Boxworth, the assessment on 28 January (6 weeks after the second spray) showed 100% of untreated plants had phoma A leaf spot, but phoma B had declined and only affected 28% untreated plants. Only dose effects were significant for decreases in phoma A incidence, though both incidence and severity were significantly decreased overall by fungicides (75% and 95% control respectively). Overall, Phoma B control incidence and severity was decreased by fungicides and increasing dose achieved a lower incidence of spotting with 14% plants affected at 0.25 dose compared with 4% plants affected at full dose. Terrington was assessed on 12/13 February, when phoma A affected 93% of untreated plants (0.4% leaf area affected); this was decreased by fungicides to 11% (0.01% area). There were significant effects of dose on phoma A incidence ranging from 17% at 0.25 dose to 4% at full dose, but no comparable significant product effects on phoma severity. Product differences were significant for phoma A incidence and ranged from 3% plants affected with Proline to 19% plants affected with Caramba

Control of phoma stem canker was very effective and higher doses decreased the canker index from 15.5 at 0.25 dose to 11.2 at full dose.. At Boxworth 74% untreated plants had stem canker (index 25.0) compared with an average of 48% after fungicide treatment (index 13.2). There were no product differences for control of canker at Boxworth, but there were at Terrington (untreated had 65% plants with canker (index 32.8) where Proline treatments had less canker (9.3%) than those with Caramba (19.3%). Phoma stem lesions affected 74% untreated plants at Boxworth and 81% plants at Terrington that was decreased to 48% and 40% overall respectively by fungicide treatments. Control of stem lesions was better at higher doses, but there were no differences between products

At Boxworth and Terrington, the untreated yields were 3.54 and 4.13 t/ha respectively. Yield responses were slightly smaller than in 2006 and 2007 and averaged 0.27 t/ha over all fungicides at Boxworth (non-significant) and 0.32 t/ha at

Terrington. There were no significant differences between products or doses. There were positive trends in yield averaged over all products and doses at both sites.

3.3.3. 2 Light leaf spot

Light leaf spot symptoms were first found in the crop at Aberdeen in spring. The disease affected 6.1% leaf area in control plots and 4.5% in treated plots on 10 April (GS 3,3), almost six weeks after the spring treatments were applied on 3 March. There were no significant product or dose effects at this stage. On 25 April, significant control of light leaf spot (8.3% leaf area affected in untreated) was evident with all products and light leaf spot severity ranged from 1.9% with Proline to 6.3% with Charisma and Punch C. There were no effects of dose, but Caramba had reduced plant vigour significantly. There were pale coloured leaves on many plants and plot scores for this indicated that leaves were greener in Prosaro and Caramba treated plots and at full doses. By 16 May, product and dose effects were highly significant for light leaf spot control. The untreated control had 15.9% leaf area affected, Proline gave the lowest light leaf spot severity (3.1%) and Caramba had the most severe (10.4%). There was more greening in Proline treated plots on 28 July, but no differences in light leaf spot at this late stage. Wet weather delayed harvest and no acceptable yield data were obtained.

The sprays for light leaf spot were applied on 26 November and 27 March at the High Mowthorpe site. The crop had very small plants in the autumn and despite the introduction of inoculum in autumn and spring, light leaf spot severity remained low. The crop grew slowly in spring and was checked by an application of Fox herbicide that was used to control poppies. Phoma leaf spot affected 93% untreated plants on 19 December and this was decreased to 66% plants overall by fungicides with significant product and dose effects. At the second full assessment on 22 April, phoma leaf spot affected 97% untreated plants and this was decreased to 83% plants overall by fungicides, with dose but not product differences. Very little canker was evident at harvest. Light leaf spot affected 1.2% leaf area in control plots on 22 April and 0.5% in fungicide treated plots. The commercial products all gave similar levels of light leaf spot control. There were no differences between products or doses in the incidence of light leaf spot. By 7 May, fungicide treatments, except those with strong pgr activity (e.g. Caramba), tended to give taller plants. This was significant for Proline, which increased height by 11.2 cm when the untreated control was 58.7 cm tall. Product and dose effects were still significant on17 June for light leaf spot incidence (untreated 87% plants affected; treated 54% plants affected) whilst incidence decreased from 72% at 0.25 dose to 36% plants affected at full dose. Fungicides decreased severity on stems from 2.0% to 0.6% on 17 June, but no significant differences were found on 14 July when disease severity was very similar to that recorded in June. Sclerotinia affected 7.3% untreated plants pre-harvest and increased with higher doses from 4.3% at 0.25 dose and 7.0% at full dose.

There were small but significant yield differences between products. Folicur (2.86 t/ha), Caramba (2.85 t/ha) and Prosaro (2.82 t/ha) gave greater yields than Charisma and Punch C.

3.3.3.3 Sclerotinia

For a second successive year, very severe sclerotinia stem rot developed at the Hereford site following favourable conditions for infection during 16-17 and 26-28 May. All fungicide treatments were applied on 1 May at mid-flowering (GS 4,5). In the untreated controls, there were 35% of plants affected by 6 June and 80% (index 45.8) were affected pre-harvest. There was no infection in treated plots on 6 June but they had 46% of plants affected (index 18.9) pre-harvest. The incidence of stem rot by product ranged from 41.4% for Filan to 51.3% for Priori Xtra, with similar differences on the stem rot index.. Disease control improved as dose increased from 0.25 dose (51.8% sclerotinia) to full dose (40.7% sclerotinia). At the Hereford site treatments gave an average response of 3.72 t/ha, almost double that of the untreated yield of 1.90 t/ha. All fungicides gave significant increases in yield, but Filan gave significantly higher yields than the other treatments by at least 0.56 t/ha. There was also a highly significant effect of dose with yield increasing from 3.09 t/ha at 0.25 dose to 3.60 t/ha at 0.50 dose, 4.08 t/ha at 0.75 dose and 4.11 t/ha at full dose. The difference in yield between 0.75 and full dose was again not significant.

The stem rot experiment on Romney Marsh, Kent was sprayed 25 April at mid-flowering (GS 4,4). There was only a low level of stem rot in untreated plots at the end of May but 37% plants affected (26.1% with main stem lesions(index 26.1), 16% with secondary branches affected (index 16) in untreated controls pre-harvest. Very little stem rot was present at the end of flowering and infection almost certainly occurred during mid to late May as rainfall patterns were similar to those recorded at the Hereford site. Overall control, product and dose effects were highly significant for both main stem and lateral stem lesions. Filan and Proline gave the most effective control of the both main stem and lateral stem lesions though control was 56-61% on main stems and 33-34% on lateral stems. The other products did not control lateral stem lesions. Overall control was better at higher doses with 30% incidence at 0.25 dose, 32% at 0.50 dose, 25.4% at 0.75 dose and 20.1% at full dose. The differences between 0.50 and 0.75 and between 0.75 and full dose were significant for overall incidence and main stem lesions. Yield responses averaged 0.46 t/ha in Kent (3.71 t/ha untreated) and overall fungicides significantly increased yield. Product and dose effects had no significant effect on yield. The yield from the full rate of Amistar was 4.91 t/ha which was 0.29 t/ha greater than any other treatment. Whilst this was not a significant effect, it was the first result with Amistar to suggest benefits from control of other diseases or crop greening effects. Verticillium wilt affected 56% plants at the site in Kent, but further work is required to demonstrate fungicidal control.

3.3.4 Cross-site analyses

3.3.4.1 Phoma (Figures 3.2, 3.3, 3.4, 3.5, 3.6)

The severity of phoma A leaf spotting about 6 weeks after the first fungicide treatments showed significant differences between years, sites, fungicides, dose and year x dose, but no treatment x dose interaction. Disease severity was greatest in 2007 and Boxworth had more severe spotting (0.42% leaf area affected) than Terrington (0.26% area). Proline and Prosaro had less severe spotting than Charisma and Punch C, whilst Plover and Caramba did not differ from other products.

Stem canker severity showed significant differences between years, sites, fungicides treatments dose and year x dose but no treatment x dose interaction. The annual mean canker indices for 2006, 2007 and 2008 were 24.1, 31.3 and 10.2 respectively. Boxworth had marginally more severe canker (index 23.3) than Terrington (index 20.4) but the difference was almost significant (P=0.06). Proline, Plover and Prosaro were the most effective products. Caramba had more severe canker (index 24.0) than all the other products (index range 17.5-21.4; untreated index 44.0) but still gave acceptable stem canker control. The differences between each dose were significant and canker index decreased from 24.5 at 0.25 dose to 16.3 at full dose.

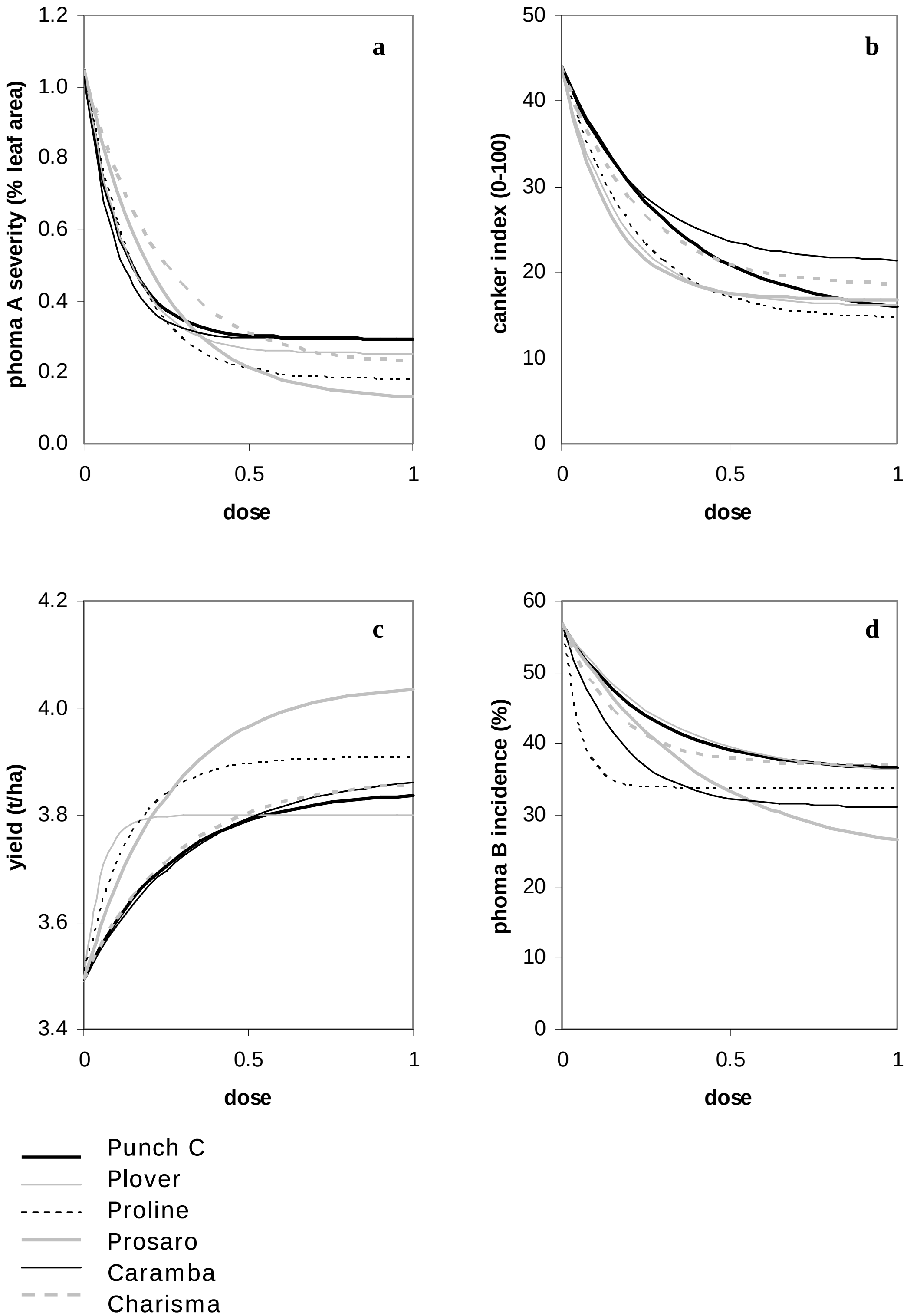


Figure 3.2: Mean data from phoma trials across three years (2006-2008) and two sites (ADAS Boxworth and ADAS Terrington): (a) phoma A leaf spot severity at first assessment; (b) canker index at final assessment; (c) yield; (d) phoma B incidence at first assessment

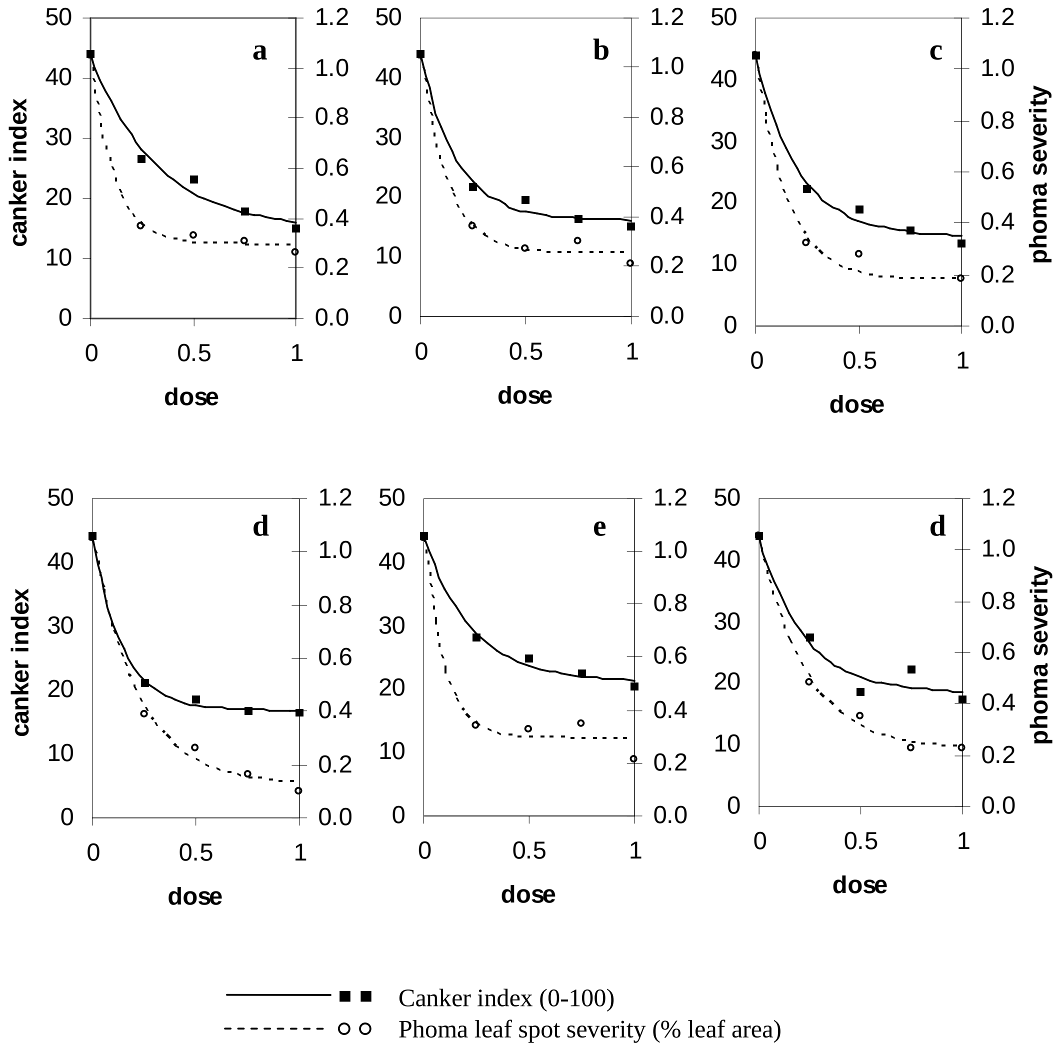


Figure 3.3: Mean data from phoma trials across three years (2006-2008) and two sites (ADAS Boxworth and ADAS Terrington), showing fitted curves and observed data points for phoma leaf spot severity at first assessment and canker index at final assessment: (a) Punch C, (b) Plover, (c) Proline, (d) Prosaro, (e) Caramba and (f) Charisma.

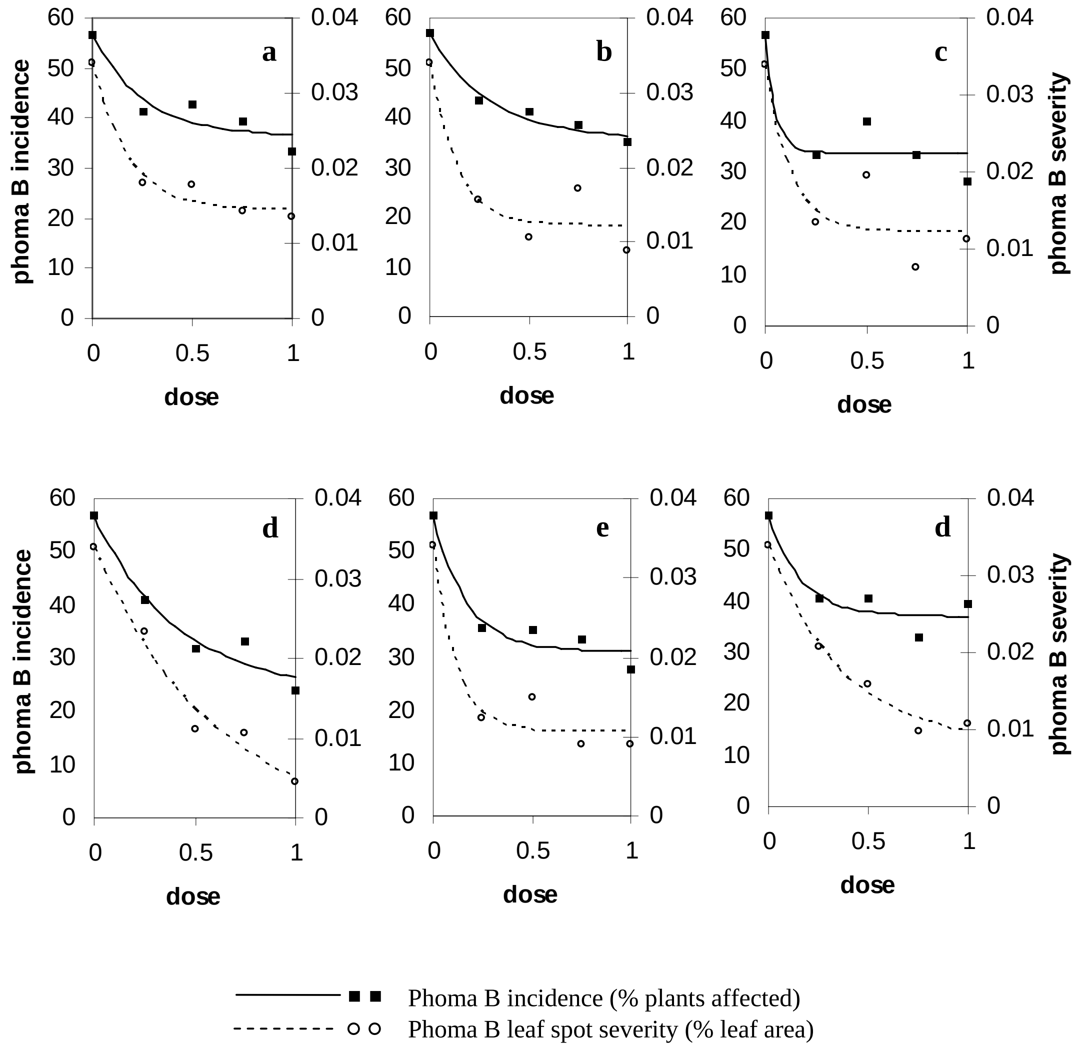


Figure 3.4: Mean data from phoma trials across three years (2006-2008) and two sites (ADAS Boxworth and ADAS Terrington), showing fitted curves and observed data points for phoma B leaf spot incidence (% plants affected) and severity (% leaf area) at first assessment: (a) Punch C, (b) Plover, (c) Proline, (d) Prosaro, (e) Caramba and (f) Charisma.

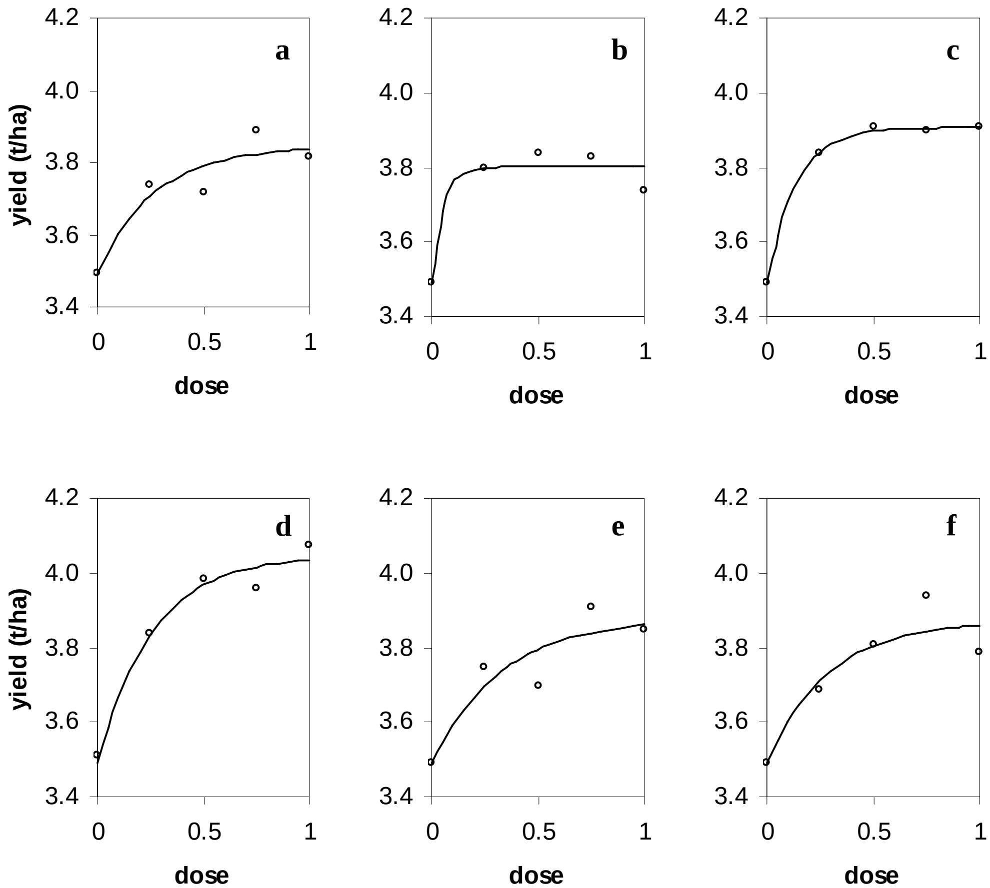


Figure 3.5: Mean data from phoma trials across three years (2006-2008) and two sites (ADAS Boxworth and ADAS Terrington), showing fitted curves and observed data points for yield: (a) Punch C, (b) Plover, (c) Proline, (d) Prosaro, (e) Caramba and (f) Charisma.

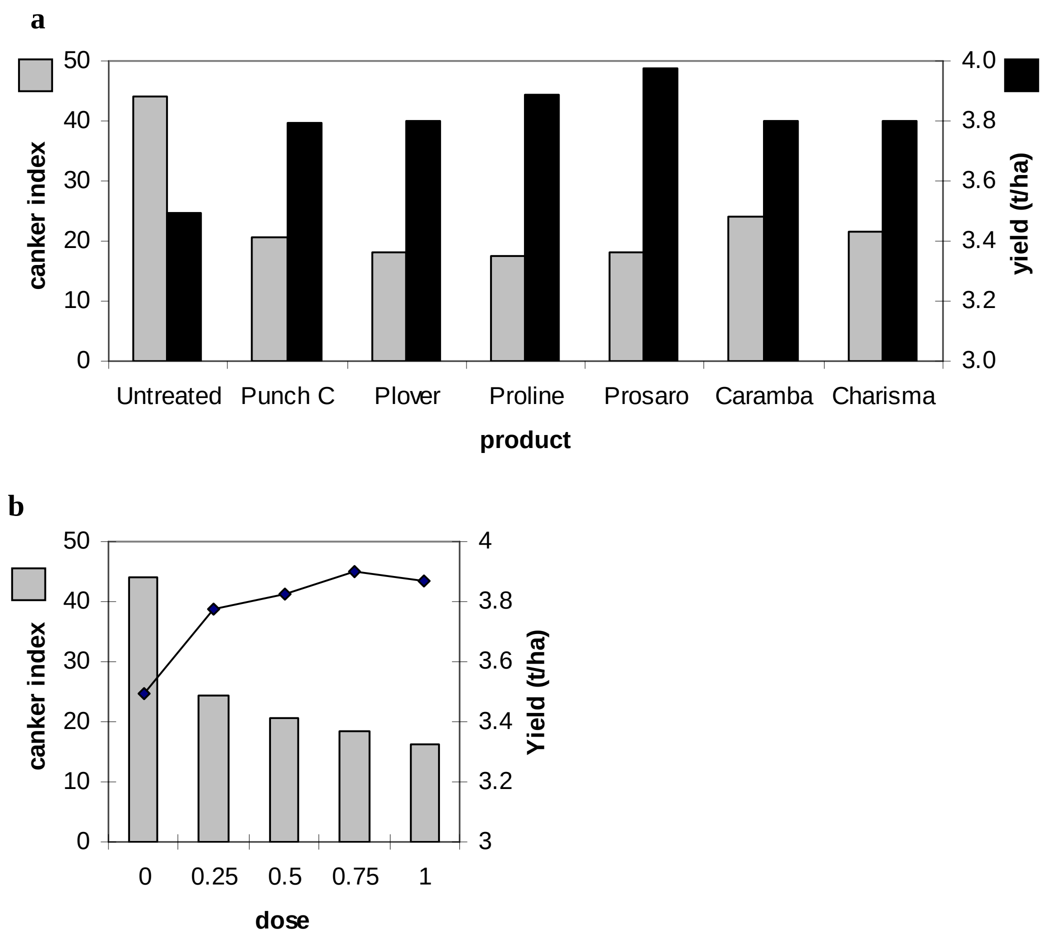


Figure 3.6: Mean data from phoma trials across three years (2006-2008) and two sites (ADAS Boxworth and ADAS Terrington), showing canker index (0-100) and yield (t/ha): (a) data averaged across doses for each product; (b) data averaged across products for each dose.

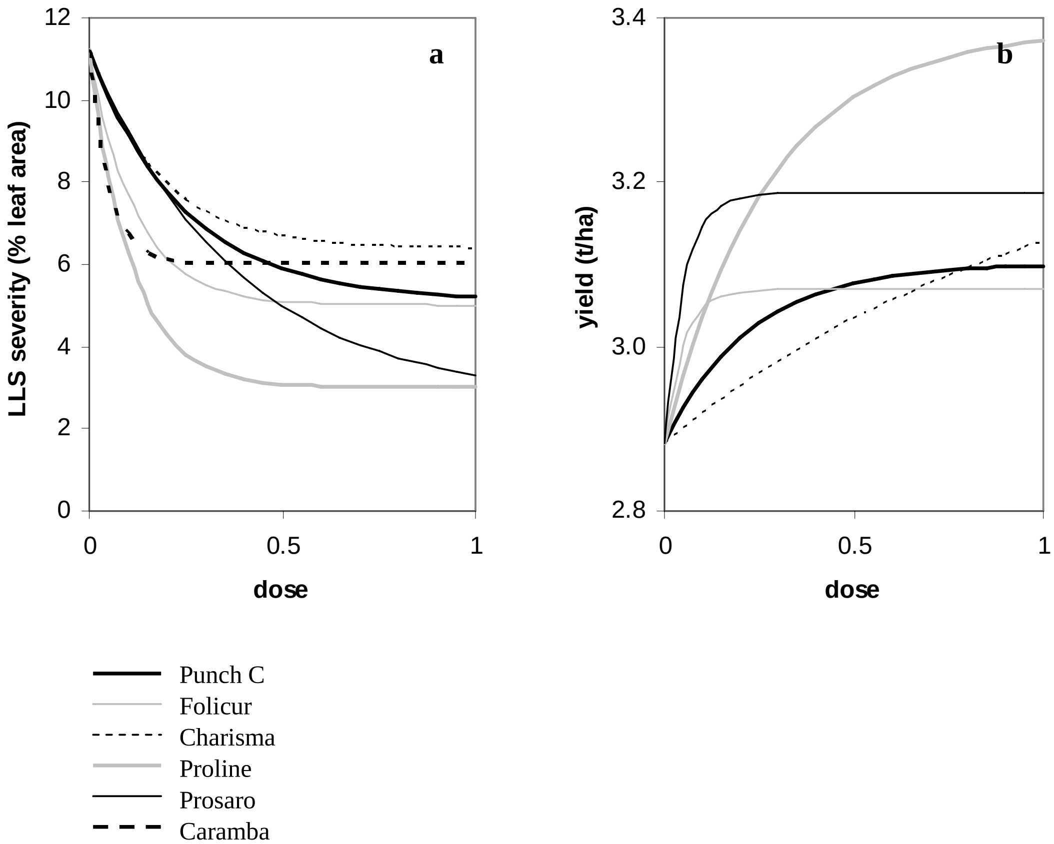


Figure 3.7: Mean data from light leaf spot trials across three years (2006-2008) at SAC: (a) light leaf spot severity; (b) yield [curve fitting was not possible for Caramba yield].

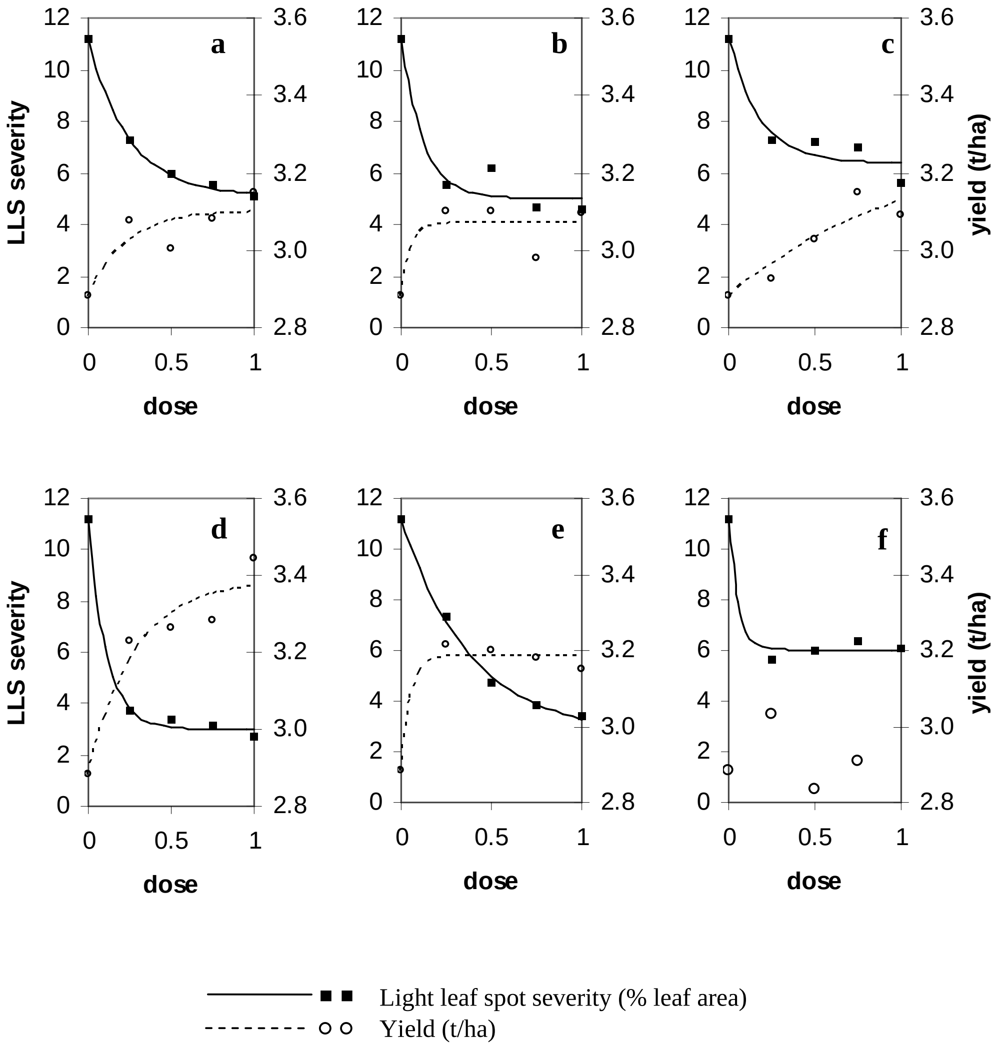
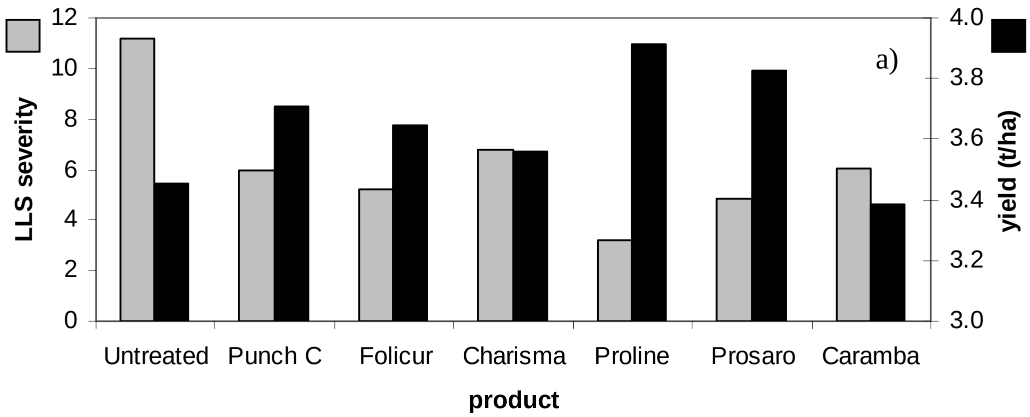


Figure 3.8: Mean data from light leaf spot trials across three years (2006-2008) at SAC, showing fitted curves and observed data points for light leaf spot severity and yield: (a) Punch C, (b) Folicur, (c) Charisma, (d) Proline, (e) Prosaro and (f) Caramba [curve fitting was not possible for Caramba yield].

a



b

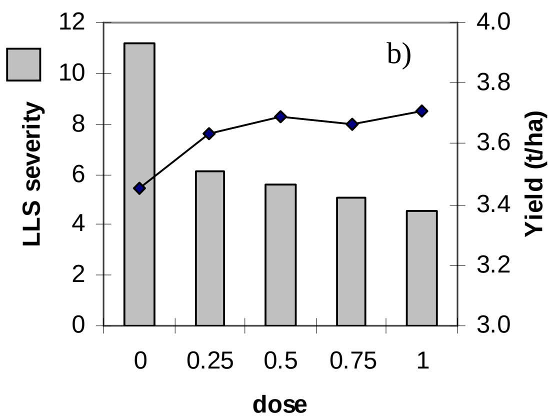


Figure 3.9: Mean data from light leaf spot trials across three years (2006-2008) at SAC, Aberdeenshire, showing light leaf spot severity (% leaf area) and yield (t/ha) (yield for 2006 and 2007 only: (a) data averaged across doses for each product; (b) data averaged across products for each dose.

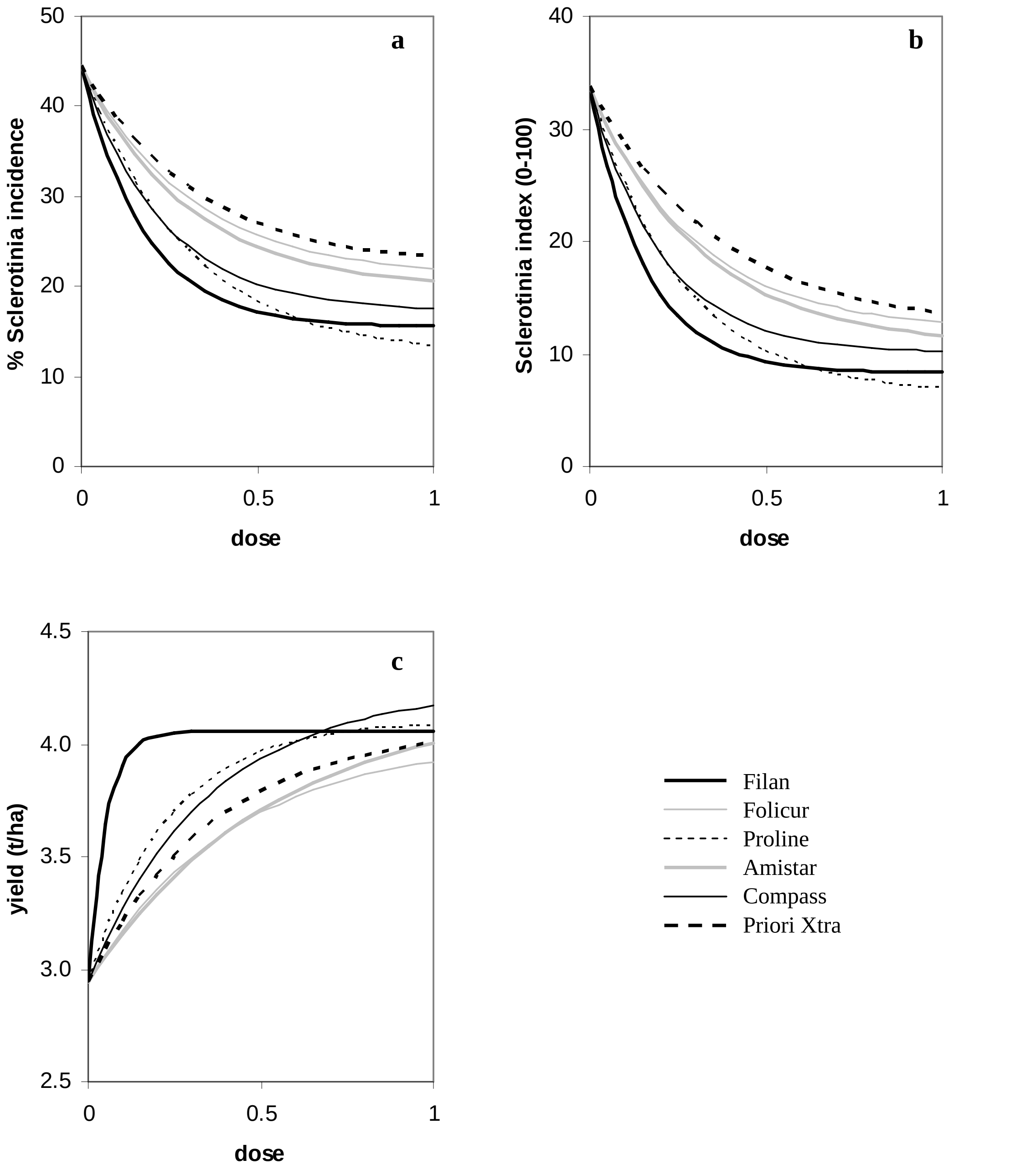


Figure 3.10: Mean data from Sclerotinia trials across three years (2006-2008) and two sites (Romney Marsh and ADAS Rosemaund): (a) Sclerotinia incidence at final assessment; (b) Sclerotinia index at final assessment; (c) yield.

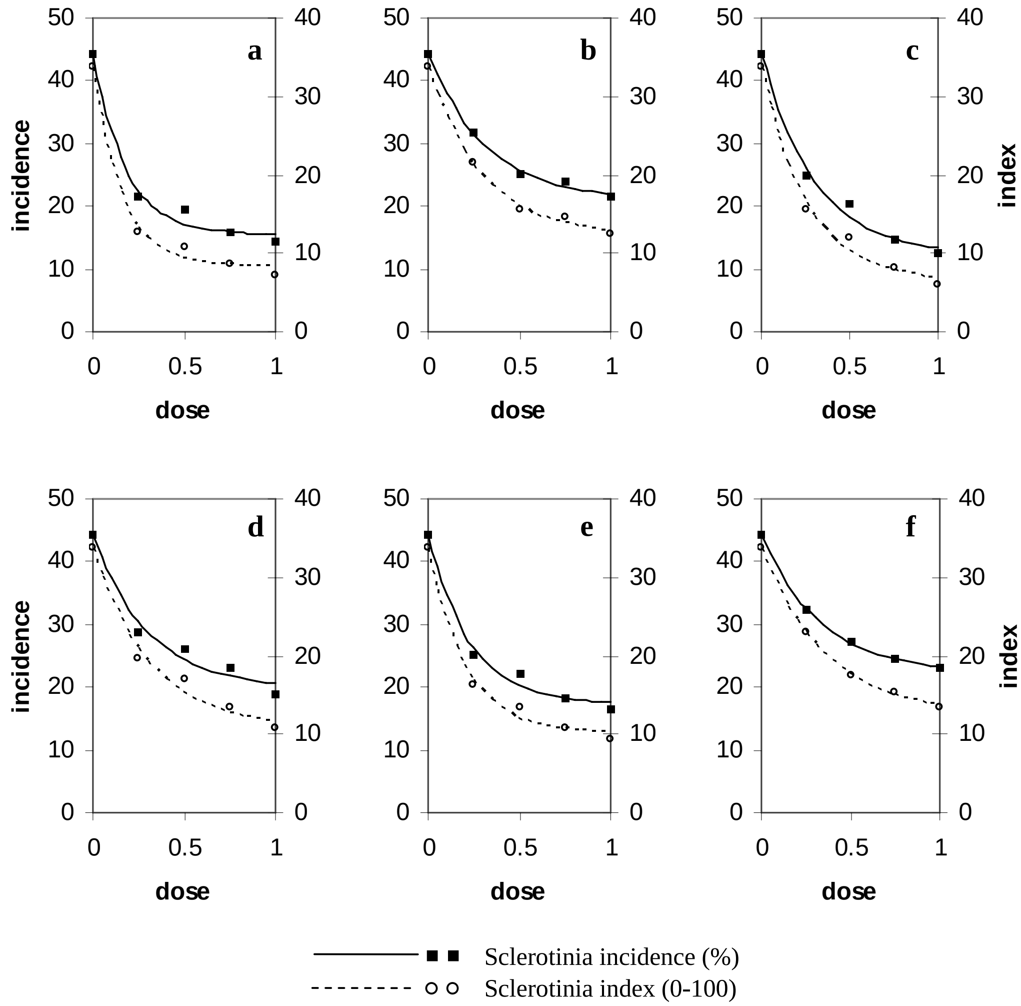


Figure 3.11: Mean data from Sclerotinia trials across three years (2006-2008) and two sites (Romney Marsh and ADAS Rosemaund), showing fitted curves and observed data points for Sclerotinia incidence and index at final assessment: (a) Filan, (b) Folicur, (c) Proline, (d) Amistar, (e) Compass and (f) Priori Xtra.

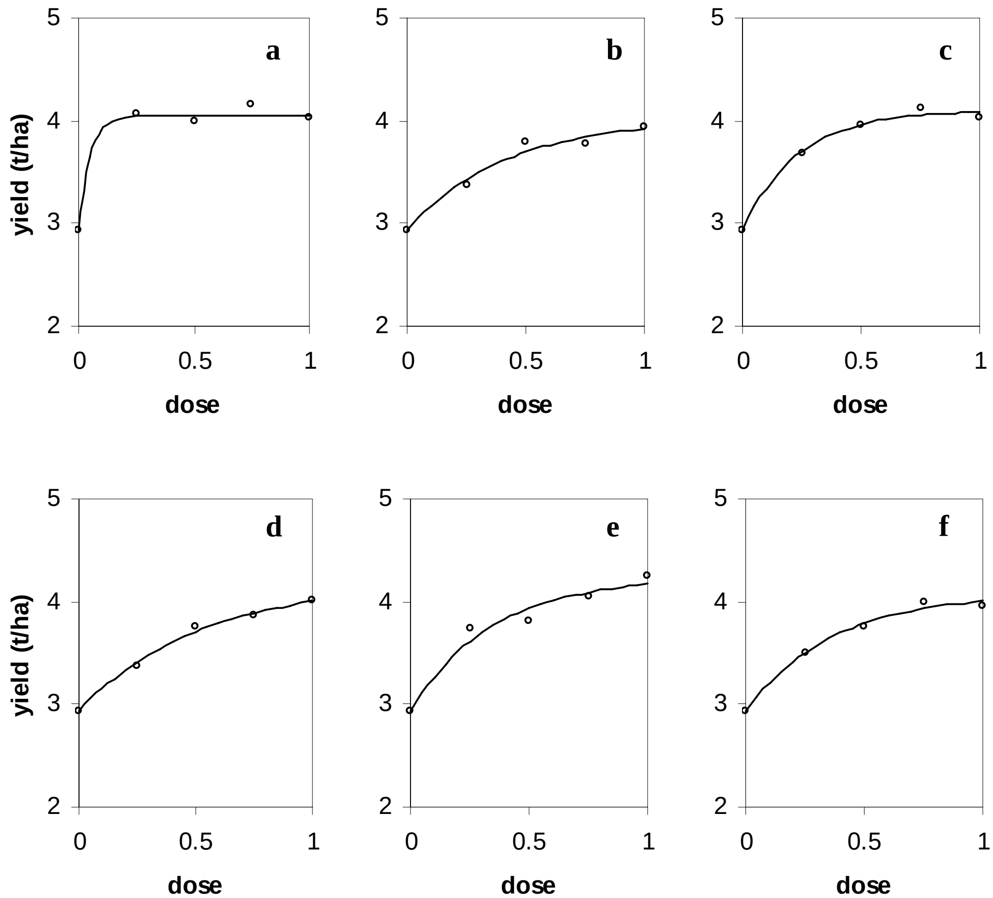
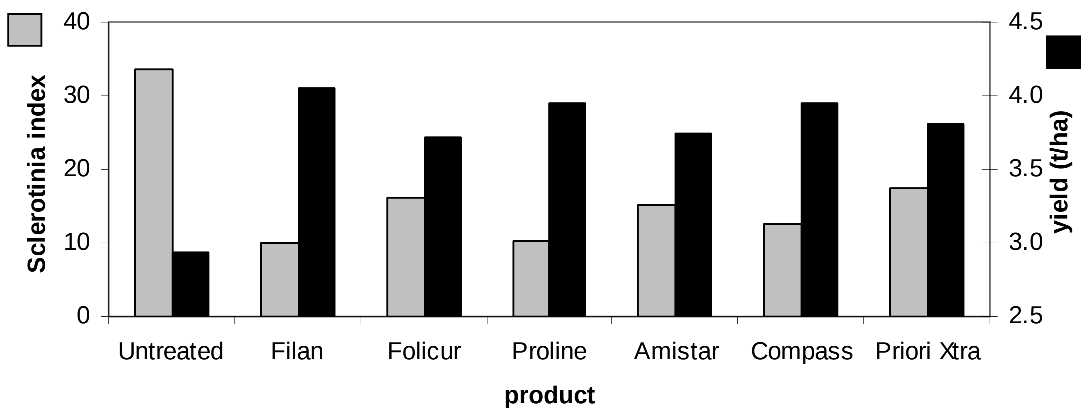


Figure 3.12: Mean data from Sclerotinia trials across three years (2006-2008) and two sites (Romney Marsh and ADAS Rosemaund), showing fitted curves and observed data points for yield: (a) Filan, (b) Folicur, (c) Proline, (d) Amistar, (e) Compass and (f) Priori Xtra.

a



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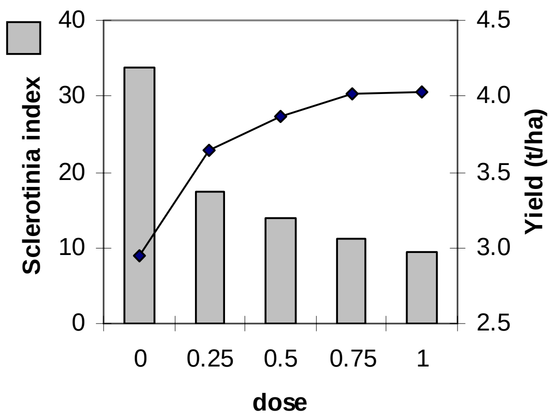


Figure 3.13: Mean data from Sclerotinia trials across three years (2006-2008) and two sites (Romney Marsh and ADAS Rosemaund), showing Sclerotinia index (0-100) and yield (t/ha): (a) data averaged across doses for each product; (b) data averaged across products for each dose.

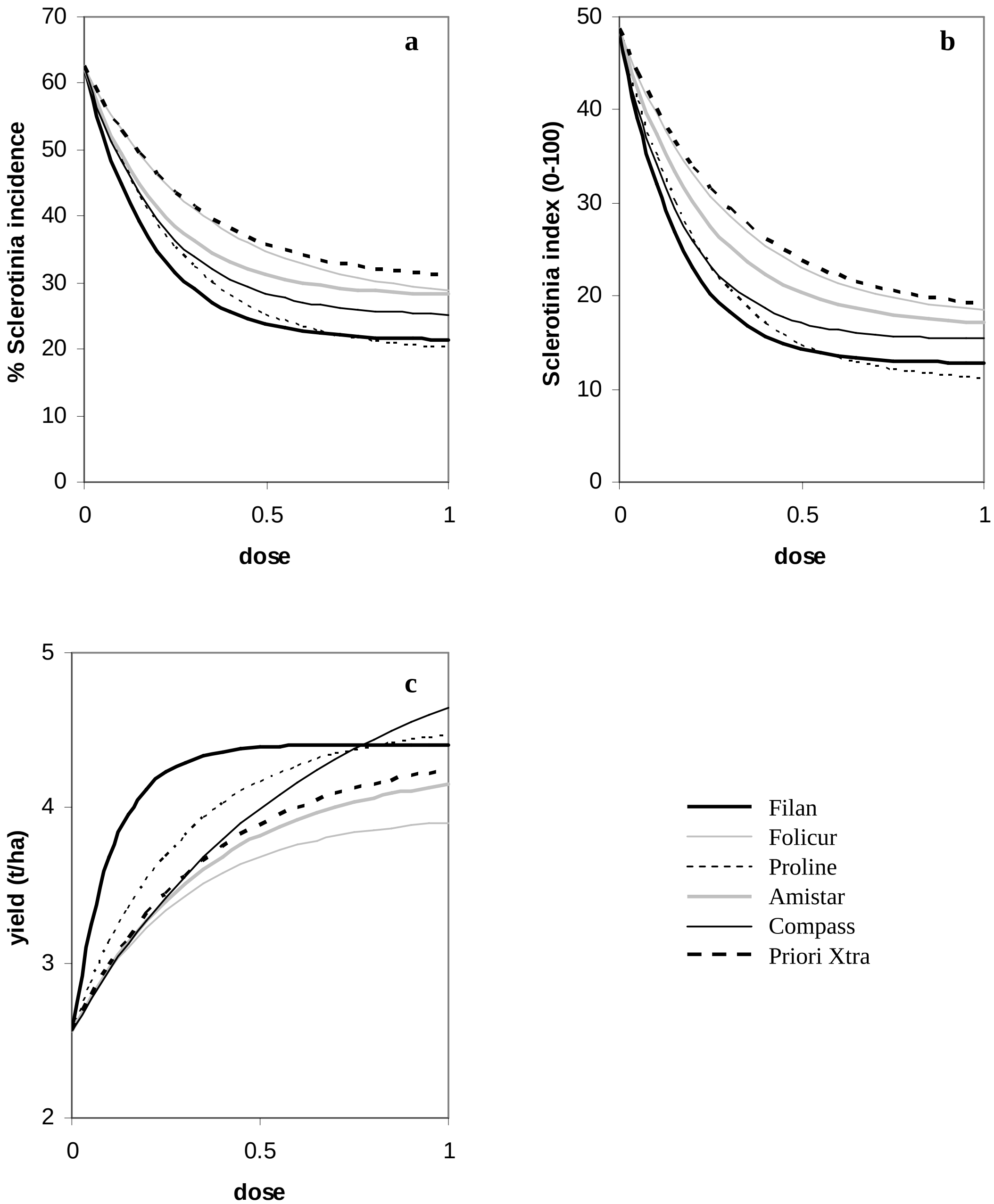


Figure 3.14: Mean data from Sclerotinia trials across three years (2006-2008) at ADAS Rosemaund, Herefordshire: (a) Sclerotinia incidence at final assessment; (b) Sclerotinia index at final assessment; (c) yield.

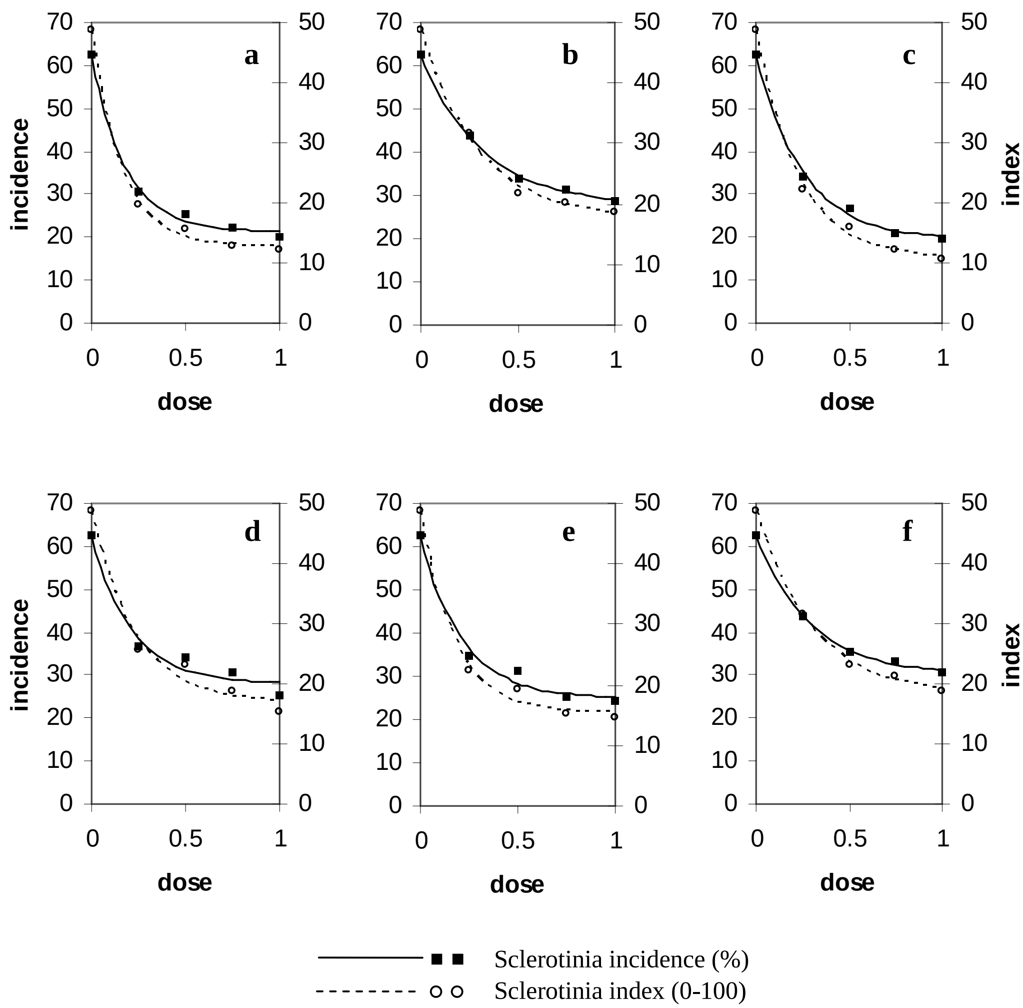


Figure 3.15: Mean data from Sclerotinia trials across three years (2006-2008) at ADAS Rosemaund, Herefordshire, showing fitted curves and observed data points for Sclerotinia incidence and index at final assessment: (a) Filan, (b) Folicur, (c) Proline, (d) Amistar, (e) Compass and (f) Priori Xtra.

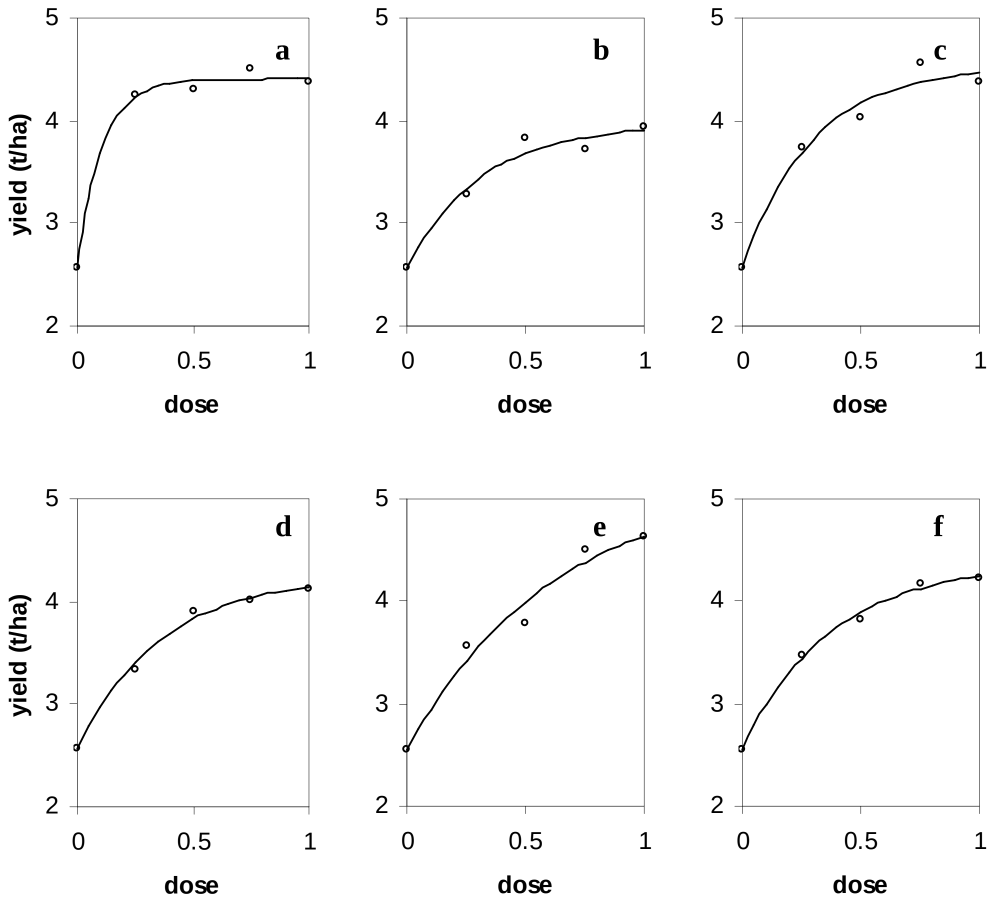


Figure 3.16: Mean data from Sclerotinia trials across three years (2006-2008) at ADAS Rosemaund, Herefordshire, showing fitted curves and observed data points for yield: (a) Filan, (b) Folicur, (c) Proline, (d) Amistar, (e) Compass and (f) Priori Xtra.

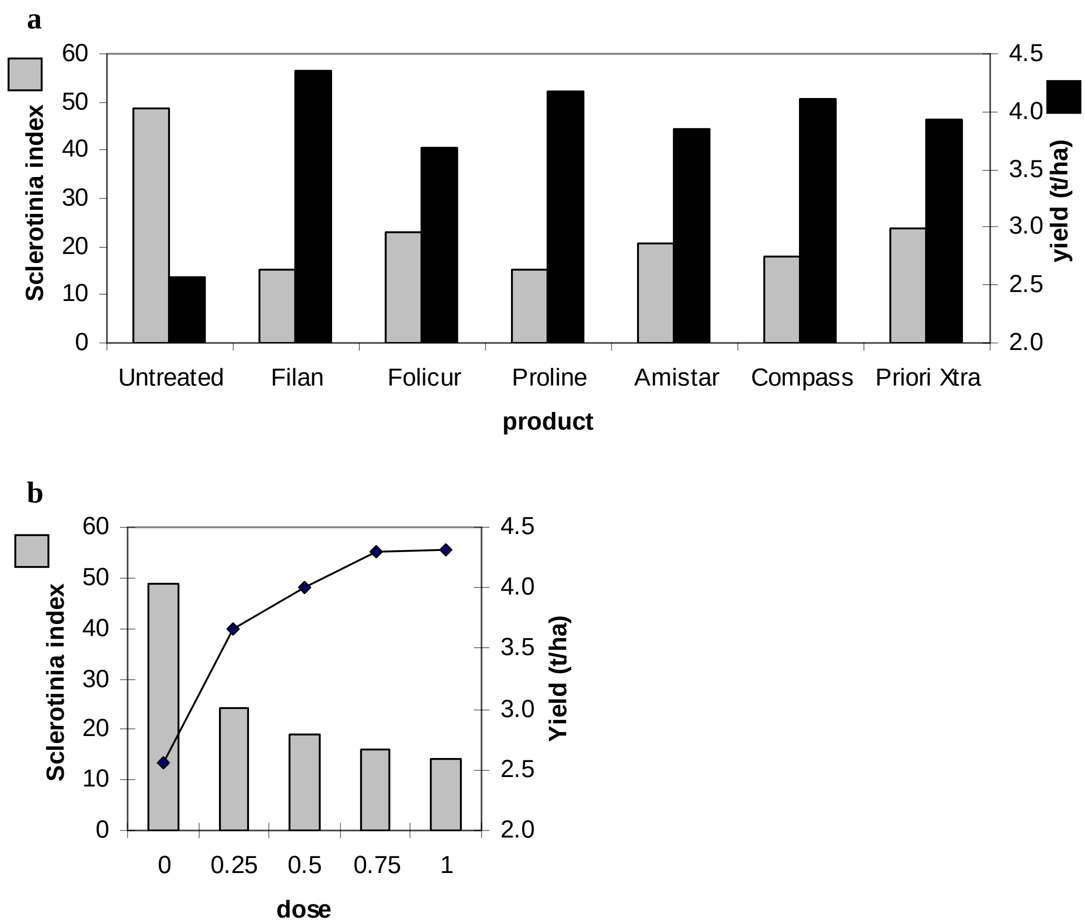


Figure 3.17: Means from Sclerotinia trials across three years (2006-2008) at ADAS Rosemaund, Herefordshire, showing Sclerotinia index (0-100) and yield (t/ha): (a) data averaged across doses for each product; (b) data averaged across products for each dose.

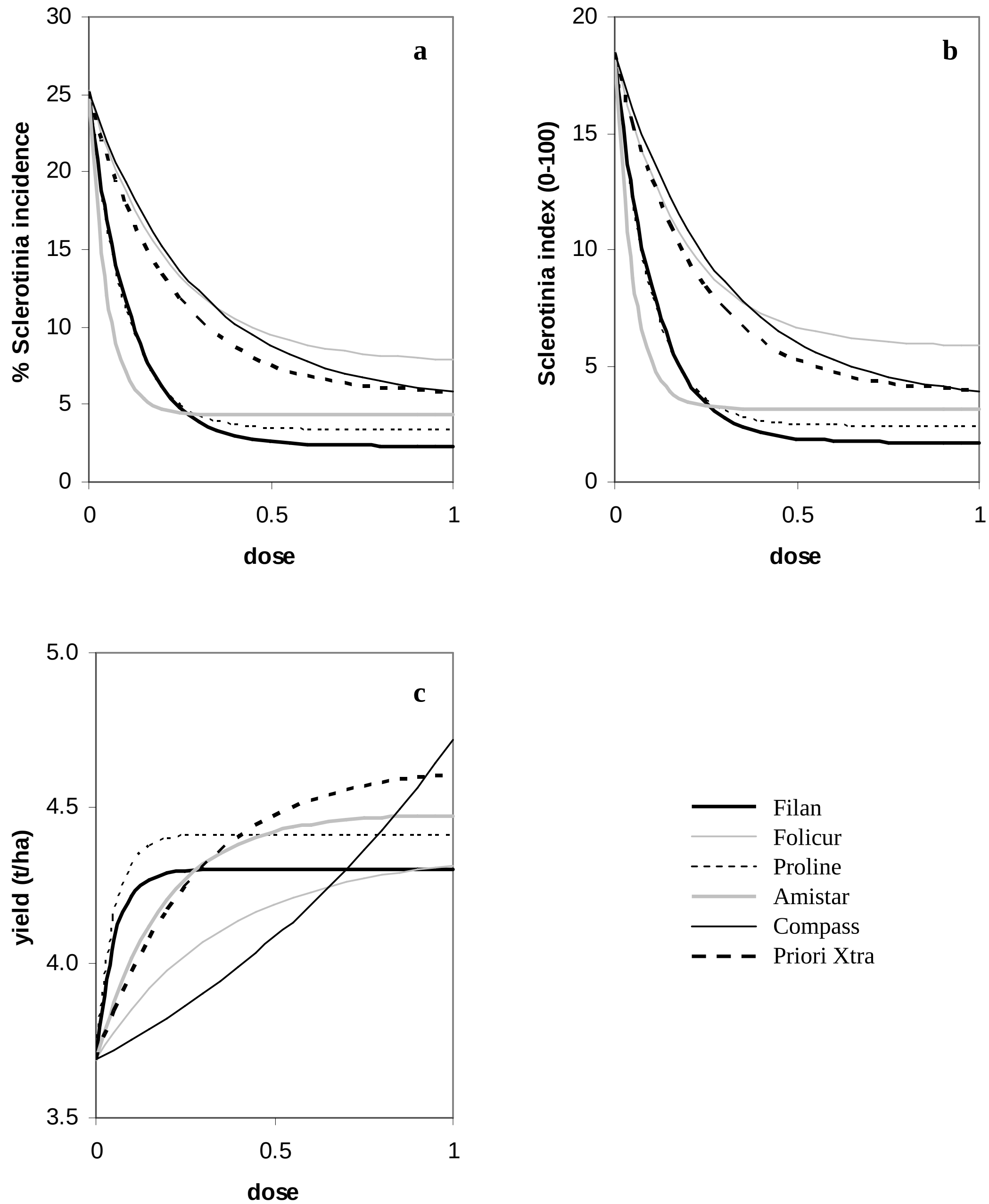


Figure 3.18: 2005-06 Sclerotinia trial at ADAS Rosemaund, Herefordshire: (a) Sclerotinia incidence at final assessment; (b) Sclerotinia index at final assessment; (c) yield.

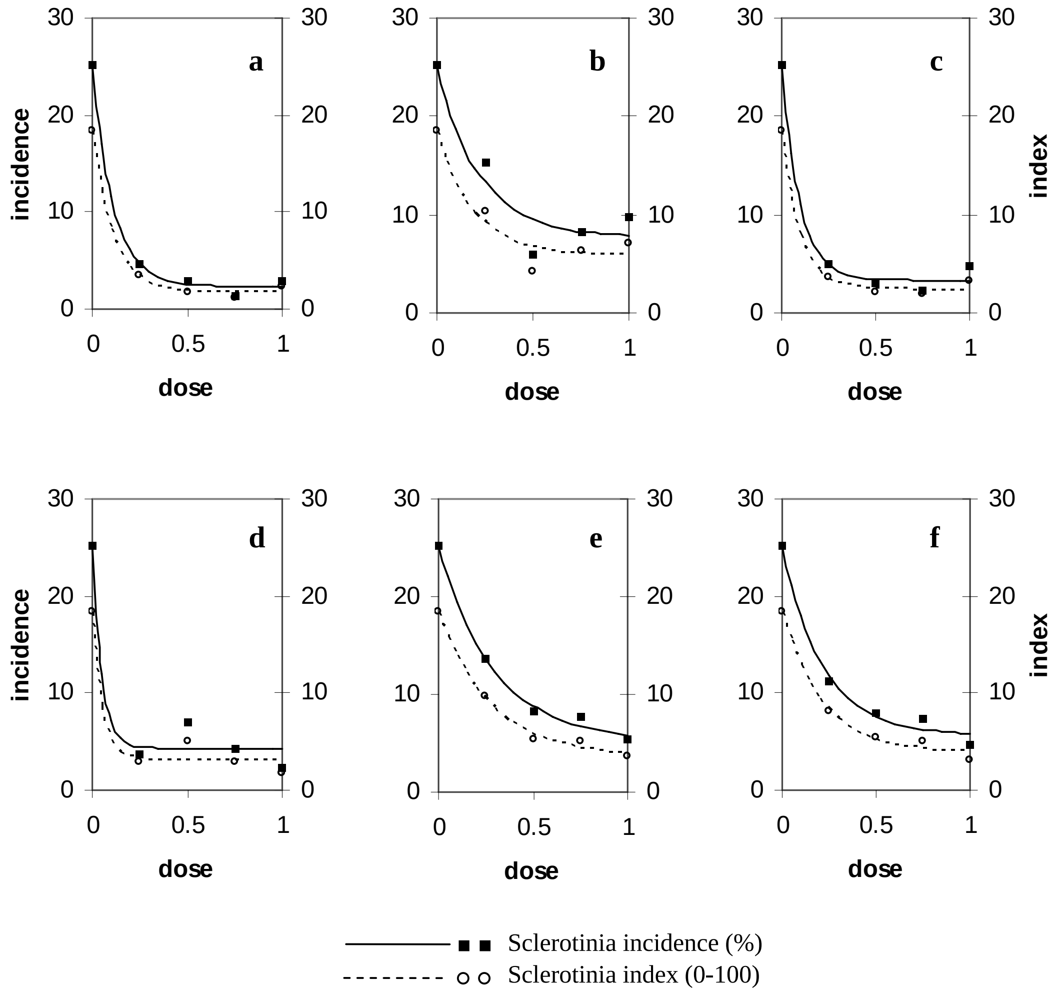


Figure 3.19: 2005-06 Sclerotinia trial at ADAS Rosemaund, Herefordshire, showing fitted curves and observed data points for Sclerotinia incidence and index at final assessment: (a) Filan, (b) Folicur, (c) Proline, (d) Amistar, (e) Compass and (f) Priori Xtra.

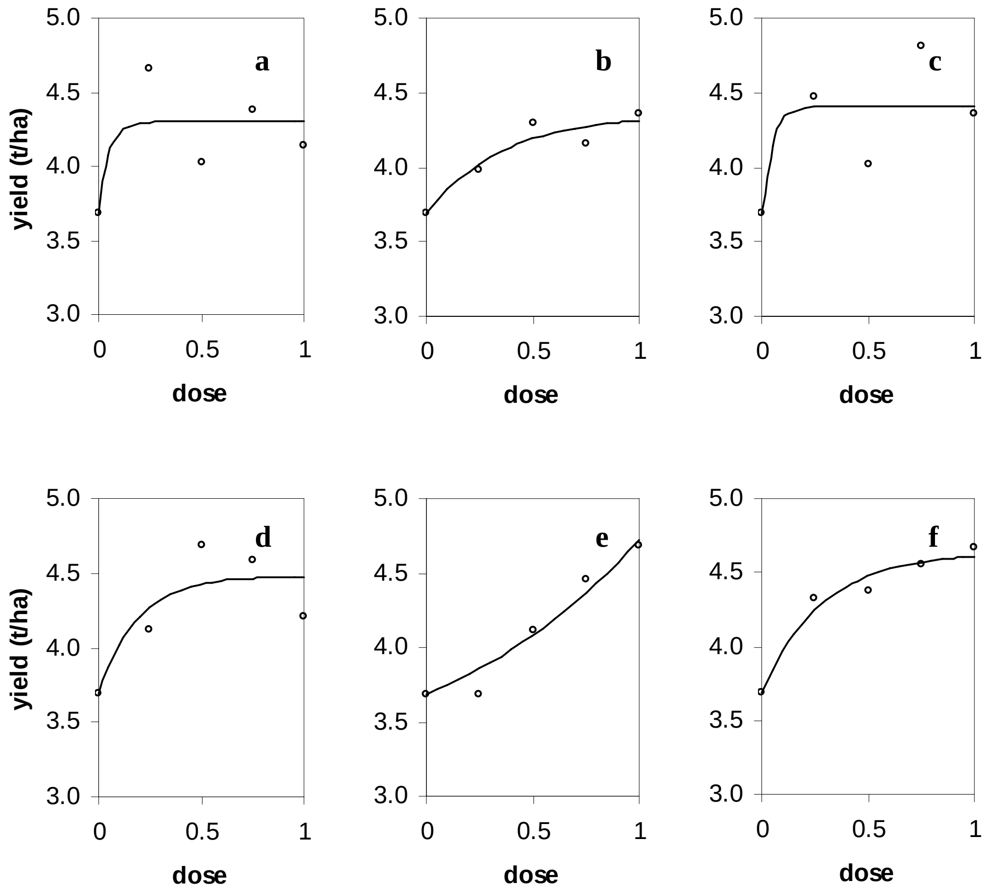


Figure 3.20: 2005-06 Sclerotinia trial at ADAS Rosemaund, Herefordshire, showing fitted curves and observed data points for yield: (a) Filan, (b) Folicur, (c) Proline, (d) Amistar, (e) Compass and (f) Priori Xtra.

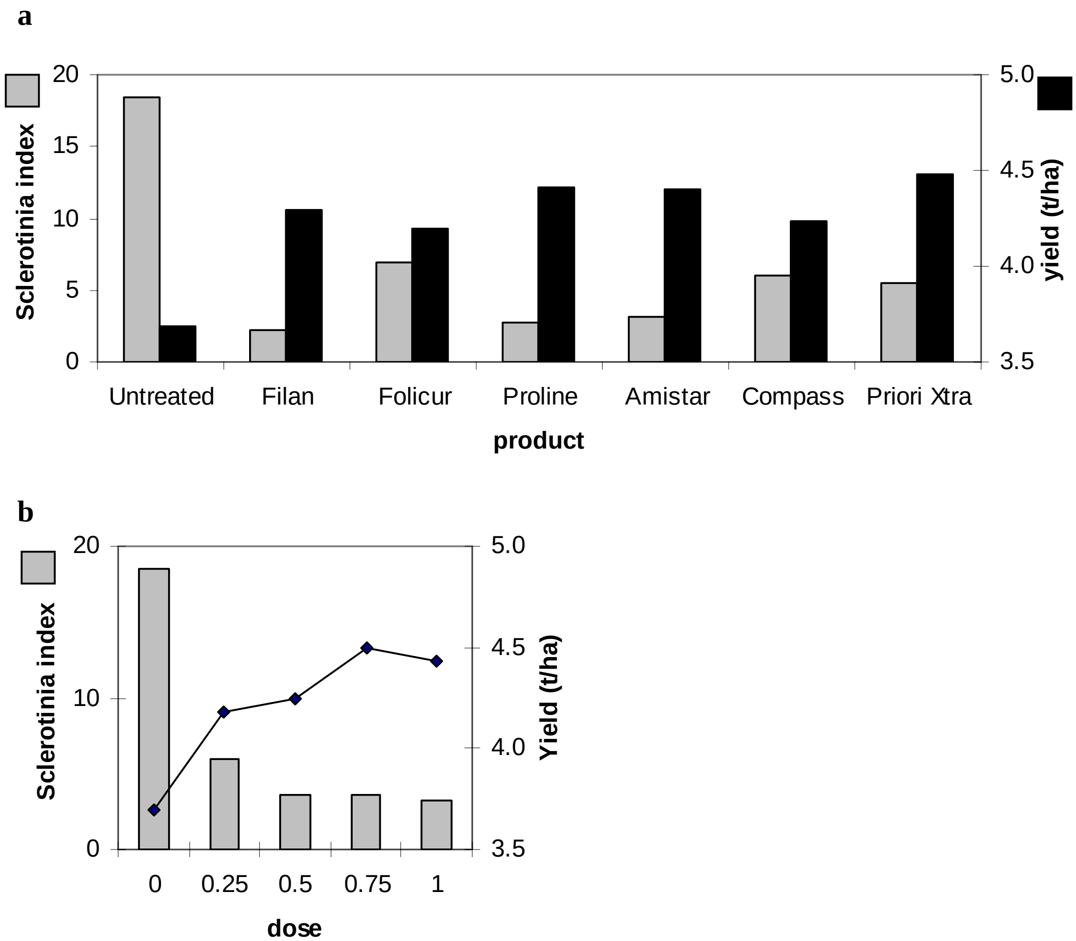


Figure 3.21: Means from 2005-06 Sclerotinia trial at ADAS Rosemaund, Herefordshire, showing Sclerotinia index (0-100) and yield (t/ha): (a) data averaged across doses for each product; (b) data averaged across products for each dose.

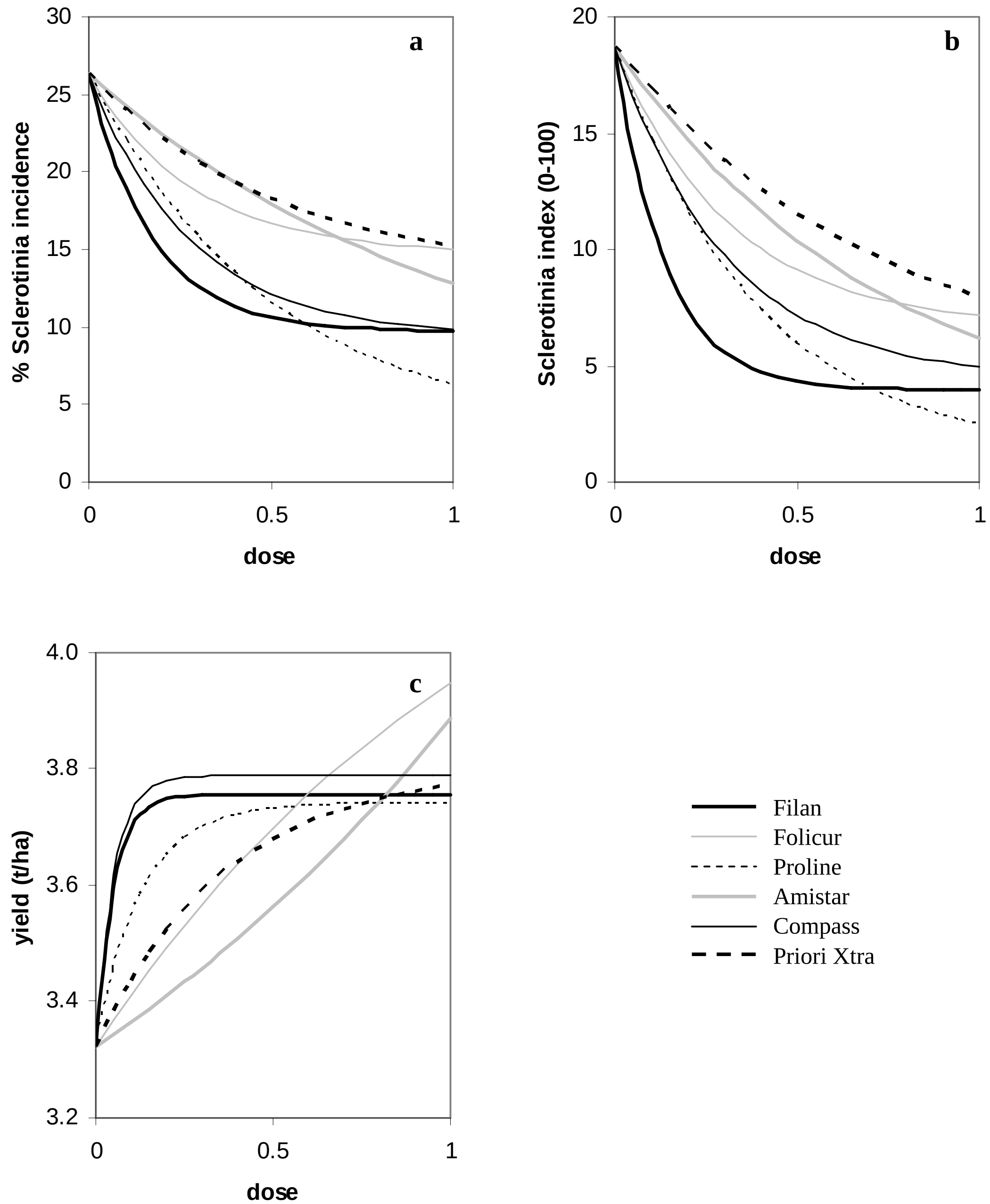


Figure 3.22: 10. Mean data from Sclerotinia trials across three years (2006-2008) in Romney Marsh, Kent: (a) Sclerotinia incidence at final assessment; (b) Sclerotinia index at final assessment; (c) yield.

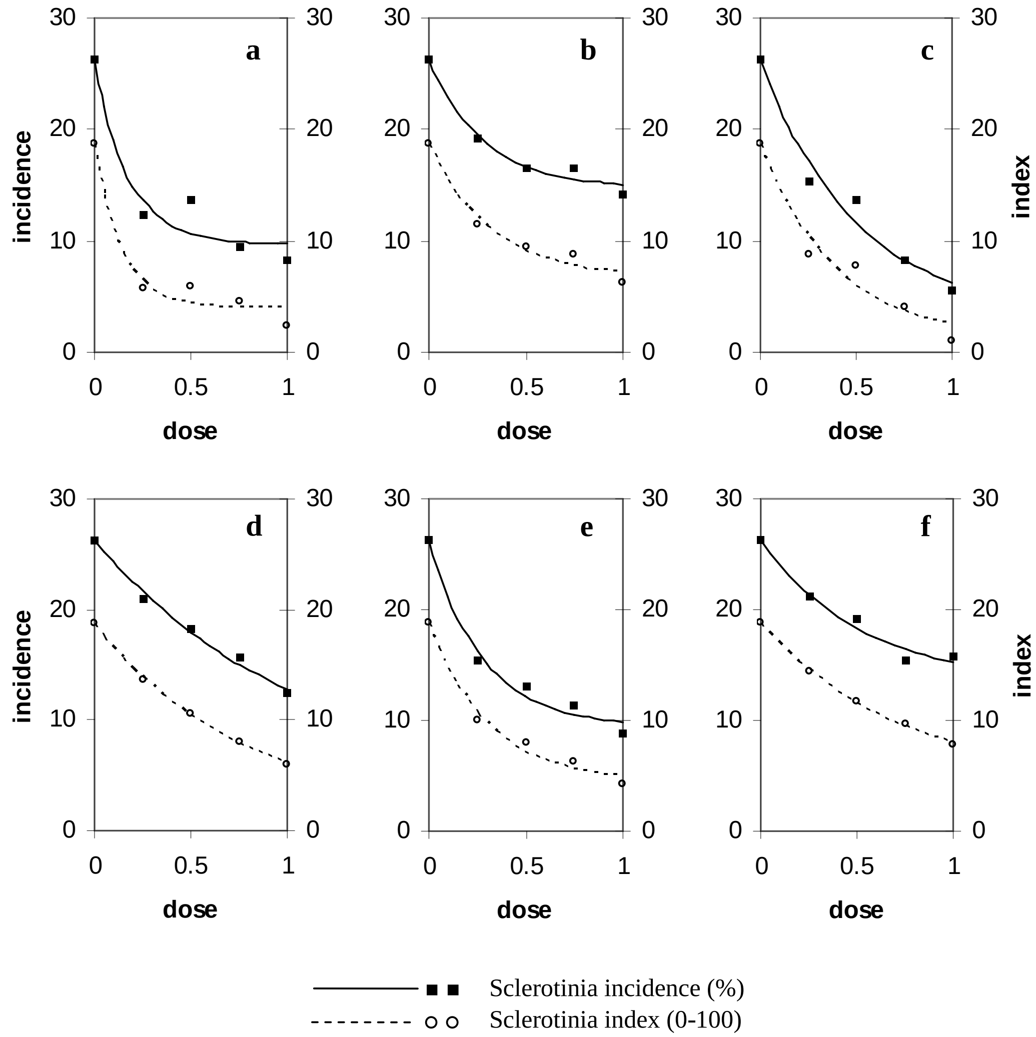


Figure 3.23: Mean data from Sclerotinia trials across three years (2006-2008) in Romney Marsh, Kent, showing fitted curves and observed data points for Sclerotinia incidence and index at final assessment: (a) Filan, (b) Folicur, (c) Proline, (d) Amistar, (e) Compass and (f) Priori Xtra.

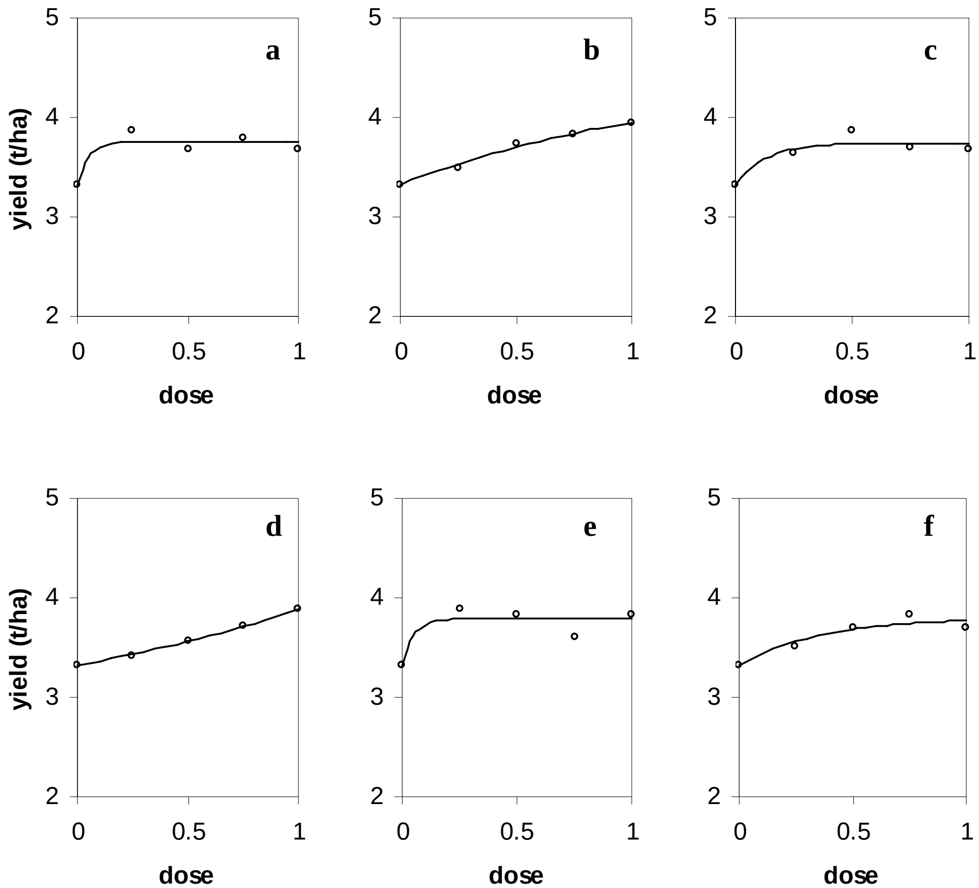
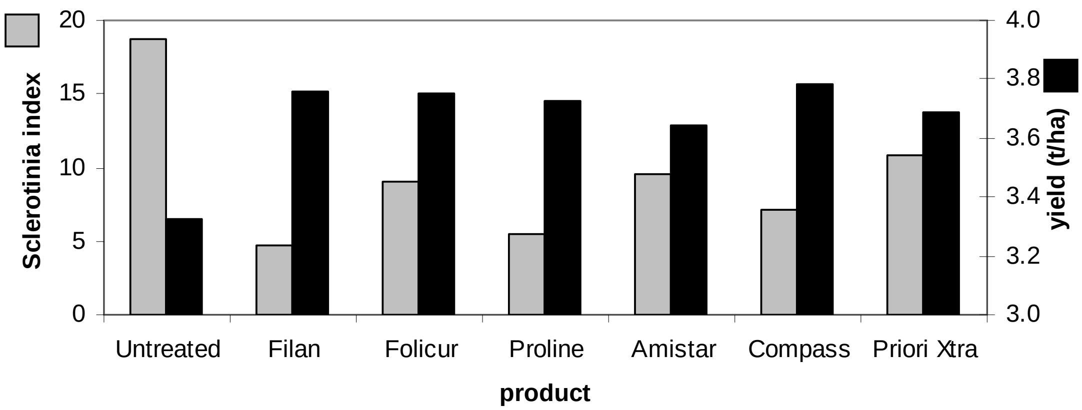


Figure 3.24: Mean data from Sclerotinia trials across three years (2006-2008) in Romney Marsh, Kent, showing fitted curves and observed data points for yield: (a) Filan, (b) Folicur, (c) Proline, (d) Amistar, (e) Compass and (f) Priori Xtra.

a



b

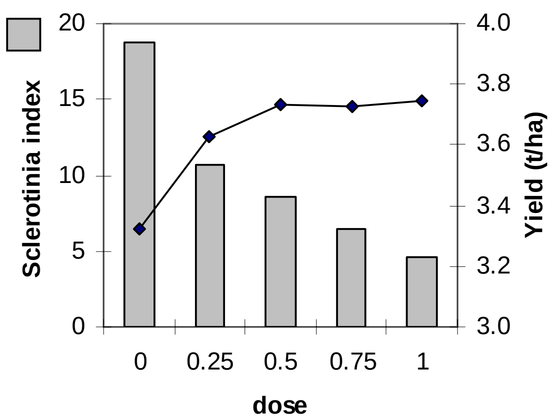


Figure 3.25: Mean data from Sclerotinia trials across three years (2006-2008) in Romney Marsh, Kent, showing Sclerotinia index (0-100) and yield (t/ha): (a) data averaged across doses for each product; (b) data averaged across products for each dose.

Yields showed significant differences between fungicide treatments, dose and year x dose, but not for sites or treatment x dose interactions. The annual mean yields for 2006, 2007 and 2008 were 4.03, 3.34 and 4.08 t/ha respectively. Boxworth and Terrington had similar yields at 3.78 and 3.85 t/ha respectively. All the products increased yields, with Prosaro giving a greater yield (3.97 t/ha) than all the other products (range 3.79-3.80 t/ha) except Proline (3.89 t/ha). All doses increased yield but there was no significant increase above 0.50 dose. The greatest yield was 3.90 t/ha at 0.75 dose.

Phoma B leaf spot incidence (Fig. 3.4) at the first assessment in late November or early December showed significant effects for control, year, fungicide, dose, but no fungicide x dose interactions. Its incidence was greater in harvest year 2007 (75% plant affected) than in 2006 (34% plants affected) and 2008 (4% plants affected). Treatments decreased incidence from 57% plants affected to 36%. Prosaro, Proline and Caramba gave better control than Charisma, Punch C and Plover, though differences were small (range of incidence 33% to39% plants affected). Control improved as dose increased, with incidence decreased from 39% plants affected at 0.25 dose to 31% at full dose. Full dose was more effective than all the other doses. Phoma B severity was very low (0.01% leaf area affected) and no product differences were found.

3.3.4.2 Light leaf spot (Figures 3.7, 3.8, 3.9)

Only the data from the Aberdeen sites was included in the three year analyses and yield data were only available for 2006 and 2007. The severity of light leaf spot averaged over three assessments in spring each year showed significant differences between years, fungicides, dose and year x fungicide, but no treatment x dose interaction. Mean severity was 6.8% leaf area affected in 2006, 6.6% in 2007 and 5.2% in 2008, whilst untreated means were 12.3%, 13.0% and 8.3% respectively. Proline gave better control of light leaf spot than all the other treatments and Prosaro was better than all the remaining products except Folicur. Overall, untreated levels were 11.2% leaf area affected and treated severity 5.3%. Disease severity was decreased progressively as dose increased from 6.1% area affected at 0.25 dose to 4.6% at full dose. Full dose was significantly more effective than half dose. Yields showed significant differences between control in the two years, fungicide treatments, and for control x treatment x dose interactions, but not for dose. Mean yields were

3.49 t/ha in 206 and 3.79 t/ha in 2007. Untreated yield averaged 3.45 t/ha compared with 3.67 t/ha for all treatments. Dose trends between 0.25 and full dose were from 3.64 to 3.71 t/ha. Proline (3.92 t/ha, a response of 0.47 t/ha) gave a significantly higher yield than all the other products except Prosaro (3.82 t/ha). The dose response curves for light leaf spot (Fig. 3.7) emphasise the higher activity of Proline at lower doses and the continuation of yield responses above 0.5 dose.

3.3.4.3 Sclerotinia (Figures 3.10, 3.11, 3.12, 3.13)

The combined data on sclerotinia incidence from all six experiments showed highly significant effects from year, site, fungicide, dose and their interactions except for fungicide x dose interactions. The Hereford sites averaged 31% sclerotinia compared with 15% in Kent. Overall fungicides decreased incidence from 44% to 22%. Products were ranked in order of efficacy as Filan, Proline>Compass>Amistar, Folicur, Priori Xtra. Each increase in dose gave a significant improvement in control with incidence decreasing from 27% at 0.25 dose to 17% at full dose.

The combined data on sclerotinia severity index from all six experiments showed highly significant effects from year, site, fungicide, dose and their interactions except for fungicide x dose interactions. The Hereford sites had an average sclerotinia index of 20.4 compared with 8.3 in Kent. Overall fungicides decreased incidence from 33.7 to 13.0. Products were ranked in order of efficacy as Filan (index 9.9), Proline>Compass>Amistar, Folicur, Priori Xtra (index 17.3) – identical to the incidence data. Each increase in dose gave a significant improvement in control with index decreasing from 17.5 at 0.25 dose to 9.4 at full dose. Filan was more effective than other products at low doses and had a flat response curve above 0.5 dose (Fig. 3.10).

The combined data on sclerotinia yield from all six experiments showed highly significant effects from year, site, fungicide, dose and their interactions except for the five factor year x site x control x fungicide x dose interactions (only narrowly outside significance at P=0.051). The Hereford sites averaged 3.97 t/ha compared with 3.68 t/ha in Kent. Products were ranked in order of yield as Filan, Compass, Proline> Priori Xtra, Amistar, Folicur Each increase in dose gave a significant improvement in control up to 0.75 dose with no additional benefit at full dose.

Because of the large variation in sclerotinia incidence between sites, cross-site analyses have also been done separately for the Hereford and Kent sites. At the

Hereford site, sclerotinia incidence averaged 63% plants affected in untreated controls and 29% in treated plots. The combined data on sclerotinia incidence from all three experiments showed highly significant effects from year, fungicide, dose and their interactions except for fungicide x dose interactions (Figures 3.14, 3.15, 3.16, 3.17). Products were ranked in the same order of efficacy as the six site analyses: Filan, Proline>Compass>Amistar, Folicur, Priori Xtra. Product mean incidence ranged from 24.6% with Filan to 35.8% with Priori Xtra. Each increase in dose improved control of sclerotinia, as incidence was decreased from 62.6% in the untreated to 36.1% at 0.25 dose and 23.8% at full dose. There were very similar effects on sclerotinia severity with the same product ranking as indicated for sclerotinia incidence (range: Filan index 15.1 to Priori Xtra index 23.8; untreated index 48.7). Each increase in dose decreased severity from 24.3 at 0.25 dose to 14.2 at full dose. Yield analyses showed significant effects from all factors: control, year, treatment, dose and their interactions. Untreated yield was 2.56 t/ha and the mean treated yield 4.07 t/ha, a response of 1.51 t/ha. Products were ranked in the order: Filan (4.36 t/ha)> Proline, Compass> Priori Xtra, Amistar> Folicur (3.69 t/ha). There were significantly increased yields with dose up to 0.75 dose and then no further increase at full dose. The responses ranged from 1.11 t/ha at 0.25 dose up to 1.74 t/ha at 0.75 dose. The yield response curves at Hereford show yield is still increasing at full dose for all products except Filan (Fig. 3.14).

The Kent site had very low levels of sclerotinia in 2006 with 0.5% plants affected in the untreated controls and 0.3% in treated plots. Incidence was much higher in 2007 (41% in untreated) and 2008 (37% in untreated). About 10% of these plants in 2007 and 2008 had lesions only on the smaller branches. All factors had significant effects on sclerotinia incidence (Figs 3.22, 3.23, 3.24, 3.25), but there was no significant fungicide x dose interaction. Products were ranked in the same order of efficacy as the six site analyses: Filan (10.9% sclerotinia), Proline, Compass> Folicur, Amistar, Priori Xtra (17.8% sclerotinia). Each increase in dose decreased disease incidence significantly and incidence was 26.3% in the untreated, 17.6% at 0.25 dose and 10.7% at full dose. The severity indices based on main stem lesions only averaged 0.3 in 2006, 7.6 in 2007 and 17.1 in 2008. All factors had significant effects on sclerotinia incidence but there was no significant fungicide x dose interaction. Product rankings were the similar to that described for sclerotinia incidence, with Filan giving a significantly lower index than all the other products except Proline. There was a significant yield response overall in Kent where untreated yield averaged 3.32 t/ha and treated yield was 3.71 t/ha. There were no significant yield differences between products (range 3.64-3.76 t/ha) or doses (range 3.63-3.74 t/ha), clearly quite different to the performance of products at the Hereford site. The dose response curves show distinct differences with yield increasing steeply with dose for Amistar and Folicur, but reaching a plateau by 0.5 dose for Filan and Compass (Fig. 3.22).

3.4 Discussion

The aim was to expose products to different natural epidemics so that the properties of the various fungicides were characterised in relation to dose. Products have been exposed to testing disease pressure and the project has therefore provided detailed new information on fungicide efficacy and impact on yield. There has been previous work comparing full and half dose but no systematic study of products at a range of doses dose. Data on product efficacy are available for fungicides on wheat and barley and are available on the HGCA website (www.hgca.com). The cereal fungicide performance project targets individual diseases with single sprays and is therefore more strongly oriented to product efficacy than to yield response. The oilseed rape protocols with one or two fungicide applications provide valuable yield response data as other diseases are kept at low levels by site selection or oversprays. The yield adapt is important as it is clear that responses relate to both disease control and physiological effects on the plant. The latter may be positive or negative and influence the economic benefits of treatments.

There were significant differences in disease severity between years and data is available for moderate to severe disease situations. Data under low disease pressure is limited, but trends for positive yield effects from fungicides were obtained. It is important that fungicides are evaluated at range of sites and years to establish their performance. The number of experiments completed for each disease is still small and careful interpretation of yield benefits from treatments is required before selecting appropriate doses and products for use on farms. For examples, the benefits from metconazole in stem canker trials were associated with stem canker control and plant growth regulatory effects on medium to large plants in autumn and these may not occur in crops where plants are small. Similarly the benefits may be larger in dry summers if treatments lead to improved rooting at depth. At the stem canker sites, plants were moderate to large in the autumn and fungicides were applied at or soon after the threshold of 10-20% plants affected was reached. The data from 2006/07 provides support for use of products at 0.75 dose where crops have early infection (including cotyledons) and have disease levels well above threshold. Generally, there were only small yield benefits (c. 0.1t ha^{-1}) from using doses above 0.5 and this dose is widely used on farms (Garthwaite *et al.,* 2007). Data for light leaf spot control are more limited, but doses of Proline should be kept about 0.5 dose for yield response. Soil type and variety may also be important for the economic performance of products. Such effects are often smaller than seasonal variation which is both large and difficult to predict (see PASSWORD project, Gladders *et al*., 2006).

The comparison of disease control efficacy should be robust under a wide range of conditions. Product performance may be different in future if fungicide resistant strains become established. At present the performance of azole products against light leaf spot may be impaired by fungicide resistance (Burnett, 2003) and in future work fungicide sensitivity will be monitored in each experiment. There was very high efficacy of products against phoma leaf spot in autumn 2007, suggesting few problems in *L. maculans* populations. Phoma B (*L. biglobosa*) developed slightly later than *L. maculans* and appeared to be more difficult to control. There is laboratory data for *L. biglobosa* indicating that it has higher and a wider range of ED50 values (i.e. is less sensitive) for flusilazole and tebuconazole than *L. maculans* (Eckert *et al.,* 2004).

Re-infection by phoma leaf spot started only three weeks after application in 2006 and disease control six weeks after treatment was less effective than usual. However, it was the efficacy (percentage) of control rather than the ranking of products that varied between sites. This also applied to sclerotinia products where the sites in Kent and Hereford gave similar rankings of products for disease control. The sclerotinia did show differences in dose responses for yield. If products are applied under ideal conditions or low disease pressure then it may not be possible to statistically separate commercial products.

Many of the fungicides had direct effects on the plant making leaves darker green and, in some cases, reducing leaf size. Such effects may contribute to yield. Growth regulatory effects of metconazole appeared to be beneficial for yield and compensated for slightly weaker activity against stem canker. Metconazole was used on 241,000 ha in 2005-06 (Garthwaite *et al.,* 2007) when plants were also large and farmers used this product to control stem canker and reduce growth of the foliage in autumn. The yield benefit from prothioconazole/tebuconazole compared with prothioconazole alone was also associated with growth regulatory effects as treated plots remained more erect pre-harvest, particularly in 2007. In 2008 stem cankers were mainly small lesions and are thought not to affect yield (West *et al*., 2002). Nevertheless control of small cankers was clearly demonstrated and yield responses were obtained.

At current prices for rapeseed, a yield response of 0.1 t/ha (=£25) would enable the cost of one full dose or 2 x half dose of most products to be recovered. Control of light leaf spot on leaves was demonstrated, but there were no significant positive yield responses or dose effects in 2007. The crop was not heavily infected during the winter and the crop produced an acceptable canopy despite significant foliar infection. High yield loss is often associated with loss of plants or aerial plant parts and this has not been a feature of these experiments. On farms the benefits of fungicides could be much larger (>1 t/ha) as indicated in previous projects (Gladders *et al.,* 1998). It might be argued that doses should be at least 0.50 and probably higher given the problems of making timely applications in Scotland. However, the experiment identified negative effects from higher doses of Caramba and other some other products with growth regulatory activity on yield in Scotland. Further work is in progress to establish if these effects also occur in northern England. It proved difficult to achieve good control of light leaf spot and this may be due to the long interval between applications as well as to reduced sensitivity of the pathogen to azole fungicides (Burnett, 2003). As only azole fungicides are available for control of light leaf spot, new products with good activity against this disease are needed. The use of varieties with strong resistance to light leaf spot is a key part of managing this disease.

Spray timing is critical for sclerotinia control as fungicides have little or no curative activity. Infection could occur at any stage during flowering (and was also noted on leaves prior to flowering) and product efficacy may reflect both inherent activity against sclerotinia and persistence. These results indicate that there are some differences in product efficacy and in relation to dose. For disease control, higher doses were more effective than low doses whilst for yield response dose effects were less significant and 0.75 dose was only beneficial under high disease pressure. The use of weaker products and low doses at high risk sites could result in considerable loss of yield (>0.5 t ha^{-1}). Disease control efficacy is still a key criterion as this will influence the return of new sclerotia to the soil and hence affect future disease risk. Given the difficulty of predicting sclerotinia severity in crops, growers are encouraged to use robust doses of fungicides to achieve good control of sclerotinia in oilseed rape. Single sprays did not protect the crop against infection at the late flowering stage in 2007 and 2008 (Gladders *et al*., 2008). Stem rot control averaged only 57% at Hereford site in 2007 and fell short of the target of 90% control achieved in other experiments (ADAS, unpublished data). A second spray about three weeks after the first spray (or pgr treatment) should be considered to maintain protection at high risk sites. Good spray penetration into the crop canopy is important and fungicides should be applied in a minimum of 200 litres water/ha.

This project has characterised the main commercial fungicides and offers new information about product performance on disease control and yield response. Significant differences between product and dose have been identified for existing products. This can be exploited to improve the profitability of crop production. In addition, data has been gathered on some new products that are awaiting registration and this will be made available when products are launched.

The oilseed rape crop area is currently 500,000 ha and it is estimated that diseases are capable of causing average yield losses of 0.5 t/ha worth £125/ha (total losses £62.5 million), but can be higher in some years (Fitt *et al.,* 1997). Fungicide costs of about £12 million have been incurred annually, but are now increasing with more widespread use of fungicides for sclerotinia control. If this research is exploited, there would be yield benefits from improved disease control by selecting the most appropriate product and opportunity to reduce costs of fungicides by reducing dose. Improving stem canker or light leaf spot control through better product or dose selection might produce a benefit of 0.2 t/ha worth £50/ha. Using higher doses or more effective products for sclerotinia control could improve margins by £100/ha at high disease sites. Experiments provided some data on physiological (non-disease) effects and benefits by examination of disease control and yield responses. A yield benefit of 0.1 t/ha on 40% of the crop area through improved product performance would be worth £5 million/annum. A saving of fungicide costs of £2/ha on 40% of the crop area provides an additional benefit of £0.4 million/annum.

Up-to-date information on new products should enable strategies to protect products against the development of fungicide resistant strains to be deployed more effectively. Base-line data will enable shifts in product performance or fungicide sensitivity to be detected more readily.

The project is expected to have a significant impact on selection of product and dose and contribute to improved targeting of inputs. The data are of immediate value to industry for exploitation, providing guidance on effective doses in relation to disease severity. In future, there are opportunities to exploit web-based delivery of dose-response curves with HGCA. Reduced doses and more effective use of fungicides should produce some environmental benefits through reduced risk of toxicity to aquatic organisms. Increased awareness of products will allow greater diversification of fungicide chemistry, particularly for sclerotinia control reducing the risks of fungicide resistance and ineffective applications.

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3.3.3 Published papers

Gladders, P, Roques S, Moore A, Smith J A, Ritchie F, Oxley S J P, Torrance J, Dyer C. 2009. Practical implications of fungicide performance data from winter oilseed rape. *Aspects of Applied Biology* **91**, *Crop Protection in Southern Britain:* 33-39.

3.6 Appendices

Appendix A. Site details

A.1 ADAS Boxworth Phoma, 2005/06.

Site:	ADAS Boxworth, Cambs		
Field name:	Pamplins South		
Soil texture:	Clay loam		
Drainage:	Good		
Previous cropping:	2005 Winter wheat 2004 Winter oilseed rape- some parts resown with spring oilseed rape 2003 Winter wheat		
Soil analysis: (December)	pH 8.0 ADAS Indices – P 21 mg/l (2), K 308 mg/l (3), Mg 82 mg /l (2) 3.58% organic matter		
Seed bed cultivations		:	Qvon on 12 August 2005 Power harrowed on 16 August 2005
Crop: Winter oilseed rape	Cultivar	:	Labrador
	Sowing date	:	27 August 2005
	Seed rate		6.0 kg/ha drilled and rolled in
	Fertiliser	:	12:18:0:0 (400 l/ha) on 1 September 2005 34.5% N product (174 kg/ha) + ammonium sulphate (100 kg/ha) on 6 March 2006 34.5% N product (290 kg/ha) on 7 April 2006
Herbicides:	Katamaran (1.5 l/ha) + Trfluralin 480 (2 l/ha) on 1 September 2005 Falcon (0.25 l/ha) + mineral oil (1 l/ha) on 13 September 2005; Aramo (1 l/ha) on 27 October 2005.		
Fungicides:	Experimental treatments only.		
Insecticides:	Cypermethrin 100 0.14 l/ha on 13 September 2005		
Molluscicides:	Draza (5 kg/ha) on 1 and 15 September 2005 Minipellets (15 kg/ha) on 29 September 2005		
Growth regulator:	-		
Desiccant	Glyphos (4 l/ha) on 06 July 2006		
Harvest date:	20 July 2006		

A.2 ADAS Boxworth AFD Phoma, 2006/07.

Site:	ADAS Boxworth, Cambs		
Field name:	Samsons East		
Soil texture:	Clay loam		
Drainage:	Good		
Previous cropping:	2006 Winter wheat 2005 Winter wheat 2004 Winter wheat		
Soil analysis: (December)	pH 7.7 ADAS Indices – P 23 mg/l (2), K 273 mg/l (3), Mg 92 mg /l (2) 4.37% organic matter		
Seed bed cultivations		:	Flat lift 14 August 2006 Qvon/press on 16 August 2006 Power harrowed on 17 August 2006
Crop: Winter oilseed rape	Cultivar	:	Winner
	Sowing date	:	04 September 2006
	Seed rate	:	5.0 kg/ha drilled and rolled in
	Fertiliser	:	7:21:0:0 (400 l/ha) on 6 September 2006 Ammonium sulphate (100 kg/ha) on 21 March 2007 34.5% N product (290 kg/ha) on 11 April 2007
Herbicides:	Butisan S (1 l/ha) + Glyphos (2 l/ha) on 4 September 2006 Trifluralin 480 (2 l/ha) on 5 September 2006 Crawler (3.5 kg/ha) on 31 January 2007		
Fungicides:	Experimental treatments only.		
Insecticides:	Cypermethrin 100 (0.25 l/ha) on 13 October 2006 Aphox (0.409 kg/ha) on 1 May 2007		
Molluscicides:	Minipellets (15 kg/ha) on 05 September 2006		
Growth regulator:	-		
Trace elements:	-		
Desiccant	Reglone (3 l/ha) + Companion Gold (0.52 l/ha) on 11 July 2007		
Harvest date:	17 July 2007		

A.3 ADAS Boxworth AFD Phoma, 2007/08.

Site:	ADAS Boxworth, Cambs		
Field name:	Mill Ground field at Elsworth (Grid Reference TL323627)		
Soil texture:	Clay loam		
Drainage:	Good		
Previous cropping:	2007 Winter wheat 2006 Winter wheat 2005 Winter beans		
Soil analysis: (February)	pH 7.8 ADAS Indices – P 25 mg/l (2), K 302 mg/l (3), Mg 112 mg /l (3) 3.02% organic matter		
Seed bed cultivations		:	Level lift (subsoil tracks drilled) and rolled on 20 August 2007
Crop: Winter oilseed rape	Cultivar	:	Winner
	Sowing date	:	20 August 2007
	Seed rate	:	6.0 kg/ha
	Fertiliser	:	Urea (46%, 80kg/ha) on 2 October 2007 DAP (18:46:0, 300 kg/ha) on 9 February 2008 Urea (46%, 175kg/ha) on 9 March 2008 Ammonium sulphate (21:0:0:60, 238 kg/ha) on 1 April 2008
Herbicides:	Fusilade Max (0.5 l/ha) on 20 October 2007 Kerb (2.0 l/ha) + Slither (0.1l/ha) on 7 November 2007 Galera (0.33 l/ha) on 5 March 2008		
Fungicides:	Experimental treatments only.		
Insecticides:	Cypermethrin (0.25 l/ha) on 1 and 20 October 2007		
Molluscicides:	Minipellets (5.0 kg/ha) on 7 and 21 August, 1 October 2007		
Growth regulator:	-		
Trace elements:	-		
Desiccant	Glyphos (4.0 l/ha) on 13 July 2008		
Harvest date:	29 July 2008		

A.4 ADAS Terrington AFD Phoma, 2005/06

Site:	ADAS Terrington, Norfolk		
Field name:	Bullock Road		
Soil texture:	Silty clay loam		
Drainage:	Good		
Previous cropping:	2005 Winter wheat 2004 Winter wheat 2003 Sugar beet		
Soil analysis: (December)	pH 7.9 ADAS Indices – P 24 mg/l (2), K 279 mg/l (3), Mg 273 mg /l (5)		
Seed bed cultivations		:	Ploughed on 21 August 2005 Power harrowed on 4 September 2005
Crop: Winter oilseed rape	Cultivar	:	Winner
	Sowing date	:	7 September 2005
	Seed rate		6.0 kg/ha drilled and rolled in
	Fertiliser	:	12:18:0:0 (204 l/ha) on 7 September 2005 34.5% N product (59 kg/ha) + ammonium sulphate (51 kg/ha) on 03 March 2006, 34.5% N product (147.8 kg/ha) on 6 April 2006
Herbicides:	Butisan S (1 l/ha) on 13 September 2005 Aramo (1 l/ha) on 22 October 2005.		
Fungicides:	Experimental treatments only.		
Insecticides:	-		
Molluscicides:	Draza (5 kg/ha) on 7 September 2005 and 1 February 2006, Mini pellets (15 kg/ha) on 22 September 2005		
Growth regulator:	-		
Trace elements:	-		
Desiccant	Glyphosate (4 l/ha) on 07 July 2006		
Harvest date:	18 July 2006		

A.5 ADAS Terrington AFD Phoma, 2006/07

Site:	ADAS Terrington, Norfolk		
Field name:	Grove 18		
Soil texture:	Silty clay loam		
Drainage:	Good		
Previous cropping:	2006 Winter wheat 2005 Winter wheat 2004 Sugar beet		
Soil analysis:	pH 7.6 ADAS Indices – P 33 mg/l (3), K 266 mg/l (3), Mg 184 mg /l (4)		
Seed bed cultivations		:	Ploughed on 8 August 2006, Power harrowed on 8 August 2006 Rolled on 11 August 2006
Crop: Winter oilseed rape	Cultivar	:	Winner
	Sowing date	:	10 September 2006
	Seed rate	:	6.0 kg/ha drilled and rolled in
	Fertiliser	:	N (28kg/ha) and P (84 kg/ha) applied on 11 September as 7:21:0:0 N (21 kg/ha) and S (24kg/ha) applied on 26 March N (160kg/ha) applied on 10 April
Herbicides:	Butisan S (1 l/ha) + Trifluralin 480 (2 l/ha) on 11 September 2006		
Fungicides:	Experimental treatments only.		
Insecticides:	-		
Molluscicides:	Mini pellets (5 kg/ha) on 07 October 2006 Mini pellets (8 kg/ha) on 16 October 2006		
Growth regulator:	-		
Trace elements:	-		
Desiccant	Glyphos (4 l/ha) on 09 July 2007		
Harvest date:	27 July 2007		

A.6 ADAS Terrington AFD Phoma, 2007/08

Site:	Bentinck Farm, Terrington St Clement, Kings Lynn, Norfolk		
Field name:	Sows Field		
Soil texture:	Silty clay loam		
Drainage:	Good		
Previous cropping:	2007 Winter wheat 2006 Peas 2005 Winter wheat		
Soil analysis: (January)	pH 7.7 ADAS Indices – P 16 mg/l (2), K 271 mg/l (3), Mg 284 mg /l (5) 3.04% organic matter		
Seed bed cultivations		:	Flat Lifted on 20 August 2007 Direct drilled behind sub-soil tine
Crop: Winter oilseed rape	Cultivar	:	Winner
	Sowing date	:	28 August 2007
	Seed rate		6.0 kg/ha
	Fertiliser	:	34.5% N product (90 kg/ha) on 25 October 2007 Double Top (244 kg. ha) on 5 March 2008 34.5% N product (360 kg/ha) on 4 April 2008
Herbicides:	Fusilade Max (0.3 l/ha) on 10 October 2007 Galera (0.35 l/ha) on 3 March 2008		
Fungicides:	Experimental treatments only.		
Insecticides:	Toppel 10 (0.25 l/ha) on 10 October 2007		
Molluscicides:	Luxan Trigger (7.5 kg/ha) on 28 August 2007, (7 kg/ha) on 13 September 2007, (7.5 kg/ha) on 22 September 2007		
Growth regulator:			
Trace elements:			
Desiccant	Clinic Ace (3 l/ha) on 22 July 2008		
Harvest date:	1 August 2008		

A.7 SAC Aberdeen. AFD Light Leaf Spot 2005/06

Site:	Inverurie, Aberdeen		
Field name:	Mains 6		
Soil texture:	Medium Loam		
Drainage:	Good		
Previous cropping:	2005 Winter barley 2004 Winter wheat 2003 Winter OSR		
Soil analysis:	pH 6.9 P 10.2 mg/l (mod), K 122 mg/l (mod), Mg 272 mg /l (high) S 7.7 (mod) 6.2% organic matter		
Cultivations		:	Power harrowed on 01 September 2005
Crop: Winter oilseed rape	Cultivar	:	Castille
	Sowing date	:	02 September 2005
	Seed rate		6.0 kg/ha drilled and rolled in
	Fertiliser	:	30:0:0:s N product (90 kg/ha) + 0:26:26 (24 kg/ha) on 17 March 2006 30:0:0:s N product (90 kg/ha) on 24 April 2..6
Herbicides:	Butisan s (1.0 l/ha) on 3 September 2005 Kerb (1.7kg) on 8 November 2005.		
Fungicides:	Experimental treatments only.		
Insecticides:			
Molluscicides:	Metorex green (8 kg/ha) on 3 September and 6 October 2005		
Growth regulator:	-		
Trace elements:	-		
Swathed	27 July 2006		
Harvest date:	7 August 2006		

A.8 SAC Aberdeen. AFD Light Leaf Spot 2006/07

Site:	Blackburn Aberdeenshire		
Field name:	Steading 2		
Soil texture:	Medium loam		
Drainage:	Good		
Previous cropping:	2006 Winter Barley 2005 Winter wheat 2004 Spring Barley		
Soil analysis: (December)	pH 5.8 P 14.4 mg/l (high), K 149 mg/l (mod), Mg 113 mg /l (mod) S 6.1 (mod) 6.3% organic matter		
Cultivations		:	Power harrowed on 30 August 2006
Crop: Winter oilseed rape	Cultivar	:	Castille
	Sowing date	:	31 August 2006
	Seed rate	:	6.0 kg/ha drilled and rolled in
	Fertiliser	:	20:10:10 N product (100kg/ha) on 28 August 2006 30:0:0:s N product (90 kg/ha) on 30 March 2007 30:0:0:s N product (90 kg/ha) on 20 April 2007
Herbicides:	Butisan s (1.5 l/ha) on 1 September 2006		
Fungicides:	Experimental treatments only.		
Insecticides:			
Molluscicides:	Allure (15 kg/ha) on 03 September 2006		
Growth regulator:	-		
Trace elements:	-		
Swathed	26 July 2007		
Harvest date:	10 August 2007		

A.9 SAC Aberdeen. AFD Light Leaf Spot 2007/08

Site:	Ellon, Aberdeenshire	
Field name:	Grid NJ979 342	
Soil texture:	Clay loam	
Drainage:	Poor	
Previous cropping:	2007 Set aside 2006 Set aside 2005 Set aside	
Soil analysis:	pH 6.8 P 7.0 mg/l (mod), K 211 mg/l (high), Mg 227 mg /l (high) S 15.9 (high) 7.0% organic matter	
cultivations		: Power harrowed on 1 September 2007
Crop: Winter oilseed rape	Cultivar	: Castille
	Sowing date	: 1 September 2007
	Seed rate	: 6.0 kg/ha drilled and rolled in
	Fertiliser	: 20:10:10 N product (100kg/ha) 29 August 2007, 30:0:0:s N product (90 kg/ha) on 28 February 2008 30:0:0:s N product (90 kg/ha) on 3 April 2008
Herbicides:	Butisan S (1.5 l/ha) on 2 September 2007	
Fungicides:	Experimental treatments only.	
Insecticides:		
Molluscicides:	Allure (15 kg/ha) on 03 September 2007 Allure (8 kg/ha) on 21 September and 8 October 2007	
Growth regulator:	-	
Trace elements:	-	
Swathing / desiccation	Swathing started and abandoned 30 July 2008 Desiccant 5l/ha Glyphosate on 4 August 2008	
Harvest date:	28 August 2008	

A. 10 ADAS High Mowthorpe AFD Light Leaf Spot, 2007/08

Site:	ADAS High Mowthorpe, Duggleby, N. Yorks		
Field name:	Crow Wood		
Soil texture:	Silty clay loam		
Drainage:	Good		
Previous cropping:	2007 Winter wheat 2006 Winter wheat 2005 Winter oilseed rape		
Soil analysis:	pH 8 ADAS Indices – P 15 mg/l (1), K 125 mg/l (2), Mg 33 mg/l (1)		
Seed bed cultivations		:	Ploughed and power harrowed on 6 September 2007
Crop: Winter oilseed rape	Cultivar	:	Castille
	Sowing date	:	6 September 2007
	Seed rate		6.6 kg/ha
	Fertiliser	:	Extran (94 kg/ha) on 19 October 2007 0:20:30 (250 kg/ha) on 7 February 2008 Nuram 35 (189 l/ha) on 15 February 2008 Nuram 35 (234 l/ha) on 6 March 2008 Nuram 35 (210 l/ha) on 17 April 2008
Herbicides:	Sultan (1 l/ha) + Trifluralin (1.3 l/ha) on 11 September 2007 Novall (2 l/ha) Jan/Feb 2008 Oram (1 l/ha) on 17 March 2008		
Fungicides:	Experimental treatments only.		
Insecticides:	Cypermethrin (0.25 l/ha) on 8 October 2007 Mavrik (0.2 l/ha) on 19 May 2008		
Molluscicides:	TDS Major on 10 September and 2 October 2007		
Growth regulator:			
Trace elements:	Opte b (5 l/ha)		
Desiccant	Glyphosate (4 l/ha)		
Harvest date:	16 September 2008		

A. 11 ADAS Rosemaund, AFD Sclerotinia, 2005/06

Site:	Ocle Pychard, Nr Hereford		
Field name:	Forty Acres		
Soil texture:	Silty clay loam		
Drainage:	Good		
Previous cropping:	2005 Winter wheat 2004 Winter beans 2003 Winter wheat		
Soil analysis: (July)	pH 5.9 ADAS Indices – P 12 mg/l (1), K 71 mg/l (1), Mg 199 mg/l (4) 2.98% organic matter		
Crop: Winter oilseed rape	Cultivar	:	Lioness
	Sowing date	:	24 August 2005
	Seed rate		3.9 kg/ha
	Fertiliser	:	Double top (209 kg/ha) on 20 March 2006 34.5:0:0 (305 kg/ha) on 3 April 2006 Urea (50 l/ha) on 11 May 2006
Herbicides:	Fusilade Max (0.6 l/ha) on 6 September 2005 Kerb Flo (1.75 l/ha) on 20 October 2005		
Fungicides:	Contrast/Punch C (0.4 l/ha) on 10 November 2005		
Insecticides:	Hallmark (0.25 l/ha) on 20 October 2005		
Molluscicides:	Draza (5.6 kg/ha) on 25 August 2005		
Growth regulator:	-		
Trace elements:	-		
Desiccant	Roundup (2.5 l/ha) on 12 July 2006		
Harvest date:	21 July 2006		

A.12 ADAS Rosemaund AFD Sclerotinia, 2006/07

Site:	Weobley, Nr Hereford		
Field name:	Barn Meadow		
Soil texture:	Silty clay loam		
Drainage:	Good		
Previous cropping:	2006 Winter wheat 2005 Winter oilseed rape 2004 Winter wheat		
Soil analysis: (December)	pH 6.3 ADAS Indices – P 17 mg/l (2), K 173 mg/l (2-), Mg 54 mg/l (2) 2.69% organic matter		
Crop: Winter oilseed rape	Cultivar	:	Catalina
	Sowing date	:	1 September 2006
	Seed rate		4.0 kg/ha
	Fertiliser	:	0:6:24 (494 kg/ha) on 28 March 2007 30%N + 27% SO_3 (370 kg/ha) on 15 April 2007
Herbicides:	Falcon (0.375 l/ha) on 4 October 2006 Kerb (1.0 kg/ha) on 20 November 2006 Galera (0.35 l/ha) on 7 March 2007		
Fungicides:	Caramba (0.6 l/ha) on 29 October 2006 Sunorg Pro (0.4 l/ha) on 24 March 2007 Sanction (0.3 l/ha) on 20 November 2006		
Insecticides:	Mavrik (0.85 l/ha) on 4 October 2006 Cypermethrin (0.25 l/ha) on 29 October 2006 Mavrik (0.2 l/ha) on 5 May 2007		
Molluscicides:	-		
Growth regulator:	-		
Trace elements:	-		
Desiccant	-		
Harvest date:	3 August 2007		

A.13 ADAS Rosemaund AFD Sclerotinia, 2007/08

Site:	Weobley, Nr Hereford
Field name:	Big Meadow
Soil texture:	Silty clay loam
Drainage:	Good
Previous cropping:	2007 Winter wheat 2006 Potatoes 2005 Winter wheat
Soil analysis: (December)	pH 5.7 ADAS Indices – P 32 mg/l (3), K 94 mg/l (1), Mg 60 mg/l (2) 2.0% organic matter
Crop: Winter oilseed rape	Cultivar : Castille Sowing date : 4 September 2007 Seed rate 5.0 kg/ha Fertiliser : Fibrophos (500 kg/ha) on 1 September 2007 30%N + SO_3 (250 kg. ha) on 18 March 2008 34.5:0:0 (370 kg/ha) on 3 April 2008
Herbicides:	Zealot (0.5 l/ha) on 10 October 2007 Dow Shield (0.375 l/ha) on 12 November 2007 Propyzamide 50 (1.0 l/ha) on 29 January 2008 Clinic Ace (2.85 l/ha) + Exchange (0.5 l/ha) + Pod Stik (1.0 l/ha) on 19 July 2008
Fungicides:	-
Insecticides:	Mavrik (0.1 l/ha) on 10 October 2007 Cypermethrin (0.25 l/ha) on 12 November 2007 Mavrik (0.2 l/ha) on 26 April 2008
Molluscicides:	Huron (4.5 kg/ha) on 10 October 2007
Growth regulator:	-
Trace elements:	-
Desiccant	-
Harvest date:	14 August 2008

A.14 Romney Marsh AFD Sclerotinia, 2005/06.

Site:	St Mary in the Marsh, Kent (Romney Marsh)		
Field name:	Cow Marsh		
Soil texture:	Silty clay loam		
Drainage:	Good		
Previous cropping:	2005 Winter wheat 2004 Winter oilseed rape 2003 Winter wheat		
Soil analysis: (April)	pH 7.5 ADAS Indices – P 18 mg/l (2), K 383 mg/l (3), Mg 108 mg /l (3) 4.83% organic matter		
Crop: Winter oilseed rape	Cultivar	:	Es Astrid
	Sowing date	:	31 August 2005
	Seed rate	:	5.0 kg/ha
	Fertiliser	:	Ammonium nitrate (100 kg/ha) on 15 September 2005 Extra S (150 kg/ha) on 13 March 2006 Ammonium nitrate (425 kg/ha) on 13 April 2006
Herbicides:	Trifluralin (2 l/ha) + Butisan S (1.5 l/ha) + Kn540 (1 l/ha) on 2 September 2005 Fusilade Max (0.5 l/ha) on 22 September 2005 Crawler (2.5 kg/ha) on 31 January 2006		
Fungicides:	Plover (0.25 l/ha) on 17 November 2005		
Insecticides:	Cypermethrin (0.25 l/ha) on 22 September 2005 Contest (0.1 kg/ha) on 4 May 2006		
Molluscicides:	Mini slug pellets (5 kg/ha) on 5 and 15 September 2005		
Growth regulator:	-		
Trace elements:	-		
Desiccant	Kn540 (2 l/ha) on 17 July 2006		
Harvest date:	26 July 2006		

A.15 Romney Marsh AFD Sclerotinia, 2006/07.

Site:	St Mary in the Marsh, Kent (Romney Marsh)		
Field name:	Tyrells		
Soil texture:	Silty clay loam		
Drainage:	Good		
Previous cropping:	2006 Winter wheat 2005 Winter oilseed rape 2004 Winter wheat		
Soil analysis: (July)	pH 7.0 ADAS Indices – P 42 mg/l (3), K 499 mg/l (4), Mg 175 mg /l (3) 4.96% organic matter		
Crop: Winter oilseed rape	Cultivar	:	Castille
	Sowing date	:	1 September 2006
	Seed rate	:	5.0 kg/ha
	Fertiliser	:	Tsp (phosphate, 135 kg/ha) on 1 October 2006 Ammonium nitrate (34.5% N, 100 kg/ha) on 5 October 2006 Urea38 + S19 (175 kg/ha) on 8 March 2007 Urea38 + S19 (350 kg/ha) on 4 April 2007
Herbicides:	Aramo (1 l/ha) + Butisan S (1.5 l/ha) on 8 October 2006 Crawler (3.5 kg/ha) on 10 November 2006 Fox (1 l/ha) on 31 January 2007 Laser (1 l/ha) + TOIL (1 l/ha) on 16 March 2007		
Fungicides:	Sunorg Pro (0.4 l/ha) on 11 October 2006 Capitan 25 (0.4 l/ha) on 10 November 2006		
Insecticides:	Cypermethrin (0.25 l/ha) on 1 and 8 October 2006		
Molluscicides:	Minipellets (8.0 kg/ha) on 5 October 2006		
Growth regulator:	-		
Trace elements:	-		
Desiccant	-		
Harvest date:	24 July 2007		

A.16 Romney Marsh AFD Sclerotinia, 2007/08.

Site:	St Mary in the Marsh, Kent (Romney Marsh)
Field name:	Green Shed
Soil texture:	Silty clay loam
Drainage:	Good
Previous cropping:	2007 Winter wheat 2006 Winter oilseed rape 2005 Winter wheat
Soil analysis: (February)	pH 7.6 ADAS Indices – P 17 mg/l (2), K 334 mg/l (3), Mg 151 mg /l (3) 4.64% organic matter
Crop: Winter oilseed rape	Cultivar : Es Astrid Sowing date : 7 September 2007 Seed rate : 4.5 kg/ha Fertiliser : 30:0:0:19 (300 kg/ha) on 29 February 2008 34:0:0 (275 kg/ha) on 3 March 2008
Herbicides:	Novall (2.5 l/ha) on 5 October 2007 Laser (0.8 l/ha) + Crop oil (1 l/ha) on 22 October 2007 Crawler (3.5 kg/ha) + Falcon (0.5 l/ha) on 15 December 2008
Fungicides:	Plover (0.25 l/ha) on 22 October 2007 Proline (0.3 l/ha) on 13 December 2007
Insecticides:	Permasect (0.25 l/ha) on 5 October and 13 December 2007
Molluscicides:	Minipellets (5.0 kg/ha) on 19 September 2007
Growth regulator:	-
Trace elements:	-
Desiccant	Roundup Ultimate (2 l/ha) + Buffalo Elite (1 l/ha) on 11 July 2008
Harvest date:	17 July 2008

Appendix B. Spray application details and conditions at spraying

B.1 Application details, Boxworth 2005/06.

Application date	Growth Stage	Weather
18 October 2005	1,07	Overcast, dry and cool after cool, dry weather. Crop damp. Temp. 17°C. RH 76%. Light breeze (6-8 kph) with slight spray drift evident.
13 December 2005	1,06 – 1,12	Sunny and cool after cool, dry weather. Crop damp. Temp. 3.0-5.7°C. RH 74-75%. Light breeze (4-7 kph) with moderate spray drift evident.

Spray application equipment:

Sprayer: OPS with 3.0 m boom

Nozzles: LD02F110 (Lurmark).

Water volume: 200 l/ha

Pressure: 2.0 bar

B.2 Application details, Boxworth 2006/07.

Application date	Growth Stage	Weather
12 October 2006	1,03 – 1,07	Sunny and warm after warm, dry weather. Crop dry. Temp. 19.1-22.8°C. RH 48-68%. Calm (<2 kph) with no drift.
18 December 2006	1,14 – 1,16	Cloudy, cool and humid after cool, dry weather. Crop wet. Temp. 4.9-5.8°C. RH 93%. Calm (<2 kph) with no drift.

Spray application equipment:

Sprayer: OPS with 3.0 m boom

Nozzles: LD02F110 (Lurmark).

Water volume: 200 l/ha

Pressure: 2.0 bar

B.3 Application details, Boxworth 2007/2008.

Application date	Growth Stage	Weather
24 October 2007	1,04 – 1,07	Overcast and cool after cool, dry weather Crop dry. Temp. 6.9-9.4°C RH 73% Light breeze (2-4 mph) with no spray drift evident.
12 December 2007	1,10	Sunny, dry and cool after dry, frosty weather. Crop damp. RH 80-84% Temp.1.2-2.5°C Light breeze (1-2 mph) with no spray drift evident.

Spray application equipment:

Sprayer: OPS with 3.0 m boom

Nozzles: 02F110 (Lurmark).

Water volume: 200 l/ha

Pressure: 2.0 bar

B.4 Application details, Terrington 2005/06

Application date	Growth Stage	Weather
01 November 2005	1,07	Temp 11.5°C -13.0°C Humidity 73% Wind 7 mph Crop damp Dry to follow
19 December 2005	1,12	Temp 7.5°C – 4.7°C Humidity 70% Wind 0 mph Crop Dry Dry and sunny to follow

Spray application equipment:

Sprayer: OPS with 3.0 m boom

Nozzles: LD02F110 (Lurmark).

Water volume: 200 l/ha

Pressure: 2.0 bar

B.5 Application details, Terrington 2006/07

Application date	Growth Stage	Weather
13 October 2006	1,04	Crop Dry Temp. 12.0–9.5°C RH 83% Wind 6 mph Dry & sunny to follow
20 November 2006	1,08	Crop Damp Temp 9.0–14.0°C RH 70% Wind 0 mph Dry to follow

Spray application equipment:

Sprayer: OPS with 3.0 m boom

Nozzles: LD02F110 (Lurmark).

Water volume: 200 l/ha

Pressure: 2.0 bar

B.6 Application details, Terrington 2007/08

Application date	Growth Stage	Weather
01 November 2007	1,08	Crop Damp Temp. 9.7–15.6°C RH 84% Wind 4 mph Dry & sunny to follow
13 December 2007	1,11	Crop wet (after thaw) Temp 3.0-2°C RH 80% Wind 4 mph Dry to follow

Spray application equipment:

Sprayer: OPS with 3.0 m boom

Nozzles: LD02F110 (Lurmark).

Water volume: 200 l/ha

Pressure: 2.0 bar

B.7 Application details, SAC Aberdeen 2005/6

Application date	Growth Stage	Weather
09 November 2005	1,04 – 1,08	Cloud cover 50% Crop damp Temp. 13 ^{o}C Wind speed 4-6 kph Soil damp
20 April 2006	3,03	Cloud cover 80% Crop dry Temp. 11 ^{o}C Wind speed 0-2 kph Soil dry

Spray application equipment:

Sprayer: AZO sprayer with 2.0 m boom

Nozzles: SD02F110 (Lurmark).

Water volume: 200 l/ha

Pressure: 2.0 bar

B.8 Application details, SAC Aberdeen 2006/7

Application date	Growth Stage	Weather
07 November 2006	1,06 – 1,08	Cloud cover 50% Crop dry Temp 13 °C Wind speed 0 kph Soil damp
07 March 2007	2,01	Cloud cover 20% Crop dry Temp 10 °C Wind speed 4 kph Soil damp

Spray application equipment:

Sprayer: AZO sprayer with 2.0 m boom

Nozzles: SD02F110 (Lurmark).

Water volume: 200 l/ha

Pressure: 2.0 bar

B.9 Application details, SAC Aberdeen 2007/8

Application date	Growth Stage	Weather
14 November 2007	1,04 – 1,06	Cloud cover 10% Crop dry Temp 11 ^{o}C Wind speed 0 kph Soil damp
31 March 2008	3,01	Cloud cover 50% Crop dry Temp 10 ^{o}C Wind speed 6-8 kph Soil damp

Spray application equipment:

Sprayer: AZO sprayer with 2.0 m boom

Nozzles: SD02F110 (Lurmark).

Water volume: 200 l/ha

Pressure: 2.0 bar

B.10 Application details, High Mowthorpe 2007/08

Application date	Growth Stage	Weather
26 November 2007	1,03	Overcast, dry and cold after a week of cool, dry weather with some frosts following some heavy rain. Crop dry. Temp. 2–4°C Calm - slight W breeze (0-2kph) with no spray drift evident.
27 March 2008	2,0	Cool following several days of frosty weather with showers. Sunny and dry for treatments 3 – 14 incl. followed after 1.5 hours by a rain shower. Treatments 15 – 34 incl. applied later in sunny, dry, and cool conditions onto dry foliage. Temp. 6-8°C RH 80% Light W breeze (2-6 kph) with no spray drift evident.

Spray application equipment:

Sprayer: OPS with 3.0 m boom

Nozzles: LD02F110 (Lurmark).

Water volume: 200 l/ha

Pressure: 2.0 bar

B.11 Conditions at application, Weobley, Hereford 2006

Target date	Products Applied	Actual Date	Growth Stage	Weather (recorded at time of application)
Early to mid flowering	Treatments 3-30	06/05/06	4,5 (BBCH 65)	Overcast and cool after dry and warm weather. Crop dry. Temperature 15°C Humidity 61% Light wind 1.2-2 mph, slight drift.

Spray application equipment

Sprayer: OPS

Nozzles: LD02F110 (Lurmark).

Water volume: 200 l/ha

Pressure: 2.0 bar

B.12 Conditions at application, Weobley, 2007

Target date	Products Applied	Actual Date	Growth Stage	Weather (recorded at time of application)
Early to mid flowering	Treatments 3-30	11/04/07	4,1 – 4,3 (BBCH 61 - 63)	Sunny and warm after dry and warm weather. Crop dry. Temperature 17°C Humidity 48% Light wind 1.2-2 mph, slight drift.

Spray application equipment

Sprayer: OPS

Nozzles: LD02F110 (Lurmark).

Water volume: 200 l/ha

Pressure: 2.0 bar

B.13 Conditions at application, Weobley, 2008

Spray application equipment

Sprayer: OPS

Nozzles: LD02F110 (Lurmark).

Water volume: 200 l/ha

Pressure: 2.0 bar

B.14 Application details, Romney Marsh 2005/06.

Application date	Growth Stage	Weather
3 May 2006		Sunny, warm and dry after dry weather. Crop dry. Temp. 18°C. RH 65%. Calm (<2 kph) with no drift evident.

Spray application equipment

Sprayer: OPS with 2.0 m boom

Nozzles: 02F110 (Lurmark).

Water volume: 200 l/ha

Pressure: 2.0 bar

Target date	Products Applied	Actual Date	Growth Stage	Weather (recorded at time of application)
Early to mid flowering	Treatments 3-30	01/05/08	4,5 (BBCH 65)	Overcast and warm after dry and hot weather. Crop dry. Temperature 13°C Humidity 54% Light wind 1.2-2 mph, slight drift.

B.15 Application details, Romney Marsh 2006/07.

Application date	Growth Stage	Weather
11 April 2007	3,07 – 4,02 (BBCH 59 – 62)	Sunny and hot after hot, dry weather. Crop dry. Temp. 22.1-30.0°C. RH 27-41%. Calm (<2 kph) with no drift evident.

Spray application equipment

Sprayer: OPS with 2.0 m boom

Nozzles: 02F110 (Lurmark).

Water volume: 200 l/ha

Pressure: 2.0 bar

B.16 Application details, Romney Marsh 2007/08.

Application date	Growth Stage	Weather
25 April 2008	4,04 (BBCH 64)	Sunny, warm and dry after warm, showery weather. Crop dry. Temp. 20.8-21.6°C. RH 42-51%. Breezy (10-12 kph) with moderate drift evident.

Spray application equipment:

Sprayer: OPS with 2.0 m boom

Nozzles: 02F110 (Lurmark).

Water volume: 200 litres

Pressure: 2.0 bar