PROJECT REPORT 326

EFFECTS OF ADDED SULPHUR ON FUNGICIDE CONTROL OF LIGHT LEAF SPOT

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By

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ABSTRACT

Growers in Scotland have recently voiced concerns that triazole fungicides, the main products available for control of light leaf spot, are not giving as good control of the disease now as compared with a few years ago. This has implications for growers throughout the UK. Other methods of controlling light leaf spot or ways of enhancing fungicide efficacy need to be identified. Preliminary investigations have shown that light leaf spot may be transmitted via the seed but further studies are required to confirm this. The aim of this project was to determine if application of sulphur fertiliser could induce disease resistance in oilseed rape plants so aiding the efficacy of fungicides and also to determine if light leaf spot was transmitted within the seed and the implications this would have for home-saving seed.

Identical factorial field experiments were set up in Aberdeen and Inverness to investigate the influence of variety, fungicide and sulphur on light leaf spot (*Pyrenopeziza brasssicae*) in oilseed rape. The sites differed in sulphur availability. Two varieties of different disease resistance were tested using both fungicide and no fungicide at two different sulphur and nitrogen levels. Application of sulphur to the soil did not delay the start of or reduce light leaf spot infection; it increased yield but was not cost-effective. Fungicide reduced disease at the low sulphur, low disease site but not at the high sulphur, high disease site. High nitrogen levels had no effect on disease, but increased yield. There were some interactions of fungicide, sulphur and nitrogen on yield but not on control of light leaf spot.

Sulphur fertiliser increased both the sulphur content of young leaves in spring and the leaf content of the amino acid cysteine and its breakdown products. Sulphur also increased the glucosinolate content of leaves at the lower sulphur status site and the glucosinolate content of seeds at both sites. Increased sulphur nutrition tended to increase all of the compounds associated with sulphur-induced resistance (SIR) but disease resistance in the field was not affected. In these experiments enhanced sulphur nutrition could not be used to improve the efficacy of fungicides.

Three field experiments were carried out in Aberdeen to investigate seed transmission of light leaf spot and the potential for home-saving seed. Five varieties were used (Apex, Bristol Lipton, Pronto, Synergy), with seed from different parental sources, including home-saved seed from parental crops that had received a fungicide treatment or had no fungicide treatment and certified seed. Experimental plots did not receive fungicide. The source of the parent seed had no influence on the levels of light leaf spot shown in the daughter crop. Application of fungicide or sulphur fertiliser to the parent crop had no influence on levels of light leaf spot in the daughter crop. It is concluded from this work that light leaf spot is not transmitted in the seed or, if it is, is of no importance for disease development in the daughter crop. All varieties tested could be grown from home-saved seed with no penalties in yield or agronomic characteristics compared with crops grown from certified seed. Breakdown of the heterosis effect was not apparent from home-saving seed of the restored hybrid Pronto and variety association Synergy, when grown in small plots.

SUMMARY

Light leaf spot (*Pyrenopeziza brassicae*) is one of the most important diseases of winter oilseed rape in the UK. Each year approximately £10 million are spent on fungicides to control diseases but despite this, losses in excess of £48 million are attributed to light leaf spot. Growers in Scotland routinely spray crops in the autumn and spring for light leaf spot control but have recently raised concerns that triazole fungicides, the only products available for control of light leaf spot in Scotland, are not giving as good control of light leaf spot now as compared with a few years ago. This could have implications for all growers in the UK. Other methods of controlling light leaf spot or ways of enhancing fungicide efficacy need to be identified. Researchers at the Federal Institute of Soil Science and Plant Nutrition (FAL) at Braunschweig, Germany, suggest that application of sulphur fertilisers can induce disease resistance (sulphur-induced resistance – SIR) in oilseed rape plants through the breakdown of the sulphur containing amino acid cysteine within leaves. Hydrolysis of cysteine by the action of the enzyme L-cysteine desulphydrase releases H_2S, a known anti-fungal agent, so inducing resistance within the plant.

Preliminary trials at SAC Aberdeen indicated that disease control in the growing oilseed rape crop affects the levels of light leaf spot in the crop grown from that seed, suggesting that light leaf spot may be seed-borne. However, these effects have not been quantified accurately nor the results translated into a form (e.g. yield penalty) whereby a grower home-saving seed can take this into account. Seed transmission of light leaf spot could have major implications on autumn spray decisions, the light leaf spot forecast (HGCA Project Report No. OS41), the development of a decision support system for oilseed rape (PASSWORD – HGCA Project No. 2155) and also where certified seed is sourced. This could favour growers in the south to the detriment of growers in the north, but has an impact on levy payers throughout the UK, particularly those who home-save seed.

The aims of this project were:

1. To establish the importance of sulphur nutrition as a means of light leaf spot control versus fungicides, with the potential to reduce variable costs.
2. To establish the importance of the enzyme L-cysteine desulphydrase in terms of light leaf spot resistance and evaluate it as a quick method for screening varieties which would not require further evaluation (carried out by colleagues at FAL, Germany).
3. To determine if light leaf spot is transmitted via the seed.

To establish the importance of sulphur nutrition as a means of light leaf spot control versus fungicides with the potential to reduce variable costs.

Methods

Six factorial experiments were carried out at Aberdeen and Inverness, during the seasons 2000 – 2003. The sites at Aberdeen and Inverness were high and low in respect of sulphur availability. Two varieties were grown at each site, Bristol (SAC light leaf spot resistance rating 3) and Lipton (SAC resistance rating 7). Treatments were two fungicide levels (nil and treated), two sulphur levels (0 and 100 kg S/ha) and two nitrogen levels (100 and 200 kg N/ha). The fungicide used was Punch C (active ingredients (a.i) flusilazole + carbendazim), applied at 0.4 l/ha in the autumn and 0.4 l/ha in the spring, with the exception of the Aberdeen site in 2000/2001 when 0.4 l/ha Punch C was applied in April and 0.5 l/ha Folicur (a.i. tebuconazole) was applied in May, bad weather in autumn and Foot & Mouth having prevented spraying. Sulphur was applied as sulphate of potash (K_2SO_4) and the potassium balanced in non-sulphur treated plots with muriate of potash (KCl). Sulphur was applied in one application at both sites in Year 1; in Years 2 and 3, 50 kg S/ha was applied in the autumn and 50 kg S/ha was applied in the spring at both sites. Nitrogen was applied as 34% N in the spring, 100 kg N/ha to all plots at first spring application and 100 kg N/ha to higher plots at second application. Disease assessments were carried out at regular intervals during the season. Plots were harvested and yields were measured.

Key Results

- Light leaf spot infection was higher at the Aberdeen sites (3-year average of 94% incidence, 5.5% severity at stem extension, GS 3.3) than at the Inverness sites (average 37% incidence, 2.9% severity). In accordance with the HGCA funded Forecasting Light Leaf Spot Project (No. OS41) both sites had severe epidemics (>25% plants affected (incidence) at GS 3.3).
- Fortnightly assessments of symptoms showed that application of 50 kg S/ha to soil in the autumn resulted in no detectable delay in the onset of light leaf spot in the autumn in either variety at either site nor did it reduce disease infection during the autumn/winter months.
- Variety resistance had no effect on disease incidence post stem-extension at either site but the light leaf spot resistant variety Lipton showed slightly more severe infection than the susceptible variety Bristol, especially at the lower disease sites at Inverness (the disease cycle for Bristol was in decline post-stem extension).
- Application of 100 kg S/ha to the soil did not reduce the incidence or severity of light leaf spot post-stem extension in either Bristol or Lipton at either site.
- Application of two sprays of 0.4 l/ha Punch C, one in the autumn and one in the spring, did not reduce incidence or severity of light leaf spot infection at the high disease sites in Aberdeen.
- Fungicide significantly reduced both incidence and severity of light leaf spot at the lower disease sites in Inverness. Disease incidence was reduced from 40% to 35%.
- Increasing the nitrogen levels from 100 kg N/ha to 200 kg N/ha did not increase light leaf spot infection.

- There were no interactions between variety, fungicide and sulphur in reducing levels of light leaf spot infection at either Aberdeen or Inverness.
- Yields were higher at Aberdeen (average 3.39 t/ha) than at Inverness (2.59 t/ha).
- The light leaf spot resistant variety Lipton yielded significantly more than the susceptible variety Bristol, 3.12 t/ha compared with 2.87 t/ha (mean over 2 sites and 3 years).
- Application of fungicide increased yield and economic returns at both sites but these were not significant, a reflection of the poor control of light leaf spot.
- Application of 100 kg S/ha gave small, but significant, yield benefits of 0.08 t/ha at the high S site in Aberdeen and 0.2 t/ha at the low S site in Inverness. However, these did not or only just covered the cost of the sulphur (£25/ha), resulting in an economic loss of £13.40 at Aberdeen and a benefit of £4.70 at Inverness respectively; the latter was not significant.
- Increasing nitrogen application from 100 kg N/ha to 200 kg N/ha had the largest single effect on yield, giving yield benefits of 0.78 t/ha at Aberdeen and 0.58 t/ha at Inverness (margins of £84/ha and £54/ha respectively).
- There were a few interactions between variety x fungicide x sulphur x nitrogen at Aberdeen but there were no clear patterns to these interactions. There were no interactions at Inverness.
- There were no interactions between fungicide and sulphur on yield or economic benefits.

Relationship between variety, sulphur fertiliser application and fungicide on sulphur content of leaves in spring

Methods

Prior to the start of flowering 15 leaves/plot were sampled from the above experiments, oven dried and analysed for mineral content. Analyses were carried out at FAL laboratories in Germany.

Key Results

- Application of 100 kg S/ha to the soil significantly increased sulphur content of leaves of both varieties in the spring. Sulphur content was increased from 0.52% to 0.84% at Aberdeen and from 0.36% to 0.72% in Inverness.
- Fungicide and nitrogen applications had no effect on sulphur content of leaves.

Relationship between variety, sulphur fertiliser application and fungicide on cysteine content of leaves in spring

Methods

Prior to the start of flowering, 7-10 young leaves/plot were sampled, wrapped in aluminium foil and immediately frozen in the field in liquid nitrogen at -80^{o}C. Samples were stored frozen, then freeze dried before sending to FAL, Germany for amino acid and glucosinolate analyses.

Key Results

The data are limited as only leaf samples from Year 1 have been analysed to date. However, the following results were found.

- Application of sulphur increased the levels of the amino acid cysteine and its breakdown products γ-glutamylcysteine and glutathione in leaves of both Bristol and Lipton at both sites (glutathione not significantly at Inverness).
- Application of fungicide generally did not interact with sulphur to increase the content of these products.

Relationship between variety, sulphur fertiliser application and fungicide on glucosinolate and cysteine content of leaves in spring and of glucosinolates in seed at harvest

Oilseed rape plants contain sulphur containing bioactive molecules, the glucosinolates, within their leaves and seeds. In the presence of the enzyme myrosinase, glucosinolates are degraded into various derivatives, including isothiocyanates, many of which have anti-fungal activity and are involved in the plants' defence against disease infection. Can application of sulphur to the soil as fertiliser increase the glucosinolate content of leaves and seeds?

Methods

Prior to the start of flowering, 7-10 young leaves/plot were sampled, wrapped in aluminium foil and immediately frozen in the field in liquid nitrogen at -80^{o}C. Samples were stored frozen then freeze dried before sending to FAL, Germany for amino acid and glucosinolate analyses. Harvested seed was also sent to FAL.

Key Results

The data for these analyses are limited with only one or two years' data available at present depending on site and analysis. However, the following results were found.

- Eight different glucosinolates were found in young leaves in the spring, the main ones were glucobrassicanapin, glucobrassicin and progoitrin.

- The levels of each individual glucosinolate varied between the two varieties but total glucosinolate contents were similar.
- Ten glucosinolates were found in the seed at the end of the season, the main ones were progoitrin and gluconapin. Glucobrassicanapin and glucobrassicin were only present at very low levels in the seed.
- Application of sulphur to the soil significantly increased total glucosinolate content of leaves of both varieties at Inverness but not at Aberdeen. Sulphur increased total glucosinolate content of seed from both varieties at both sites.
- Application of fungicide significantly reduced levels of glucosinolates in leaves of both varieties at both sites. Fungicide tended to reduce glucosinolate content of seed from both varieties but this was significant at the high disease site in Aberdeen only.

To determine if light leaf spot is transmitted via the seed

Methods

Three fully replicated field experiments were carried out in Aberdeen during the seasons 2000 - 2003. Varieties used included the conventional varieties Apex, Bristol and Lipton and the restored hybrid variety Pronto and the varietal association Synergy. Seeds from different parental sources were used, including home-saved seed from a parental crop that had received a fungicide treatment, home-saved seed from a parental crop that had no fungicide treatment and certified seed. In Years 2 and 3 seed harvested from the light leaf spot sulphur experiment (see Section 1) was also included. Crops received standard fertiliser and pesticide inputs for the region with the exception of fungicide, which was not applied. Disease assessments were carried out at 4-8 week intervals during the season, either after incubation in the laboratory or in the field. Yields were determined to 91% dry matter.

Key Results

- Disease epidemics in all three years were severe, with 60-100% plants affected in all varieties.
- Parental seed source did not affect the level of light leaf spot shown in the daughter crop not did it affect yield or agronomic characteristics of the daughter crop.
- Fungicide treatment to the parent crop did not affect the level of light leaf spot shown in the daughter crop nor did it affect yield or agronomic characteristics of the daughter crop.
- Application of sulphur fertiliser to the parent crop did not affect the level of light leaf spot shown in the daughter crop nor did it affect yield or agronomic characteristics of the daughter crop.
- Results suggest light leaf spot is not transmitted via the seed.
- Results show the use of home-saved seed does not put the crop at a disadvantage compared with a crop grown from certified seed.
- Home-saving seed of the restored hybrid Pronto and the varietal association Synergy did not lead to a discernible breakdown in agronomic performance or yield.

- Experiments were carried out in small plots with a plentiful supply of pollen from adjacent plots. Results should only be used as an indication of the potential for home-saving the varieties, particularly Pronto and Synergy, and do not reflect what may occur in whole field crops. It should also be noted that the British Society of Plant Breeders indicate that growers are not permitted to home-save seed from hybrids.

Conclusions

Application of a triazole fungicide reduced disease at the less infected site at Inverness, but not at the high disease site at Aberdeen. Application of sulphur to the soil did not delay or reduce light leaf spot infection but increased yield, particularly when fungicide and high nitrogen rates were applied. These yield increases were not cost effective. Application of sulphur to the soil, however, increased the sulphur content of leaves in the spring and increased the levels of the amino acid cysteine and its derivatives – glutamylcysteine and glutathione - suggesting the breakdown of cysteine and release of H_2S. Sulphur also tended to increase the glucosinolate content of leaves and seeds but application of fungicide reduced glucosinolates.

Application of sulphur to the soil thus increased levels of all the chemicals associated with disease defence/resistance, but there were no visible signs of reduction in levels of light leaf spot in the crop. Application of sulphur as a soil fertiliser to induce resistance to light leaf spot within the oilseed rape crop cannot be used as a reliable alternative to fungicide application and cannot be used to enhance the efficacy of fungicides at present available to growers in the UK.

Results suggest that light leaf spot is not transmitted in the seed or if it is then this is of little relevance in the daughter crop. Thus, seed source and treatments to parent crops should not influence light leaf spot infection in daughter crops. Home-saving seed did not put crops at a disadvantage in terms of yield and agronomic characteristics when compared with crops grown from certified seeds. Home-saving seed of the restored hybrid variety Pronto and the varietal association Synergy did not lead to a discernible breakdown in agronomic performance or yield but this may not be the case when grown on a farm scale.

Implications for growers

- Fungicide did not control light leaf spot where the disease epidemic was very severe, almost 100% incidence.
- Fungicide did control light leaf spot where the disease epidemic was less severe, 37% incidence, but only resulted in a reduction of 5%.

- Where light leaf spot epidemics are naturally severe, as in Scotland, north and west England and Wales, application of sulphur may show small yield benefits of 0.1–0.2 t/ha or more but cannot be used to induce resistance within the oilseed rape crop to reduce light leaf spot infections.
- Application of sulphur fertiliser cannot be used as a replacement for fungicide nor can it be used to improve the efficacy of the triazole fungicides available to oilseed rape growers.

- Parental seed source does not affect the level of light leaf spot, yield or agronomic characteristics shown in the daughter crop.
- Application of fungicides or sulphur fertiliser to the parent crop does not affect the levels of light leaf spot, yield or agronomic characteristics shown in the daughter crop.
- Results suggest light leaf spot is not transmitted in the seed or is of no importance in disease development in the daughter crop.
- The use of home-saved seed does not put the crop at a disadvantage compared with a crop grown from certified seed.
- Home-saving seed of the varieties Pronto and Synergy did not lead to a breakdown in agronomic performance or yield but does not reflect what may occur in a field crop situation.

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Sutherland KG, 2002. Oilseed rape in Scotland. DuPont Agronomy/Press event, Stevenage, 18 September 2002

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Field trial open days (where project trials demonstrated to growers)

SAC/HGCA/Royal Northern Agricultural Society Field trials Open day, Aberdeenshire, 26 June 2002

INTRODUCTION

Light leaf spot (*Pyrenopeziza brassicae*) is one of the most important diseases of winter oilseed rape in the UK. Each year approximately £10 million are spent on fungicides to control diseases but despite this, losses in excess of £48 million are attributed to light leaf spot (Fitt *et al*, 1997). Growers in Scotland routinely apply fungicides in the autumn and spring for control of light leaf spot and yield benefits of up to 1 t/ha are possible (Sutherland, 1999).

Adjusting the sulphur nutrition of the growing crop and stimulation of the plants sulphur metabolism can reduce and slow down light leaf spot infection (Booth & Walker, 1997; Walker et al, 1999). Preliminary work carried out in parallel at the Federal Institute of Soil Science and Plant Nutrition (FAL) at Braunschweig, Germany, suggests that disease resistance in oilseed rape is related to the breakdown of the sulphur containing amino acid cysteine within the plant. Hydrolysis of cysteine releases H_2S, a known anti-fungal agent (Manners, 1982). It is suggested that the release of H_2S induces resistance within the plant. It has been found that different varieties of oilseed rape contain different levels of the enzyme possible for the hydrolysis of cysteine, L-cysteine desulphydrase, and it is suggested that the levels of this enzyme may have a potential as an indicator of disease resistance.

Screening of oilseed rape plant breeding lines at Aberdeen have suggested that different seed stocks of the same variety can show different levels of light leaf spot (Walker & Booth, 1992). Preliminary trials have indicated that disease control in the growing crop can effect the levels of light leaf spot in the crop grown from that seed (Walker *et al*, 2000), suggesting that light leaf spot may be seed-borne. However, these effects have not been quantified accurately nor the results translated into a form (e.g. yield penalty) whereby a grower home-saving seed can take this into account. Seed transmission of light leaf spot could have major implications for the light leaf spot forecast (HGCA report No. OS41; Steed & Fitt, 2000) and the development of a decision support system for oilseed rape (PASSWORD – HGCA Project No. 2155). Seed transmission would have to be considered when making decisions for autumn spray applications. Evidence of seed transmission of light leaf spot would mean that the source of seed would have to be considered, i.e. does seed come from an area at higher risk of light leaf spot impact, such as Scotland or the north of England, or from a low risk area in the south-east of England. This could favour seed growers in the south to the detriment of seed growers in the north, but has an impact on levy payers throughout the UK, particularly those who home-save seed.

AIM

To investigate the potential for sulphur metabolism to reduce fungicide inputs for controlling light leaf spot

Specific Objectives:

- To establish the importance of sulphur nutrition as a means of light leaf spot control versus fungicides, with the potential to reduce variable costs.
- To establish the importance of the enzyme L-cysteine desulphydrase in terms of light leaf spot resistance and evaluate it as a quick method for screening varieties which would not require further evaluation.
- To determine if light leaf spot is transmitted via the seed.

SECTION 1. TO ESTABLISH THE IMPORTANCE OF SULPHUR NUTRITION AS A MEANS OF LIGHT LEAF SPOT CONTROL AND TO ESTABLISH THE IMPORTANCE OF THE ENZYME L-CYSTEINE DESULPHYDRASE IN DISEASE RESISTANCE

MATERIALS & METHODS

Field Experiments

Six field experiments were carried out , three at Aberdeen and three at Inverness, during the seasons 2000 – 2003. The sites at Aberdeen and Inverness were high and low in respect of sulphur availability from the soil (Appendix 1). Sulphur deposition from the atmosphere, another known source of sulphur for plants, is also lower in the Inverness area (Anon, 1990). Two varieties were grown at each site, one with poor resistance to light leaf spot, Bristol (light leaf spot resistance rating 3; Anon, 1996) and one with good resistance to light leaf spot, Lipton (light leaf spot resistance rating 7; Anon, 2003a). Identical treatments were proposed at both sites. Treatments were two fungicide levels, two sulphur levels and two nitrogen levels (Table 1).

Table 1. Treatments applied to field experiments to determine the importance of sulphur nutrition and its interaction with variety, fungicide and nitrogen to control light leaf spot.

Treatment No.	Variety	Fungicide	Sulphur (kg/ha)	Nitrogen (kg/ha)
1	Bristol	-	0	100
2	Bristol	-	0	200
3	Bristol	-	100	100
4	Bristol	-	100	200
5	Bristol	+	0	100
6	Bristol	+	0	200
7	Bristol	+	100	100
8	Bristol	+	100	200
9	Lipton	-	0	100
10	Lipton	-	0	200
11	Lipton	-	100	100
12	Lipton	-	100	200
13	Lipton	+	0	100
14	Lipton	+	0	200
15	Lipton	+	100	100
16	Lipton	+	100	200

The fungicide used throughout was Punch C (flusilazole + carbendazim), applied at 0.4 l/ha in the autumn and 0.4 l/ha in the spring, with the exception of the Aberdeen site in 2000/2001 when severe weather

conditions in autumn/winter and the subsequent Foot & Mouth outbreak meant that the fungicide programme had to be altered to treatment with 0.4 l/ha Punch C in April and 0.5 l/ha Folicur in May (Appendix 2)

Sulphur was applied as sulphate of potash, K_2SO_4 (potassium sulphate), to the soil, avoiding potential direct fungicidal effects that may have been associated with foliar applied sulphur. The potassium was balanced in non-sulphur treated plots with muriate of potash, KCl (potassium chloride). Sulphur was applied in one application at both sites in Year 1 (Appendix 2). As a response to Year 1 results, in Years 2 and 3 half the sulphur (50 kg S/ha) was applied in the autumn and half (50 kg S/ha) was applied in the spring at both sites. Nitrogen was applied as 34% N in the spring, 100 kg N/ha to all plots at first spring application and 100 kg N/ha to higher plots at second application.

Disease assessments were carried out at regular intervals during the autumn and winter (weather conditions permitting). In Years 2 and 3 untreated plots were assessed at 1-2 week intervals during the autumn and winter to closely follow the development of light leaf spot infection. Prior to stem extension (GS 3.5), 10 plants per plot were sampled, incubated in a damp chamber over night and leaves assessed for disease incidence (% plants affected), leaf incidence (% leaves affected) and disease severity (% leaf area infected). Stems and pods were assessed for disease incidence (% plants affected) and severity (% stem area or % pod area infected).

Enzyme analyses

At stem extension (GS 3.5 – 4.0) but prior to start of flowering, leaves were sampled for analysis. Seven to ten younger, fully developed leaves (approximately 10cm x 6 cm in size) from the upper third of the plant were taken at random, avoiding the youngest or oldest leaves. Petioles were not taken as part of the sample. Where differences in light leaf spot levels were obvious within plots, 20 leaf discs each were removed from leaves with and without light leaf spot infection, the discs removed using a 17 mm diameter cork borer. In the field, leaves/discs were placed one above the other within 25 x 25 cm pieces of aluminium foil, the foil wrapped to make as small packages as possible. The aluminium packages were immediately placed into liquid nitrogen (shock freezing) to prevent activation of enzymes by cell disruption. In the laboratory the samples were stored in a deep freezer for several days.

The leaf samples were removed from the freezer, the aluminium foil packages opened to produce a small bowl and the samples freeze dried. Once dried the samples were wrapped in the aluminium packages again and immediately placed into a desiccator. Prior to mailing to Germany for analysis, the aluminium foil packages were placed individually into a paper bag, sealed with cling film and placed into polythene bag containing 20 g $CaCl_2$ for every 10 samples. The polythene bag was sealed immediately using a vacuum sealer.

Enzyme analyses and glucosinolate determinations were carried out by colleagues in Germany.

Determination of minerals

At stem extension (GS 3.5) but prior to start of flowering, 15 leaves/plot were sampled as above. Leaves were placed into labelled paper bags and stored in a cool place whilst in the field. Samples were dried at 80^{o}C for 48 hours in a conventional crop sample oven then the paper bags plus samples placed into polythene bags. The samples were sent to colleagues in Germany for analyses.

Above ground biomass

At stem extension (GS 3.5) but prior to start of flowering the number of plants/m^2 from a guard plot were determined using a 0.25 m^2 quadrat. The total above ground biomass/m^2 was determined by sampling all plants in a 0.25 m^2 area, removing any dead leaves and measuring fresh weight and dry weight after drying in an oven at 80^{o}C for 48 hours.

RESULTS

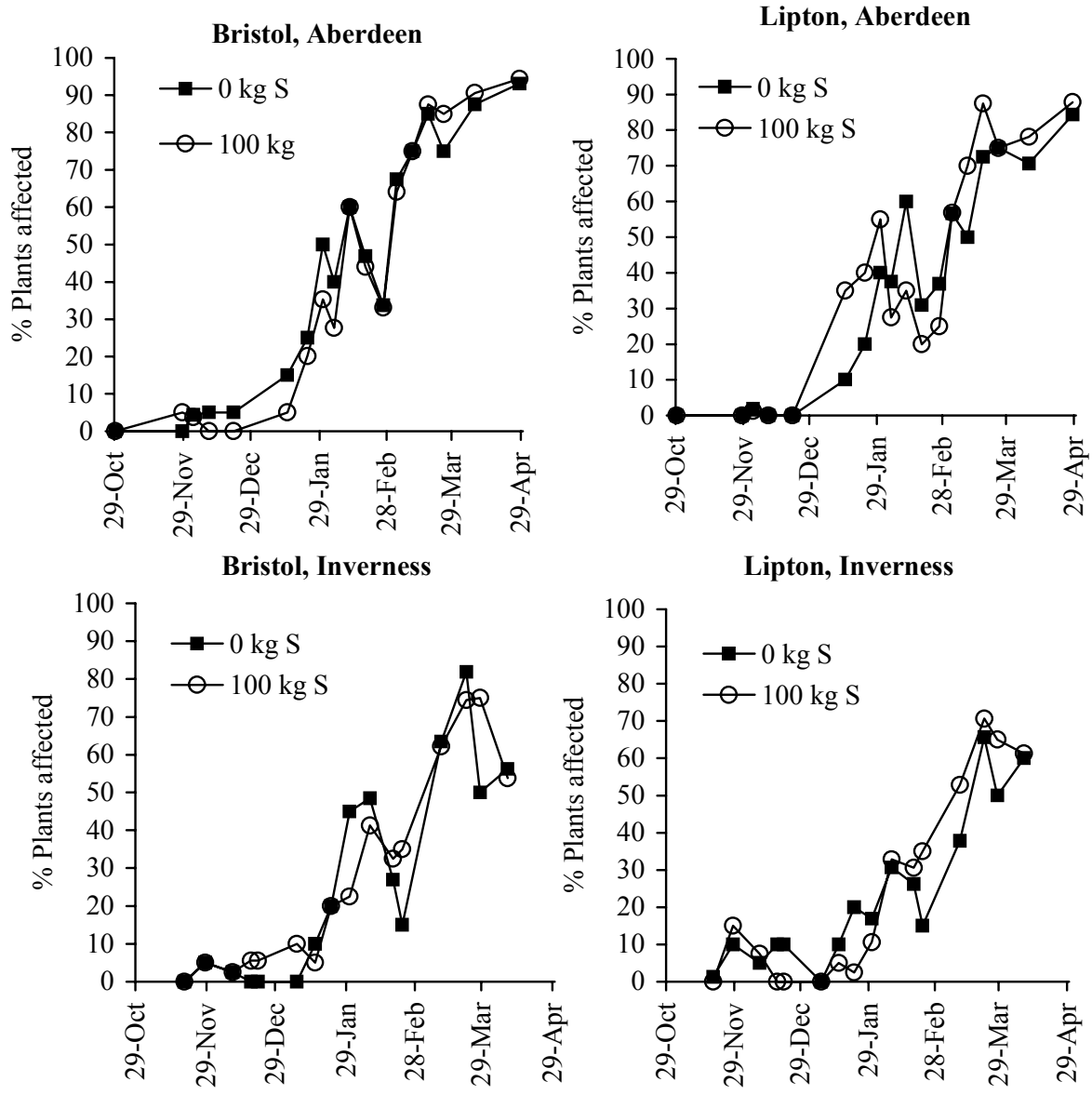
1. Effect of sulphur application on the progress of light leaf spot development

The development of light leaf spot was similar in both Bristol and Lipton at Aberdeen and Inverness (Figure 1). The disease first appeared in mid-late November and increased to a maximum in late March/April, at which time disease incidence in non-fungicide treated plots was >60%. The incidence of light leaf spot was slightly higher in Bristol than in Lipton and higher at Aberdeen than at Inverness. Disease severity followed the same pattern.

Sulphur was applied in the autumn of years 2 and 3 to determine if this delayed the initial infection by *Pyrenopeziza brassicae* and the onset of light leaf spot symptom development and hence reduced the severity of the epidemic. At the high sulphur status sites in Aberdeen, application of 50 kg S/ha in the autumn delayed the onset of disease in the susceptible variety Bristol by approximately 4 weeks in 02/03 but appeared to encourage the earlier onset of light leaf spot by 1-2 weeks in 01/02. Disease levels were variable during the seasons and there was a tendency for sulphur to slightly reduce the incidence of light leaf spot on Bristol in 02/03 but there were generally no effects of sulphur on light leaf spot incidence in 01/02. On average over the two seasons sulphur reduced the incidence of light leaf spot in Bristol (Figure 1), from an average of 42.7% plants affected to 40.6% plants affected (severity reduced from 2.6% to 2.2%; Table 2).

At Aberdeen, application of sulphur to the less susceptible variety Lipton had no effect on the onset of light leaf spot but tended to increase disease development during both seasons, particularly during the early winter (Figure 1). The average light leaf spot levels over the two seasons was 35.9% in the non-S treated plots and 38.6% in the S treated plots (severity of 2.1% compared with 2.7%, respectively; Table 2). At the low sulphur status sites in Inverness, application of 50 kg S/ha to plots of Bristol encouraged the onset of light leaf spot in 2001/02, with the disease appearing in mid-December compared with mid-January in the non-S

Figure 1. Effect of autumn and spring application of sulphur on the development of light leaf spot in winter oilseed rape, non-fungicide treated plots (mean of 2 years, 01/02 & 02/03)



treated plots. In 2002/03, light leaf spot appeared in both S-treated and non S-treated plots by mid-November and there were no differences in levels of infection. During the season sulphur had no effect or slightly increased the incidence of light leaf spot on Bristol in 2001/02 and had no effect or slightly reduced the incidence in 2002/03, the overall effect being that sulphur tended to increase the incidence of light leaf spot (Figure 1) from an average of 26.5% plants affected to 28.1% plants affected (Table 2). Sulphur did, however, tend to slightly reduce the severity of light leaf spot, from 2.0% to 1.7%.

At Inverness, application of sulphur to Lipton delayed the initial onset of light leaf spot in the autumn of 2001/02 but later in the season increased the incidence of disease. In 2002/03 light leaf spot levels were

much lower and disease appeared in both S treated and non-S treated plots at the same time. In general, the incidence of light leaf spot was slightly higher in the S treated plots. Over the two seasons, application of sulphur to Lipton tended to reduce disease incidence early in the season but increase the incidence in spring (Figure 1)

In summary, application of 100 kg S/ha 50 kg S/ha to winter oilseed rape, 50 kg of which was applied in the autumn, delayed the onset of light leaf spot at some sites in some years but in other years/sites sulphur had no effect or actually encouraged disease development. During the winter months sulphur tended to reduce the incidence of light leaf spot on Bristol at Aberdeen and on Lipton at Inverness, but increased disease incidence on Lipton at Aberdeen and on Bristol at Inverness. Results show sulphur applied as a fertiliser in the autumn cannot be used as a reliable means of delaying and reducing the development of light leaf spot epidemics.

Table 2. Incidence and severity of light leaf spot on winter oilseed rape (mean of 16 – 18 assessments per season over two seasons)

		2001/02	2002/03	Mean
Aberdeen, % Incidence				
Bristol	0 kg S	35.9	49.4	42.7
	100 kg S	35.2	46.0	40.6
Lipton	0 kg S	26.2	45.6	35.9
	100 kg S	30.6	46.5	38.6
Aberdeen, % Severity				
Bristol	0 kg S	3.0	2.3	2.6
	100 kg S	2.6	1.8	2.2
Lipton	0 kg S	2.5	1.8	2.1
	100 kg S	2.8	2.6	2.7
Inverness, % Incidence				
Bristol	0 kg S	33.1	19.9	26.5
	100 kg S	38.0	18.3	28.1
Lipton	0 kg S	37.1	8.9	23.0
	100 kg S	36.3	12.3	24.3
Inverness, % Severity				
Bristol	0 kg S	2.6	1.4	2.0
	100 kg S	2.2	1.2	1.7
Lipton	0 kg S	3.0	0.4	1.8
	100 kg S	2.8	0.6	1.7

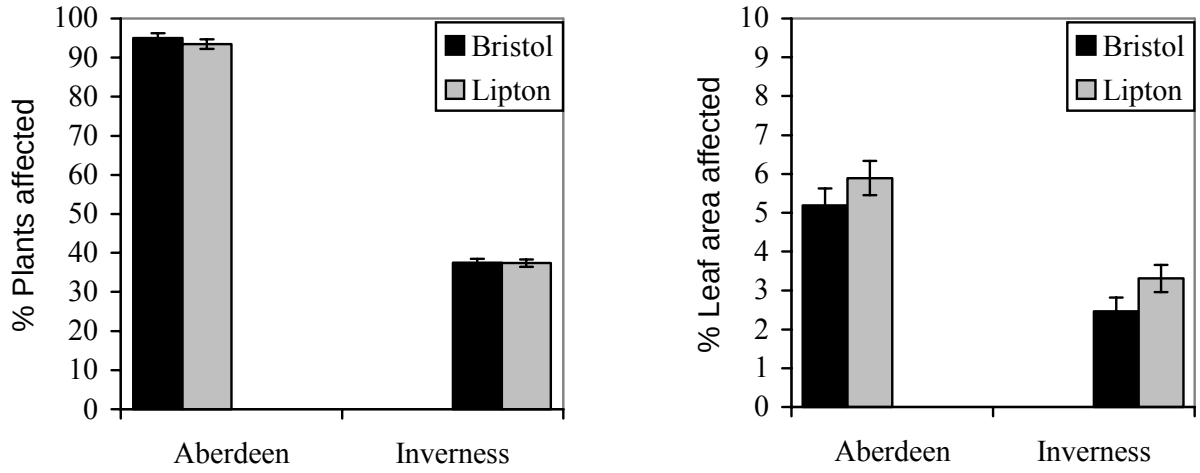
2. Interactions of variety, fungicide, sulphur and nitrogen on levels of light leaf spot in winter oilseed rape plants post-stem extension

2 a) Effect of variety.

Over the three years, varietal resistance had no effect on incidence of light leaf spot 4-6 weeks after stem extension at either Aberdeen or Inverness (Figure 2). The susceptible variety Bristol and the resistant variety Lipton both showed similar numbers of plants infected with light leaf spot. The incidence of light leaf spot was, however, much lower at the low sulphur status sites in Inverness than at the high sulphur status sites in Aberdeen, on average 37% of plants affected compared with 94% of plants affected at Aberdeen. Disease severity (% leaf area infected) was similar for both varieties at the Aberdeen sites, on average 5.5%, but the resistant variety Lipton had slightly higher levels of light leaf spot than the susceptible variety Bristol. At Inverness, disease severity was lower than that at Aberdeen, on average 3% leaf area infected with light leaf spot and Lipton showed significantly higher light leaf spot severity compared with the susceptible variety Bristol (the disease cycle in Bristol was decreasing at this time).

Thus, there were no differences in incidence of disease between the two varieties but the resistant variety Lipton tended to have more severe light leaf spot post-stem extension than the susceptible variety Bristol.

Figure 2. Effect of varietal resistance on incidence and severity of light leaf spot in oilseed rape, post stem-extension (mean of 3 years; mean of fungicide, sulphur and nitrogen treatments)

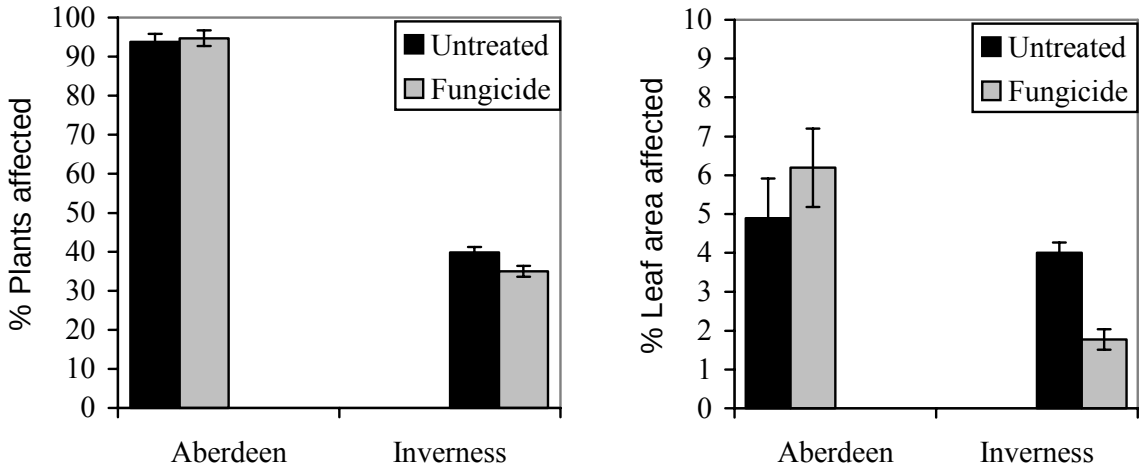


2 b) Effect of fungicide

Over the three year period 00 – 03, application of fungicide to winter oilseed rape did not reduce the incidence of light leaf spot infection at either the Aberdeen or Inverness sites, disease incidence being similar in both the untreated and fungicide treated plots (Figure 3). Application of fungicide did

not reduce the disease severity at the Aberdeen sites, where disease incidence was very high, but significantly reduced disease severity at the Inverness sites, where disease incidence was relatively low.

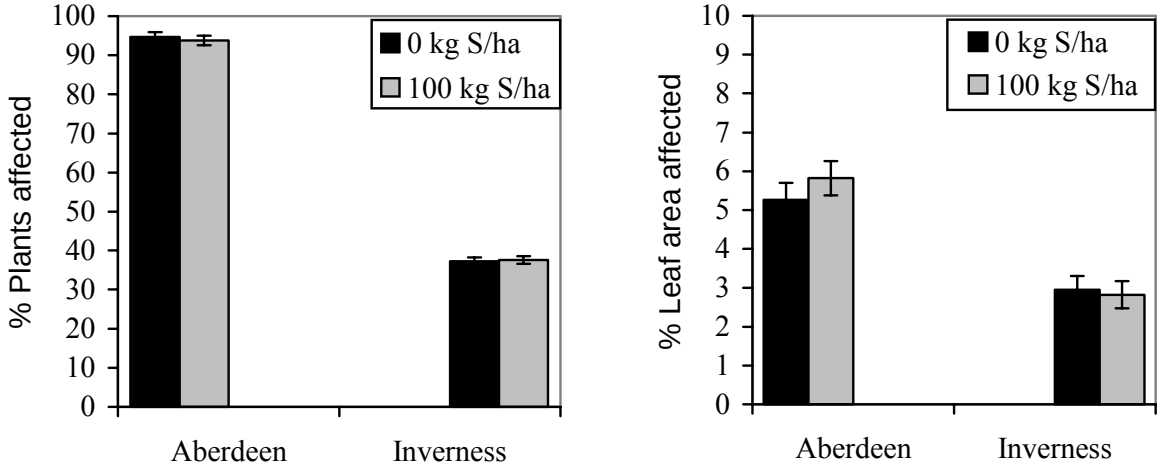
Figure 3. Effect of fungicide on incidence and severity of light leaf spot in winter oilseed rape, post stem-extension (mean of 3 years; mean of variety, sulphur and nitrogen treatments)



2 c) Effect of sulphur

Application of 100 kg S/ha had no effect in reducing either the incidence or severity of light leaf spot post stem-extension at either the high sulphur status sites in Aberdeen or the low sulphur status sites in Inverness (Figure 4).

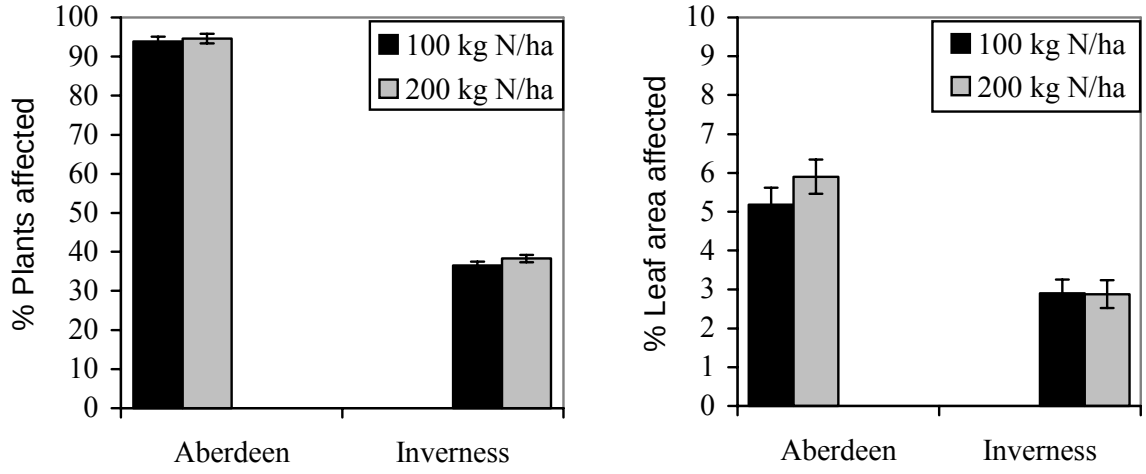
Figure 4. Effect of sulphur on incidence and severity of light leaf spot in winter oilseed rape, post stem-extension (mean of 3 years; mean of variety, fungicide and nitrogen treatments)



2 d) Effect of nitrogen

Application of 200 kg N/ha had no effect in either significantly reducing or increasing the incidence and severity of light leaf spot post stem-extension compared with 100 kg N/ha at either the Aberdeen or Inverness sites (Figure 5)

Figure 5. Effect of nitrogen on incidence and severity of light leaf spot in winter oilseed rape, post stem-extension (mean of 3 years; mean of variety, fungicide and sulphur treatments)



2 e) Interaction of variety, fungicide, sulphur and nitrogen

At Aberdeen, where disease incidence was high, application of fungicide or 100 kg S/ha did not reduce the incidence or severity of light leaf spot on the susceptible variety Bristol or on the resistant variety Lipton. There were no interactions between fungicide and sulphur in reducing the numbers of plants infected with light leaf spot in either Bristol or Lipton (Table 3). There were no four-way interactions between variety, fungicide sulphur and nitrogen. Similarly there were no interactions between fungicide and sulphur in reducing the severity of light leaf spot infection in either variety and there were no interactions between these factors and nitrogen. As shown in figures 4 and 5, application of 100 kg S/ha or 200 kg N/ha tended to increase the severity of light leaf spot on leaves.

At the low sulphur status sites in Inverness, where disease levels were lower, fungicide tended to reduce the severity of light leaf spot on the susceptible variety Bristol irrespective of sulphur applied to the soil. There were no effects of fungicide or sulphur on the incidence of light leaf spot on Bristol where the lower level of nitrogen (100 kg/ha) was applied to the soil in spring. Application of 200 kg N/ha tended to increase the incidence of light leaf spot in the variety Lipton when 100 kg S was also applied in the absence of fungicide but not when fungicide was applied.

Table 3. Interaction of variety, fungicide (Fg), sulphur (S) and nitrogen (N) on levels of light leaf spot in winter oilseed rate, Aberdeen, 2000 - 2003

			Light leaf spot on leaves, GS 3.7-4.0			
	S	N	% Incidence		% Severity	
	kg/ha	kg/ha	Fg-	Fg+	Fg-	Fg+
Bristol	0	100	94.2	95.0	3.9	4.6
	100	100	95.0	98.3	4.8	6.1
	0	200	97.5	93.3	4.7	6.8
	100	200	93.3	93.3	5.4	5.2
Lipton	0	100	92.5	95.0	4.6	6.2
	100	100	90.8	90.0	4.7	6.6
	0	200	92.5	97.5	5.3	6.1
	100	200	94.2	95.0	5.7	7.9
LSD ($p \leq 0.05$)			7.00		2.68	
LSD (same levels of Fg)			6.97		2.48	
significance			ns		ns	

ns = not significant

Application of fungicide tended to reduced both the incidence and severity of light leaf spot on the resistant variety Lipton irrespective of the amount of sulphur applied to the soil (Table 4). Where only 100 kg N was applied to the soil, application of 100 kg S/ha to the soil significantly reduced the severity of light leaf spot on leaves and this was further reduced by application of fungicide.

In summary, at the high sulphur status sites in Aberdeen disease incidence was high and there were no effects either individually or in interaction between variety, fungicide, sulphur or nitrogen in reducing the incidence or severity of light leaf spot. At the low sulphur status sites in Inverness, disease levels were lower and fungicide tended to reduce the severity of light leaf spot on the susceptible variety Bristol and both incidence and severity of disease on the resistant variety Lipton. Although there was evidence of one interaction between fungicide and sulphur reducing incidence of light leaf spot at Inverness (incidence on Bristol, 200 kg N + 100 kg S – fungicide versus 200 kg N + 100 kg S + fungicide) in most cases there were no interactions between fungicide and sulphur and a reduction in levels of light leaf spot.

Light leaf spot levels throughout the season for each site are shown in Appendices 3-8.

Table 4. Interaction of variety, fungicide (Fg), sulphur (S) and nitrogen (N) on levels of light leaf spot in winter oilseed rate, Inverness, 2000 – 2003

			Light leaf spot on leaves, GS 3.7 – 4.0			
	S	N	% Incidence		% Severity	
	kg/ha	kg/ha	Fg-	Fg+	Fg-	Fg+
Bristol	0	100	37.5	35.0	3.2	1.2
	100	100	35.8	35.0	3.4	1.8
	0	200	40.8	38.3	3.9	1.4
	100	200	43.3	34.2	3.4	1.3
Lipton	0	100	40.0	33.3	6.3	1.5
	100	100	40.8	35.0	3.9	1.8
	0	200	39.2	34.2	4.1	1.9
	100	200	41.7	35.0	3.6	3.3
LSD ($p \leq 0.05$)			5.41		1.90	
LSD (same levels of Fg)			5.48		2.01	
significance			ns		ns	

ns = not significant

3. Interactions of variety, fungicide, sulphur and nitrogen on yield and economic benefits of winter oilseed rape

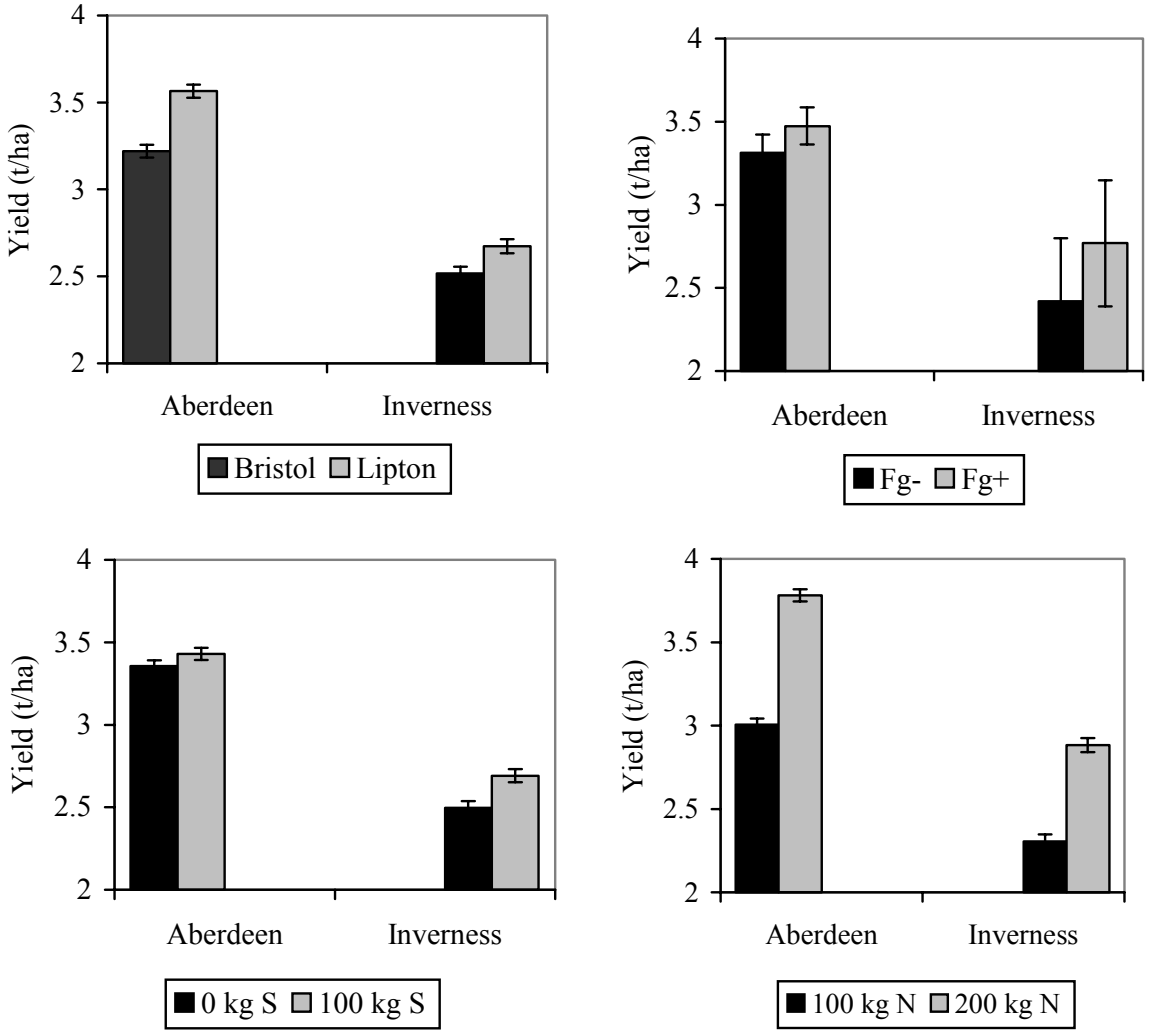
3 a) Effect of variety

Yields were higher at Aberdeen (average 3.39 t/ha) than at Inverness (average 2.59 t/ha). The light leaf spot resistant variety Lipton yielded significantly higher than the light leaf spot susceptible variety Bristol, particularly at the higher disease sites in Aberdeen (Figure 6). Taking rapeseed at a value of £152/t, the higher yields of Lipton at Aberdeen were reflected in significantly higher margins over costs at this site, £398/ha compared with £370/ha for Bristol (Figure 7). At Inverness the higher yields of Lipton were not mirrored by an increased economic return, both varieties giving returns on average £263/ha.

3 b) Effect of fungicide

Application of fungicide tended to increase the yield by 0.16 t/ha at Aberdeen and by 0.35 t/ha at Inverness but these increases were not significant (Figure 6). Economic returns were also increased by £24.50 and £53.10 at both sites respectively but again these were not significant (Figure 7).

Figure 6. Effect of variety, fungicide (Fg), sulphur (S) and nitrogen (N) on yield of winter oilseed rape (Mean of 3 years; Mean of 3 factors)



3 c) Effect of sulphur

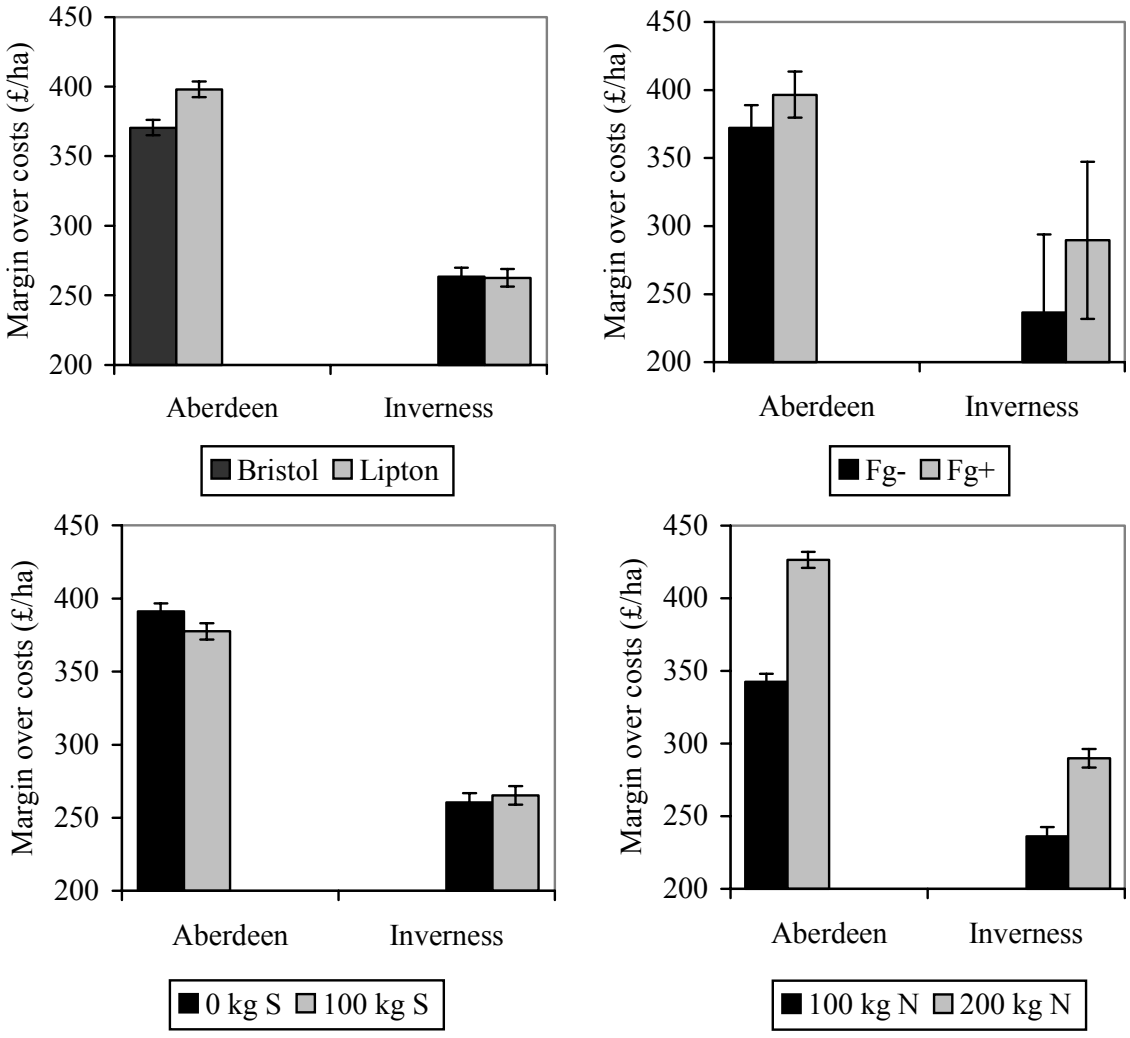
Application of 100 kg S/ha to the soil at Aberdeen, the high sulphur status site, gave a small but significant yield increase of 0.08 t/ha (Figure 6). This small increase in yield, however, did not cover the cost of the sulphur (£25/ha) and resulted in a loss of income of £13.40/ha (Figure 7). At Inverness, the low sulphur status site, application of 100 g S/ha significantly increased yield by 0.20 t/ha over no sulphur application. This resulted in a very small, but not significant, benefit of £4.70/ha (but 100 kg S/ha is not what would be commercially recommended and was chosen at this high rate for experimental purposes).

3 d) Effect of nitrogen

Application of 200 kg N/ha to the soil significantly increased average yields of oilseed rape by 0.78 t/ha at Aberdeen and 0.58 t/ha at Inverness, compared with 100 kg N/ha (Figure 6). Application of the extra

nitrogen had the largest single effect on yield at both sites. These yield benefits resulted in significant economic benefits £84/ha at Aberdeen and £54/ha at Inverness, based on nitrogen at £340/t (Figure 7).

Figure 7. Economic benefits of using fungicide (Fg), sulphur (S) and nitrogen (N) on two varieties of winter oilseed rape (Mean of 3 years; Mean of 3 factors; for cost of inputs see Table 5)



3 e) Interaction of variety, fungicide, sulphur and nitrogen on yield and economic benefits of winter oilseed rape

At Aberdeen, where light leaf spot levels were high, application of fungicide to the susceptible variety Bristol treated with 100 kg S/ha, significantly increased yield by an average of 0.42 t/ha (Table 5). This yield response was reflected in a significant increase in margins of £63.95/ha (excluding application costs). Yield benefits due to fungicide application where no sulphur was applied were not significant. On the less susceptible variety Lipton this interaction between fungicide and sulphur on yield was only seen at the high nitrogen rate of 200 kg N/ha, when yield increased by 0.29 t/ha, but this was not reflected in a significant

increase in margins. There were no interactions between fungicide and sulphur on yield at the lower disease site in Inverness (Table 6).

Table 5. Interaction of variety, fungicide (Fg), sulphur (S) and nitrogen (N) on yield and economic returns of winter oilseed rape, Aberdeen, 2000 – 2003

	S	N	Yield t/ha @ 91% DM		MOC (£/ha)[1]	
	kg/ha	kg/ha	Fg-	Fg+	Fg-	Fg+
Bristol	0	100	2.84	2.97	340.1	361.5
	100	100	2.70	3.06	295.5	350.4
	0	200	3.44	3.57	400.0	418.7
	100	200	3.36	3.84	362.4	435.4
Lipton	0	100	3.08	3.08	354.2	354.3
	100	100	3.19	3.14	344.9	338.1
	0	200	3.95	3.95	452.2	418.7
	100	200	3.92	4.21	427.3	435.4
LSD ($p \leq 0.05$)			0.248		37.63	
LSD (same levels of Fg)			0.207		31.42	
significance			ns		ns	

[1] – margin over costs based on costs of £152/t seed (Anon, 2003b), £24.80/ha for flusilazole + carbendazim, £340/t N, £120/t KCl and £145/t K_2SO_4 (Chadwick, 2003; A. Sinclair, pers. comm)

ns = not significant

At Aberdeen, application of sulphur significantly increased yield on both Bristol and Lipton varieties only when fungicide and the high rate of nitrogen were applied (Table 5). Yield was significantly increased by an average of 0.24 t/ha but the added cost of £25/ha for the sulphur meant the yield benefit was not cost effective – the benefit to the margin of £16.70 was not significant. At Inverness, application of sulphur tended to increase the yield of both varieties, irrespective of fungicide application but the yield benefits were generally not significant (Table 6). A significant yield benefit of 0.36 t/ha was seen in the susceptible variety Bristol only where sulphur and the high rate of nitrogen were applied. The margin of £29 was not significant.

Yields for all sites are shown in Appendix 9

Table 6. Interaction of variety, fungicide (Fg), sulphur (S) and nitrogen (N) on yield and economic returns of winter oilseed rape, Inverness, 2000 - 2003

	S	N	Yield t/ha @ 91% DM		MOC (£/ha)[1]	
	kg/ha	kg/ha	Fg-	Fg+	Fg-	Fg+
Bristol	0	100	1.99	2.38	213.3	272.5
	100	100	2.08	2.51	201.7	266.4
	0	200	2.43	2.80	245.6	301.7
	100	200	2.82	3.12	280.6	325.0
Lipton	0	100	2.16	2.41	213.3	251.6
	100	100	2.32	2.60	201.7	256.3
	0	200	2.68	3.12	259.9	326.6
	100	200	2.88	3.22	263.8	316.0
LSD ($p \leq 0.05$)			0.703		106.83	
LSD (same levels of Fg)			0.238		36.21	
significance			ns		ns	

[1] – margin over costs based on costs of £152/t seed (Anon, 2003b), £24.80/ha for flusilazole + carbendazim, £340/t N, £120/t KCl and £145/t K_2SO_4 (Chadwick, 2003; A. Sinclair, pers. comm)

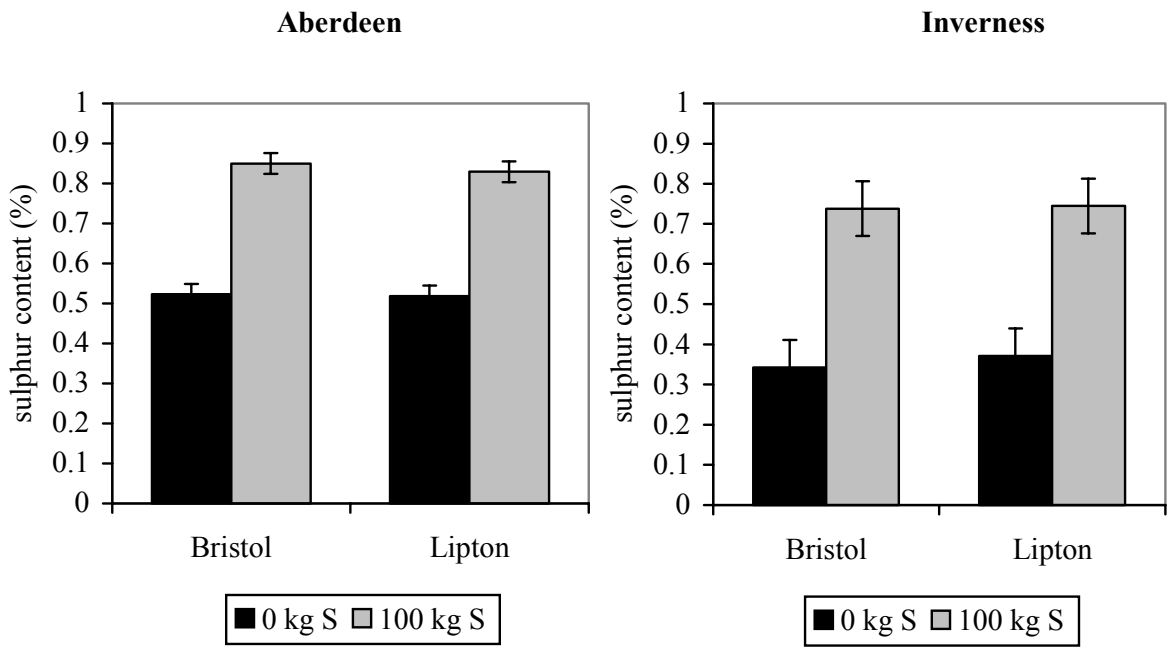
ns = not significant

4. Levels of sulphur in oilseed rape leaf tissue in spring

Application of sulphur to the soil significantly increased the sulphur content of leaf tissue in the spring at both the low sulphur status sites in Inverness and the high sulphur status sites in Aberdeen (Figure 8). Sulphur content of leaves in Aberdeen were higher than those in Inverness, both with and without S supplementation. Sulphur content of Bristol and Lipton were the same, there were no interactions between variety and sulphur application. Fungicide and nitrogen application had no effect on sulphur content of leaves.

Levels of other nutrients (P, K, Ca and Mg) are shown in Appendix 10

Figure 8. Effect of sulphur application to soil on sulphur content of leaves of winter oilseed rape in spring (Mean of two years 2000 – 2002)



5. **Relationship between sulphur nutrition, variety and fungicide on levels of glucosinolates in leaves**

A total of eight glucosinolates were found in the leaves of oilseed rape plants in Year 1 (see Appendices 11 & 12), the main ones of which were progoitrin (2-hydroxy but-3-enyl), glucobrassicanapin (pent-4-enyl) and glucobrassicin (3-indole-methyl) (Figure 9).

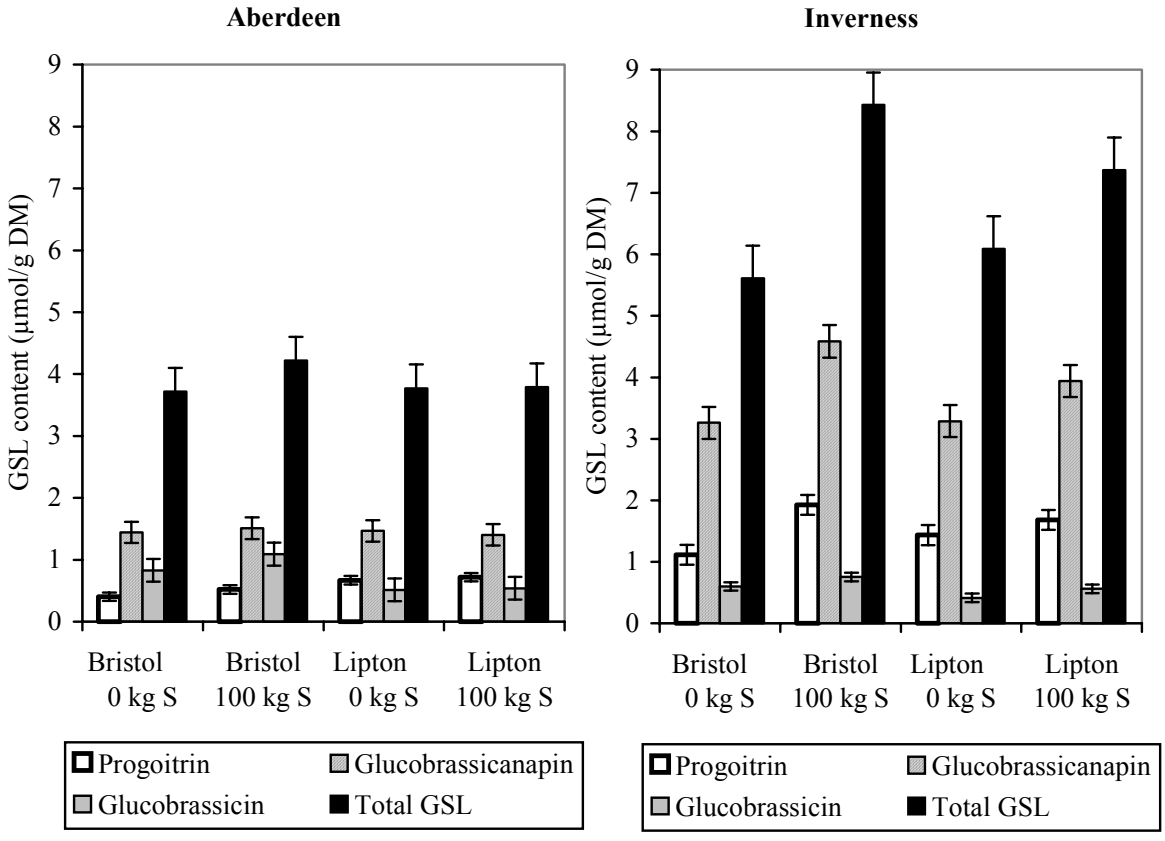
Glucobrassicanapin was the main glucosinolate present, with progoitrin and glucobrassicin at similar levels. Progoitrin and glucobrassicanapin levels were much higher at the low sulphur status site in Inverness than at the high sulphur status site in Aberdeen, whereas glucobrassicin levels were slightly higher in Aberdeen than in Inverness. The total glucosinolate levels were much higher at Inverness than in Aberdeen.

The varieties differed in their glucosinolate contents. Lipton had a higher content of progoitrin than Bristol at both sites whereas levels of glucobrassicanapin were similar in both varieties. The glucobrassicin content of Bristol was higher than in Lipton. The overall total glucosinolate content of both varieties were similar dependent on site.

Application of sulphur to the soil generally had no effect on the glucosinolate content of either variety at the high sulphur status site in Aberdeen, although soil applied sulphur did significantly increase the levels of glucobrassicin in the susceptible variety Bristol but not in Lipton (Figure 9). Application of sulphur did not increase the total glucosinolate content of leaves of either Bristol or Lipton at the high sulphur status site in Aberdeen.

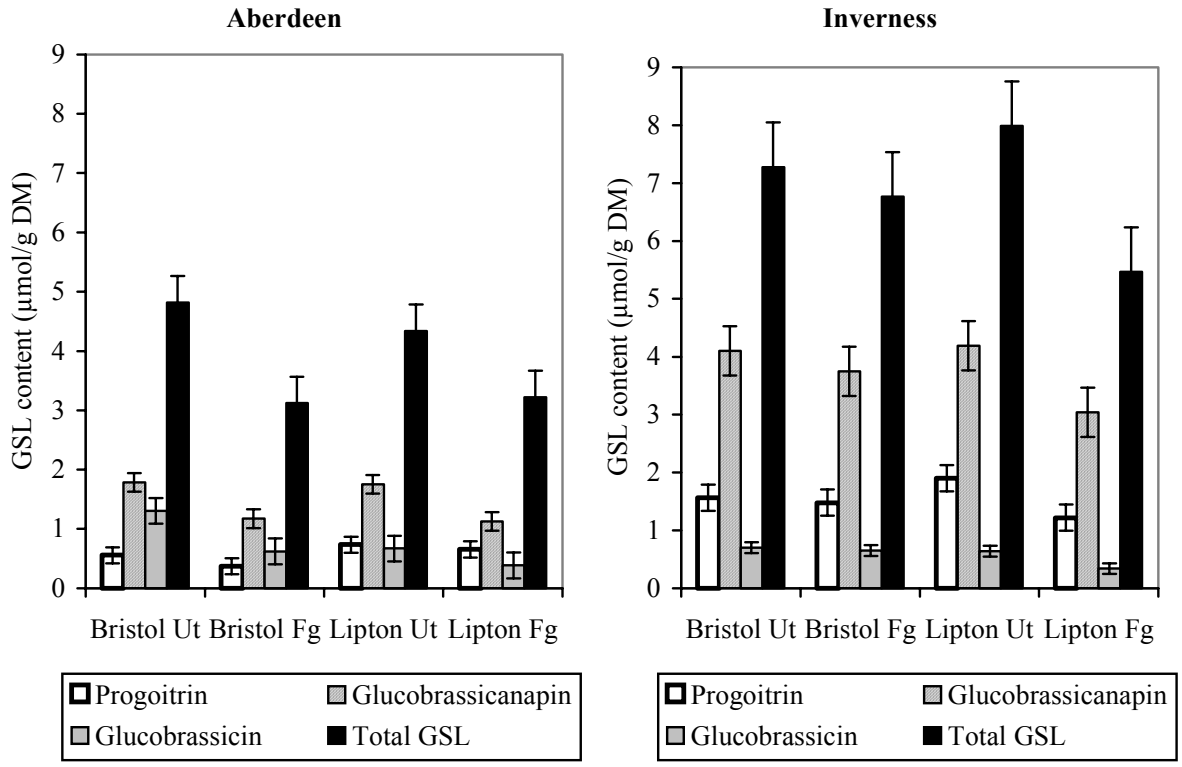
Application of 100 kg sulphur to the soil at the low sulphur status site in Inverness increased the leaf content of all glucosinolates and in all, except progoitrin in Lipton, this increase was significant. The increase in levels of progoitrin, glucobrassicanapin and total glucosinolates tended to be greater in the susceptible variety Bristol than in the resistant variety Lipton.

Figure 9. Relationship between the S nutrition and glucosinolate (GSL) content of young leaves of winter oilseed rape, 2001



Application of fungicide tended to reduce the levels of glucosinolates in young leaves in the spring at both sites but the significance was dependent on site and variety (Figure 10).

Figure 10. Relationship between the fungicide (Fg) application and glucosinolate (GSL) content of young leaves of winter oilseed rape, 2001.



At Aberdeen fungicide application significantly reduced levels of progoitrin and glucobrassicanapin in both varieties, there were no interactions between fungicide and variety (Figure 10). At Inverness, however, where levels of these two glucosinolates were higher than at Aberdeen, fungicide significantly reduced levels in the resistant variety Lipton only. Fungicide application significantly reduced levels of glucobrassicin in the leaves of Bristol but not Lipton at Aberdeen but at Inverness the opposite was found.

Application of fungicide reduced the total glucosinolate content of leaves in both varieties at Aberdeen (Figure 10). In the resistant variety Lipton this reduction in glucosinolates was significant only where high levels of nitrogen (200 kg N/ha) were applied (Table 7). In the susceptible variety Bristol, fungicide significantly reduced glucosinolate levels but there were no interactions of fungicide with variety, sulphur or nitrogen. At Inverness, fungicide application reduced total glucosinolate content of leaves (Figure 10) but this was significant only in the resistant variety Lipton and only where the low amounts of nitrogen (100 kg N/ha) were applied. Fungicide reduced glucosinolate content of leaves of Bristol at Inverness but this was not significant, the main effect being an increase due to sulphur application.

Table 7. Relationship between variety, fungicide (Fg), sulphur (S) and nitrogen (N) on total glucosinolate content of young leaves of winter oilseed rape, 2001

			Total glucosinolate content of leaves (μmol/g)			
	S	N	Aberdeen		Inverness	
	kg/ha	kg/ha	Fg-	Fg+	Fg-	Fg+
Bristol	0	100	4.71	2.52	5.20	5.73
	100	100	4.82	3.70	9.06	8.64
	0	200	4.35	3.31	6.30	5.21
	100	200	5.40	2.98	8.54	7.49
Lipton	0	100	3.95	3.30	8.20	4.69
	100	100	3.55	3.67	9.80	6.98
	0	200	4.72	3.10	6.71	4.75
	100	200	5.13	2.80	7.24	5.47
LSD ($p \leq 0.05$)			1.550		2.262	
LSD (same levels of Fg)			1.533		2.112	
significance			ns		ns	

ns = not significant

6. Relationship between sulphur nutrition, variety and fungicide on the levels of cysteine and its breakdown products in young leaves of oilseed rape.

At the high sulphur status site in Aberdeen 2002, application of 100 kg S/ha to the soil significantly increased the levels of the amino acid cysteine and its breakdown products γ-glutamylcysteine and glutathione (Table 8). Levels were increased to similar degrees in both varieties. There were no interactions between sulphur, fungicide or nitrogen on levels of cysteine. Application of fungicide significantly increased levels of γ-glutamylcysteine only when 100 kg S was applied, i.e. there was an interaction between fungicide and sulphur but nitrogen level had no effect. There were no interactions between fungicide and sulphur on glutathione content of leaves, except in the variety Bristol, where fungicide significantly increased glutathione levels only where 100 kg S/ha and the low level of nitrogen (100 kg N/ha) were applied. On the variety Lipton increasing nitrogen levels from 100 to 200 kg N/ha increased the glutathione content of leaves independent of sulphur application.

Table 8. Relationship between variety, fungicide (Fg), sulphur (S) and nitrogen (N) on levels of cysteine, γ-glutamylcysteine and glutathione in young leaves of winter oilseed rape, Aberdeen 2002.

			content of leaves (μmol/g)					
	S	N	cysteine		γ-glutamylcysteine		glutathione	
	kg/ha	kg/ha	Fg-	Fg+	Fg-	Fg+	Fg-	Fg+
Bristol	0	100	0.64	0.60	0.11	0.12	20.02	18.45
	100	100	0.90	1.00	0.25	0.41	24.34	29.11
	0	200	0.56	0.61	0.14	0.14	21.28	20.93
	100	200	0.86	0.99	0.26	0.36	27.20	28.80
Lipton	0	100	0.60	0.61	0.10	0.12	19.71	21.45
	100	100	0.78	0.96	0.23	0.36	24.35	26.26
	0	200	0.57	0.71	0.15	0.15	24.00	23.38
	100	200	0.90	0.97	0.29	0.40	30.31	29.66
LSD ($p \leq 0.05$)			0.194		0.084		1.936	
LSD (same levels of Fg)			0.206		0.080		1.827	
significance			ns		ns		ns	

ns = not significant

At the low sulphur status site in Inverness, application of sulphur significantly increased the levels of cysteine and γ- glutamylcysteine in leaves of both Bristol and Lipton in the spring (Table 9). Sulphur tended to increase levels of glutathione but the high error meant this was not significant in either variety except where the sulphur and the high level of nitrogen were applied in the absence of fungicide (note in 2001/02 sulphur significantly increased glutathione content of leaves at Inverness).

There were no effects of fungicide or nitrogen on levels of cysteine at Inverness. Whereas fungicide increased levels of γ-glutamylcysteine at the Aberdeen sites, fungicide tended not to increase levels of γ-glutamylcysteine at the Inverness site, except in the variety Lipton at the high sulphur level (100 kg S) and high nitrogen level (200 kg N). Fungicide did not increase levels of glutathione at the Inverness site.

Table 9. Relationship between variety, fungicide (FG), sulphur (S) and nitrogen (N) on levels of cysteine, γ-glutamylcysteine and glutathione in young leaves of winter oilseed rape, Inverness (mean of two years, 2000 – 2002).

			content of leaves (μmol/g)					
	S	N	cysteine		γ-glutamylcysteine		glutathione	
	kg/ha	kg/ha	Fg-	Fg+	Fg-	Fg+	Fg-	Fg+
Bristol	0	100	0.74	0.70	0.45	0.43	13.30	15.46
	100	100	1.3	1.41	0.73	0.78	22.49	22.54
	0	200	0.62	0.62	0.44	0.58	11.06	8.72
	100	200	1.43	1.25	1.05	0.90	24.30	16.49
Lipton	0	100	0.70	0.62	0.48	0.40	12.33	14.62
	100	100	1.28	1.28	0.77	0.76	20.93	19.30
	0	200	0.61	0.64	0.47	0.58	12.66	23.50
	100	200	1.39	1.53	0.94	1.17	26.39	18.06
LSD ($p \leq 0.05$)			0.253		0.235		11.051	
LSD (same levels of Fg)			0.262		0.244		10.951	
significance			ns		ns		ns	

ns = not significant

7. Relationship between sulphur nutrition, variety and fungicide on the glucosinolate content of oilseed rape seed.

Ten different glucosinolates were found in the seeds of oilseed rape, the primary ones being progoitrin and gluconapin. Glucobrassicanapin and particularly glucobrassicin that were found in high quantities in the leaves were present in low quantities in the seeds (See Appendices 13 & 14).

Glucosinolate levels in seed from the low sulphur status sites in Inverness were slightly lower than those from the high sulphur status sites in Aberdeen, on average 5.27 μmol/g dry matter compared with 6.13 μmol/g dry matter respectively. Application of sulphur at both sites increased the glucosinolate content (Figure 11): at Aberdeen sulphur increased glucosinolates content from 5.51 μmol/g to 7.71 μmol/g whereas at Inverness these were increased from 2.78 μmol/g to 7.75 μmol/g.

Figure 11. Relationship between sulphur nutrition and total glucosinolate content of seed (mean of 2 years, 2000-2002)

At the high sulphur status sites in Aberdeen application of 100 kg S/ha to the soil significantly increased glucosinolate content of seed in both Bristol and Lipton, but fungicide application significantly reduced glucosinolate content (Table 10). Sulphur tended to increase glucosinolate levels more than fungicide reduced them. When no sulphur was applied to the variety Bristol, increasing the nitrogen rate from 100 to 200 kg N/ha significantly reduced glucosinolate content of the seeds, but this was not seen when sulphur was applied. However, the converse was true for the resistant variety Lipton, where high sulphur and high nitrogen significantly increased glucosinolate content of seeds.

At the low sulphur status sites in Inverness, sulphur also increased the glucosinolate content of seed of both varieties (Table 10). Although fungicide application tended to reduce glucosinolate content, this was generally not significant except where high levels of sulphur and nitrogen were applied to the variety Lipton. Increasing the nitrogen application rate from 100 to 200 kg N/ha significantly reduced glucosinolate content of Bristol seed when no sulphur was applied (independent of fungicide application) but increased the glucosinolate content when fungicide and high sulphur levels were applied. Increasing the nitrogen application rate generally did not affect the glucosinolate content of seeds from the variety Lipton, except when high sulphur levels were applied to non-fungicide treated plots, when glucosinolate content was significantly increased.

Thus in general, sulphur increased the glucosinolate content of seeds of both the light leaf spot susceptible and resistant varieties at both the high and low sulphur status sites and fungicide reduced glucosinolates at the high disease sites of Aberdeen only. High nitrogen application reduced the glucosinolate content of Bristol seed when no soil sulphur was applied but not when sulphur was applied (independent of fungicide). High nitrogen tended to increase glucosinolate content of seed of Lipton when soil sulphur was applied but not when sulphur was omitted (again generally independent of fungicide).

Table 10. Relationship between variety, fungicide (Fg), sulphur (S) and nitrogen (N) on total glucosinolate content oilseed rape seed, (mean of two years 2000 – 2002).

			Total glucosinolate content of seed (μmol/g)			
	S	N	Aberdeen		Inverness	
	kg/ha	kg/ha	Fg-	Fg+	Fg-	Fg+
Bristol	0	100	6.20	5.43	3.68	3.18
	100	100	8.39	7.34	7.63	6.97
	0	200	5.10	4.40	1.84	1.53
	100	200	8.69	7.68	8.75	8.50
Lipton	0	100	6.03	5.11	3.67	2.97
	100	100	7.30	6.61	6.86	6.29
	0	200	6.33	5.49	3.05	2.32
	100	200	8.14	7.56	10.09	6.92
LSD ($p \leq 0.05$)			0.613		1.777	
LSD (same levels of Fg)			0.623		1.474	
significance			ns		ns	

ns = not significant

8. Summary of Results

The application of 50 kg S/ha to soil in the autumn generally did not reliably delay the onset of light leaf spot development or reduce the autumn/winter infection. Application of sulphur fertiliser in the autumn cannot be used as a reliable means of delaying or reducing the development of light leaf spot epidemics.

Over the three years of experiments, the incidence of light leaf spot (% plants affected) was much higher at the high sulphur status sites in Aberdeen (94%) than at the low sulphur status sites in Inverness (37%). Disease severity was slightly higher in Aberdeen (5.5%) than in Inverness (3%).

At the high sulphur status site in Aberdeen, where disease incidence was high, there were no effects individually and no interactions between variety, fungicide, sulphur or nitrogen on disease incidence or severity. At the low sulphur status sites in Inverness, where disease levels were lower (compared with Aberdeen), fungicide tended to reduce incidence and severity of light leaf spot in both varieties (though not always significantly). There were again generally no interactions between variety, fungicide and sulphur in reducing light leaf spot infection.

Increasing the nitrogen application from 100 kg N/ha to 200 kg N/ha gave the greatest increase in yield in both varieties at both Aberdeen (0.78 t/ha) and Inverness (0.56 t/ha). Fungicide did not increase yields or economic margins, a reflection of the poor control of light leaf spot. Application of 100 kg S/ha to the soil gave significant but small yield benefits of 0.08 – 0.20 t/ha, but these increases were not covered by the cost of the sulphur (£25/ha) or did not give significant economic benefits, even at the low sulphur status sites in Inverness.

There were a few interactions between variety x fungicide x sulphur x nitrogen at Aberdeen but not at Inverness. There were no patterns to these interactions and as a result no clear conclusions could be made except that there were no interactions between fungicide and sulphur.

Despite sulphur having no affect on levels of light leaf spot and giving only small increases in yield, application of 100 kg S/ha to the soil as fertiliser significantly increased the sulphur content of young leaves in the spring. Sulphur also increased the total glucosinolate content of leaves at the low sulphur status sites in Inverness, particularly on the light leaf spot susceptible variety Bristol, but not at the high sulphur status sites in Aberdeen. Fungicide application reduced glucosinolate content of leaves. Sulphur also increased the glucosinolate content of seeds of both varieties at both sites and fungicide reduced glucosinolate content. Finally, application of sulphur increased the levels of the amino acid cysteine and its breakdown products γ-glutamylcysteine and glutathione in leaves of both Bristol and Lipton at both sites (glutathione not significantly at Inverness). Application of fungicide generally did not interact with sulphur to increase the content of these products.

DISCUSSION

The incidence of light leaf spot at the Aberdeen sites over a 3-year period was on average 94% compared with the Inverness sites where disease incidence was on average 37%. However, according to the HGCA funded project Forecasting light leaf spot on winter oilseed rape (Steed & Fitt, 2000), any crop with greater than 25% plants infected with light leaf spot at stem extension (GS 3.3) was deemed to have a severe infection. Thus, although the Inverness sites had lower levels of light leaf spot infection than the Aberdeen sites, the epidemics were still severe.

Foliar-applied sulphur has been used as a fungicide for over 50 years against diseases such as *Blumeria graminis* in barley, the sulphur having a direct effect on the fungus (Carlile, 1995). In this present study sulphur was applied to the soil as a fertiliser to prevent this direct affect on the fungus. Previous work by Schnug (1997) at Braunschweig in Germany showed that soil-applied sulphur is used by the plant to synthesise sulphur-containing amino acids such as cysteine. Hydrolysis of cysteine by the enzyme L-cysteine desulphydrase releases H_2S, a natural anti-fungal compound within plants. Schnug suggested that release of H_2S induced resistance to light leaf spot within oilseed rape plants – sulphur induced resistance

(SIR). In this present study it was shown that application of sulphur to the soil did not reliably delay or reduce infection of oilseed rape with light leaf spot. Over the same time period 2000 – 2003, light leaf spot was almost non-existent in the Braunschweig area of Germany (Bloem, pers. comm). Results at the two Scottish sites showed that sulphur was incorporated into and increased the levels of the sulphur containing amino acid cysteine in leaves. Sulphur also increased the levels of the cysteine breakdown products γ–glutamylcysteine and glutathione, suggesting an increase in the activity of the enzymes involved in this breakdown pathway, γ–glutamylcysteine synthetase and glutathione synthetase. If application of sulphur to the soil increased the levels of L-cysteine desulphydrase then any subsequent release of H_2S either did not induce resistance (no SIR) within the two varieties tested, or the SIR was insufficient to overcome the high levels of light leaf spot found in Scotland.

In the past 2-3 years there has been growing concern in Scotland that triazole fungicides are not as effective at controlling light leaf spot as in the past. In the present study the fungicide flusilazole + carbendazim gave little or no disease control at Aberdeen. In Inverness, fungicide significantly reduced light leaf spot infection, but the disease incidence (% plants infected) was only reduced from 40% to 35%. According to Steed & Fitt (2000) this still represented a severe light leaf spot infection and such small reductions in diseases levels would not be acceptable to growers.

Booth & Walker (1997) found that application of sulphur to the soil gave small but positive reductions in light leaf spot infection of oilseed rape in Scotland, but results from this present study found that soil-applied sulphur had little effect on light leaf spot levels. However, sulphur did increase the yield of oilseed rape when fungicide and high nitrogen levels were applied. Booth & Walker (1997) also found some interactions between sulphur levels and fungicide on yield.

CONCLUSION

Application of a triazole fungicide tended to reduce disease at the less infected site at Inverness, but not at the high disease site at Aberdeen. Application of sulphur to the soil did not delay or reduce light leaf spot infection but increased yield, particularly when fungicide and high nitrogen rates were applied. These yield increases were not cost effective. On the basis of these results, application of sulphur to the soil to induce resistance to light leaf spot within the oilseed rape crop cannot be used as a reliable alternative to fungicide application or to enhance the efficacy of fungicides at present available to growers in the UK.

SECTION 2. TO DETERMINE IF LIGHT LEAF SPOT IS TRANSMITTED VIA THE SEED

MATERIALS & METHODS

Three field experiments were carried out in Aberdeen over the seasons 2000 – 2003. Seed of 4-5 varieties from different parental sources were used each year, including home-saved seed from parental crops that had received a fungicide treatment, seed from parent crops that had no fungicide treatment and certified seed. In Years 2 and 3 seed harvested from the light leaf spot sulphur experiment (see Section 1) was also included. Treatments for each year are shown in Tables 11 - 13 All varieties were sown on the same date in any one year. Seed was sown during August or early September depending on the season using an Ojyord drill. Crops received standard fertiliser and pesticide inputs for the region with the exception of fungicide, which was not applied. The experiments were of a randomised block design, 4 replicates, and plot size 40 m^2. The experiments were harvested in late July – late August depending on the season using a Sampo plot combine. Grain samples were retained and moisture contents determined. Yields were determined to 91% dry matter.

Disease assessments were carried out at regular intervals during the autumn and winter (weather conditions permitting). Plots sown from seed harvested from the light leaf spot sulphur experiment were assessed in the laboratory. Prior to stem-extension (GS 3.5), 10 plants per plot were sampled, incubated in a damp chamber over night and leaves assessed for disease incidence (% plants affected), leaf incidence (% leaves affected) and disease severity (% leaf area infected). Post stem extension, stems and pods were assessed for disease incidence (% plants affected) and severity (% stem area or % pod area infected). All plots were assessed at intervals in the field using NIAB type assessments (estimating leaf area infected at 3 points per plot) or on a 1-9 scale.

Table 11. Source of seed for experiment to determine if light leaf spot in transmitted via the seed 2000/01

Variety	Source of parent seed	Variety	Source of parent seed
Apex	Var. Trial 00 Untreated	Synergy	Var. Trial 00 Untreated
Apex	Var. Trial 00 Treated	Synergy	Var. Trial 00 Treated
Apex	Certified	Synergy	Certified
Lipton	Var. Trial 00 Untreated	Pronto	Var. Trial 00 Untreated
Lipton	Var. Trial 00 Treated	Pronto	Var. Trial 00 Treated
Lipton	Certified	Pronto	Homesaved Untreated plots (99)[a]
		Pronto	Homesaved Treated plots (99)[a]

Var. Trial 00 = seed from Variety trial, Aberdeen, harvested 2000

[a] = seed obtained from plots harvested in 00 (but sown from home-saved seed harvested in 99), 2nd generation home-saved

Table 12. Source of seed for experiment to determine if light leaf spot in transmitted via the seed 2001/02

Treat No.	Variety	Source of parent seed
1	Bristol	From sulph 01 Inverness, Fg Treated, 100 kg S/ha, 100 kg N/ha [a]
2	Lipton	From sulph 01 Inverness, Fg Treated, 100 kg S/ha, 100 kg N/ha [a]
3	Bristol	From sulph 01 Inverness, Fg Treated, 0 kg S/ha, 100 kg N/ha [a]
4	Lipton	From sulph 01 Inverness, Fg Treated, 0 kg S/ha, 100 kg N/ha [a]
5	Bristol	From sulph 01 Inverness, Untreated, 100 kg S/ha, 100 kg N/ha [a]
6	Lipton	From sulph 01 Inverness, Untreated, 100 kg S/ha, 100 kg N/ha [a]
7	Bristol	From sulph 01 Inverness, Untreated, 0 kg S/ha, 100 kg N/ha [a]
8	Lipton	From sulph 01 Inverness, Untreated, 0 kg S/ha, 100 kg N/ha [a]
9	Apex	From Var. Trial 01 Treated (Edinburgh) [b]
10	Lipton	From Var. Trial 01 Treated (Edinburgh) [b]
11	Synergy	From Var. Trial 01 Treated (Edinburgh) [b]
12	Pronto	From Var. Trial 01 Treated (Edinburgh) [b]
13	Apex	From Var. Trial 01 Untreated (Edinburgh) [b]
14	Lipton	From Var. Trial 01 Untreated (Edinburgh) [b]
15	Synergy	From Var. Trial 01 Untreated (Edinburgh) [b]
16	Pronto	From Var. Trial 01 Untreated (Edinburgh) [b]
17	Pronto	From Homesaved Treated plots (99) [c]
18	Pronto	From Homesaved Untreated plots (99) [c]
19	Apex	Certified seed
20	Lipton	Certified seed
21	Synergy	Certified seed
22	Pronto	Certified seed

[a] = Seed obtained from the sulphur experiment Inverness, harvested 01, 1st generation home-saved.

[b] = Seed obtained from the Variety Trials in Edinburgh, harvested 01, 1st generation home-saved

[c] = Seed obtained from the seed transmission experiment harvested 01, but sown from seed harvested in 99 then 00, 3rd generation home-saved

Treatments 1-8 are the original treatments intended for the experiment, treatments 9 – 22 are extra treatments requested by HGCA and not part of the original seed transmission experiment.

Table 13. Source of seed for experiment to determine if light leaf spot in transmitted via the seed 2002/03

Treat No.	Variety	Source of parent seed
1	Bristol	From sulph 02 Inverness, Fg Treated, 100 kg S/ha, 100 kg N/ha [a]
2	Lipton	From sulph 02 Inverness, Fg Treated, 100 kg S/ha, 100 kg N/ha [a]
3	Bristol	From sulph 02 Inverness, Fg Treated, 0 kg S/ha, 100 kg N/ha [a]
4	Lipton	From sulph 02 Inverness, Fg Treated, 0 kg S/ha, 100 kg N/ha [a]
5	Bristol	From sulph 02 Inverness, Untreated, 100 kg S/ha, 100 kg N/ha [a]
6	Lipton	From sulph 02 Inverness, Untreated, 100 kg S/ha, 100 kg N/ha [a]
7	Bristol	From sulph 02 Inverness, Untreated, 0 kg S/ha, 100 kg N/ha [a]
8	Lipton	From sulph 02 Inverness, Untreated, 0 kg S/ha, 100 kg N/ha [a]
9	Synergy	From HS 02 exp., originally from Treated plots (01) [b]
10	Synergy	From HS 02 exp., originally from Untreated plots (01) [b]
11	Synergy	From Var. Trial 02, Laurencekirk, Treated [c]
12	Pronto	From Var. Trial 02, Laurencekirk Treated [c]
13	Apex	From HS 02 exp., originally from Untreated plots (01) [b]
14	Lipton	From HS 02 exp., originally from Untreated plots (01) [b]
15	Synergy	From HS 02 exp., originally from Untreated plots (01) [b]
16	Pronto	From HS 02 exp., originally from Untreated plots (01) [b]
17	Pronto	From HS 02 exp – originally from Homesaved Treated plots (99) [d]
18	Pronto	From HS 02 exp. – originally from Homesaved Untreated plots (99) [d]
19	Apex	Certified seed
20	Lipton	Certified seed
21	Synergy	Certified seed
22	Pronto	Certified seed

[a] = Seed obtained from sulphur experiment Inverness, harvested 02, 1st generation home-saved

[b] = Seed obtained from Year 2 seed transmission experiment harvested 02, 2nd generation home-saved

[c] = Seed obtained from Variety Trials, Laurencekirk, harvested 02, 1st generation home-saved.

[d] = Seed obtained from Year 2 seed transmission experiment harvested 02, but sown from seed harvested in 99, 00 and 01, 4th generation home-saved

RESULTS

Year 1, 2000/01

As with the sulphur experiments, severe winter weather and the Foot & Mouth outbreak in early 2001 disrupted work in this experiment. Light leaf spot was already present in Apex and Lipton by mid-December, on average 50% incidence (3.4% severity) in Apex and 33% incidence (1.6% severity) in Lipton. Fungicide treatment to the seed source had no affect on levels of light leaf spot at this time.

By stem extension, the incidence of light leaf spot (% plants affected) was high in all varieties, >70% irrespective of parental seed source or fungicide treatment to the parental crop (Figure 12). Severity range from 10% to 21%. Within any variety, parental seed source and treatment to parental crop did not significantly affect the incidence or severity of light leaf spot, but in the varieties Apex, Lipton and Synergy disease incidences were lower in the crops grown from certified seed compared with those grown from home-saved seed. This was not seen in the variety Pronto nor was this effect seen on disease severity. Home-saving seed of the variety Pronto for two seasons (HS UT and HS FG treatments) did not significantly increase the incidence or severity of light leaf spot over that of the certified seed. Light leaf spot levels throughout the season are shown in Appendix 15.

Yields ranged from 2.96 t/ha to 3.82 /ha (Figure 13). Apex yielded on average 3.06 t/ha, which was significantly lower than the other three varieties, which yielded 3.56 t/ha (Lipton), 3.73 t/ha (Synergy) and 3.53 t/ha (Pronto). Within a variety, parental seed source and treatment to parental crop had no effect on yield.

Year 2, 2001/02

This was the first year home-saved seed was available from the light leaf spot seed experiment (see Section 1). The seed from the Inverness site was used as this site was less disrupted by weather and Foot & Mouth and fungicide were applied to the parent crop at the required standard timings in autumn and spring. Note, however, that light leaf spot levels in the parent crop were very low in 2001.

Levels of light leaf spot on leaves of the varieties Bristol and Lipton in late March were generally similar, ranging from 4.9% - 8.5% leaf area infected (Figure 14). Light leaf spot severity varied according to treatment applied to the parent crop. In the light leaf spot susceptible variety Bristol, application of 100 kg S/ha to the parent crop as a soil fertiliser tended to reduce the severity of light leaf spot in the daughter crop by an average of 0.8%, but this was not significant. Fungicide application to the parent crop actually increased the severity of light leaf spot by an average of 2.4% and this was significant where sulphur was

Figure 12 Effect of parental seed source on incidence and severity of light leaf spot in oilseed rape at stem extension 2001

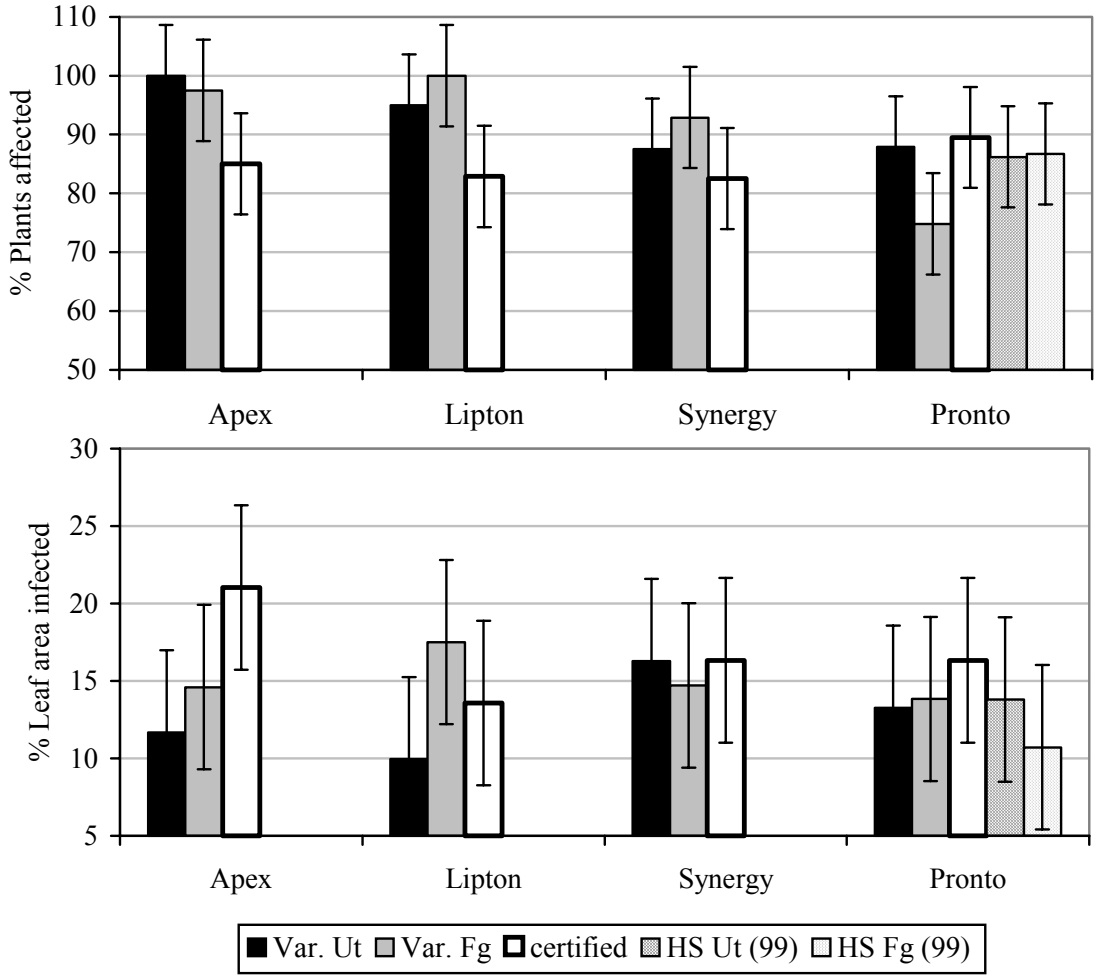
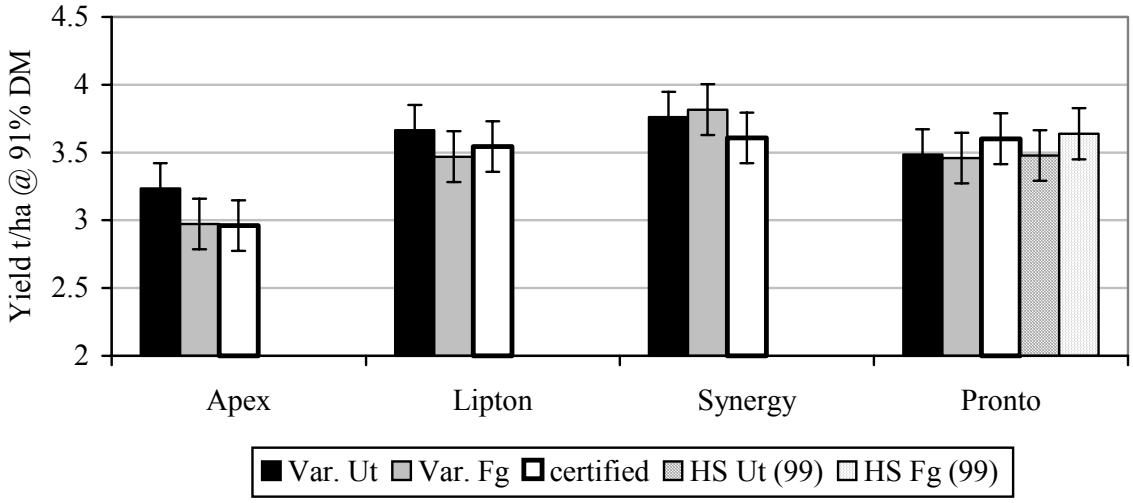


Figure 13. Effect of parental seed source on yield of oilseed rape 2001.



applied. Four weeks later the disease incidence was 100% and severity had increased to an average of 14.2% and differences between treatments were no longer seen (Figure 15). Application of sulphur to the parent crop of Bristol increased yield in the daughter crop but not significantly (Figure 16). Fungicide application to the parent crop had no effect on yield of the daughter crop.

In the light leaf spot resistant variety Lipton, application of sulphur to the parent crop did not reduce the severity of light leaf spot in the daughter crop in the spring (Figures 14 and 15). Application of fungicide significantly reduced levels of light leaf spot in March where no sulphur was applied but not where sulphur was applied. With the higher disease levels one month later in April these differences were not evident. In March, crops grown from certified seed or seed sourced from the Variety Trials in Edinburgh tended to have slightly lower disease levels than seed sourced from the sulphur experiment in Inverness, despite the Inverness parent crop showing very low levels of disease in spring 2001. These lower levels of disease were reflected in slightly higher, but generally not significantly higher, yields (Figure 16). Yields of daughter crops grown from seed from the sulphur experiment were not significantly different, irrespective of sulphur and fungicide applications to the parent crop.

Of the four varieties where seed was home-saved from Variety Trials, Apex and Synergy showed the most severe light leaf spot infection of leaves in the spring, as expected from their low resistance rating (4 and 5 respectively; Figure 14). Treatment of the parent crop with fungicide did not reduce light leaf spot severity in the daughter crop and there were no differences in disease levels between crops grown from the home-saved seed and crops grown from the certified seed. Where seed of the variety Pronto was home-saved through 3 generations, there were no differences in disease levels between these and the certified seed. Lipton, Apex, Synergy and Pronto yielded on average 3.68 t/ha, 3.07 t/ha, 3.15 t/ha and 3.66 t/ha respectively (Figure 16). Parental seed source had no effect on yield of the daughter crops of Lipton, Apex and Synergy. Similar was true of Pronto, although the crop grown from seed obtained from the Variety Trial untreated plots yielded significantly less than the crop grown from certified seed (3.38 t/ha compared with 4.15 t/ha).

Light leaf spot levels throughout the season are shown in Appendices 17 & 18.

Figure 14. Effect of parental seed source on severity of light leaf spot on leaves in March 2002

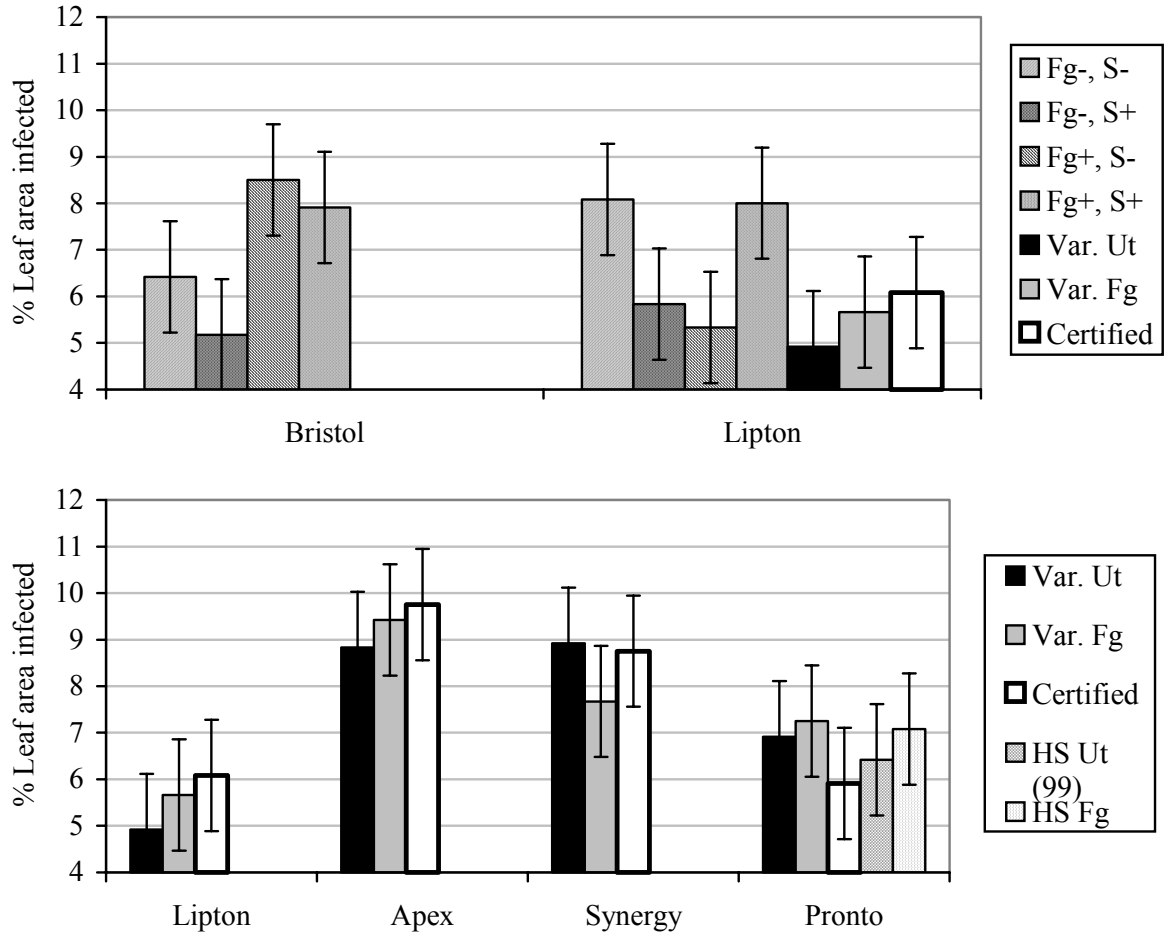


Figure 15. Effect of parental seed source on incidence and severity of light leaf spot on leaves in April 2002

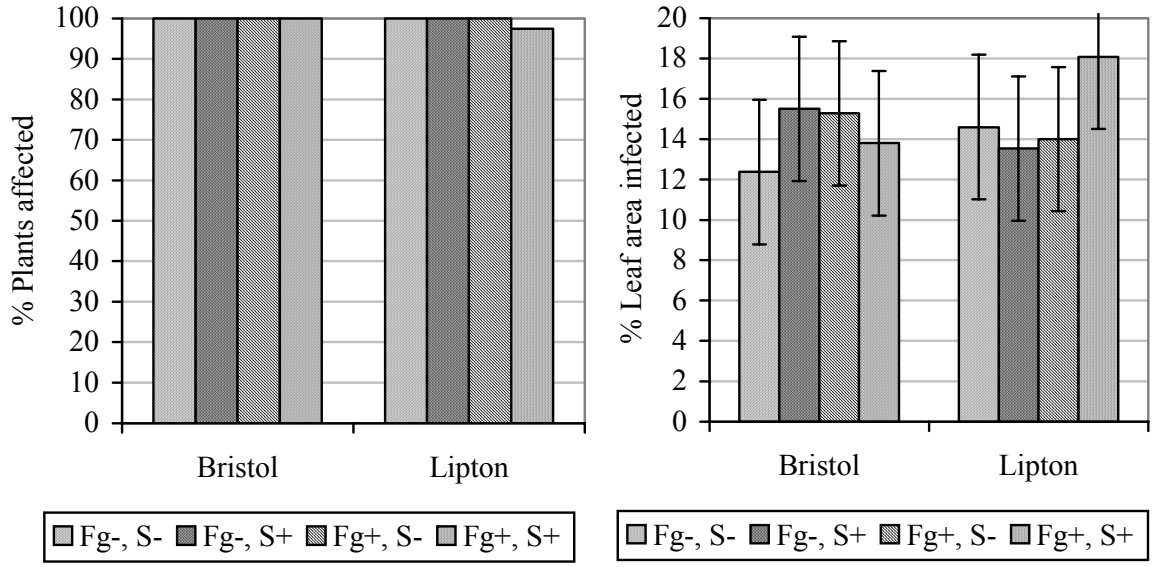
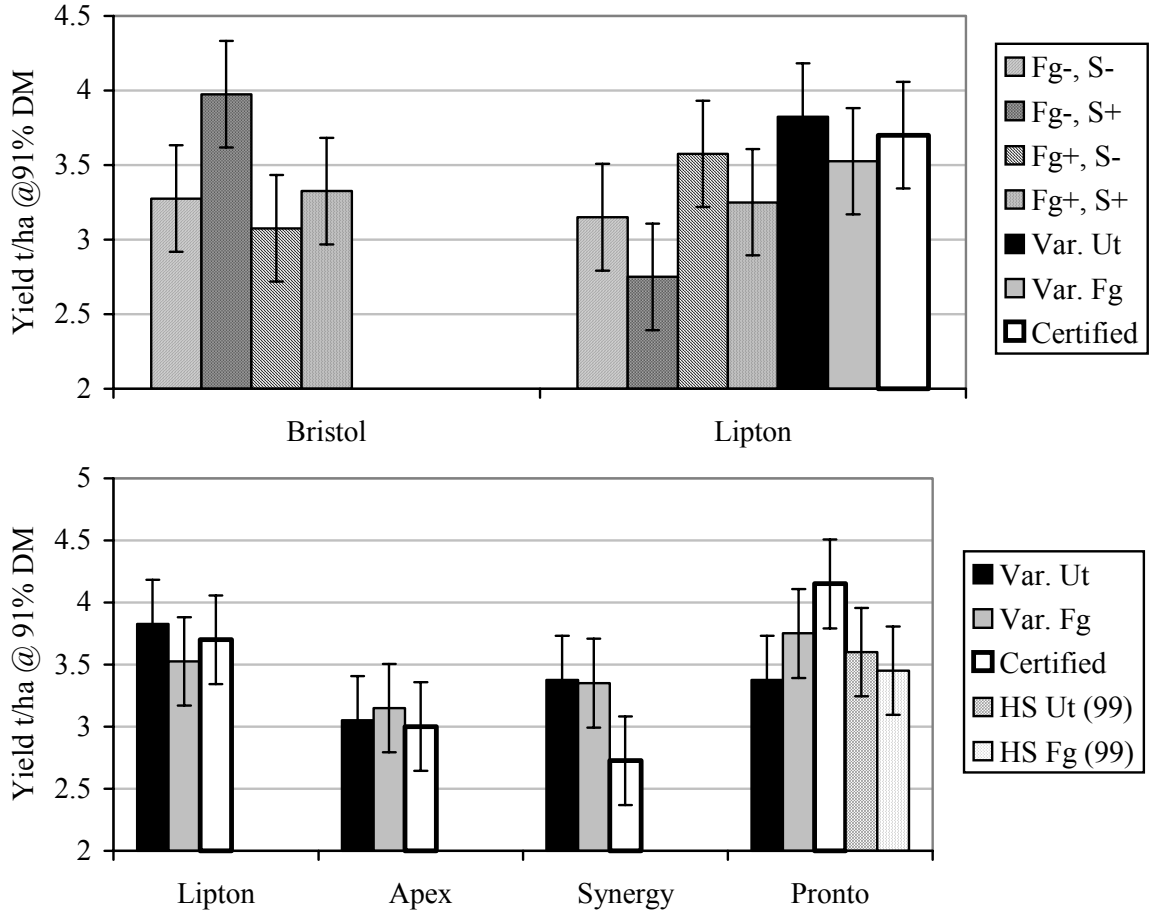


Figure 16. Relationship between parental seed source and yield of oilseed rape, 2002



Year 3, 2002-03

Some of the seed sources originally planned for this years experiment, in particular Apex and Lipton from the Variety Trial treated plots, had to be changed because these varieties were not now available in the Variety Trials.

In the crops grown from seed obtained from the light leaf spot sulphur experiment Inverness 2002/03, light leaf spot was already present by early December 2002. The incidence of light leaf spot in the susceptible variety Bristol was 35% and in the resistant variety Lipton was 17.5%. Disease severity was <1.5%. Treatments to the parent crops had no effect on disease levels in the daughter crops at this time.

By early stem extension in March 2003, light leaf spot severity had increased to an average of 3.76% in Bristol and 2.34 % in Lipton (Figure 17). Application of fungicide and sulphur fertiliser to the parent crops did not influence disease severity in the daughter crops. Disease levels in both Bristol and Lipton increased over the following two weeks and by late March (at stem extension) the disease incidence was on average 75.6% in Bristol and 79.4% in Lipton (Figure 18). Application of fungicide to the parent crop of Bristol

significantly reduced the incidence of light leaf spot in the daughter crop only where soil sulphur was also applied to the parent crop, reducing incidence from 85% to 60%. This was not seen where sulphur was omitted from the parent crop and sulphur did not have any influence on disease development in the daughter crop at all. Application of fungicide and sulphur to the parent crop of Bristol tended to reduce the severity of light leaf spot but this was not significant. Application of fungicide and sulphur to the parent crop of Lipton did not affect the incidence of light leaf spot in the daughter crop but tended to reduce the severity, which was significant (compared with the no fungicide, no sulphur treatment) when fungicide or fungicide and soil sulphur were applied.

Application of fungicide and soil sulphur to the parent crop of either Bristol or Lipton did not improve the yield of the daughter crop (Figure 19).

At early stem extension the average levels of light leaf spot present in each variety was 3.80% in Apex, 3.76% in Bristol, 3.14% in Synergy, 2.58% in Pronto and 2.26% in Lipton, a ranking which would be expected from the resistance ratings of each variety. In the varieties Apex, Lipton and Pronto, seed source had no effect on the severity of light leaf spot in the daughter crop (Figure 17). Crops grown from home-saved seed where parent crops had been treated or untreated with fungicide 1-2 generations previously, showed similar light leaf spot severity to crops grown from certified seed. In Synergy, the crop grown from seed harvested from the Variety Trial treated plots (Laurencekirk) showed significantly higher disease than crops grown from seed sourced from Aberdeen or certified seed.

Apex and Bristol, the two varieties showing the highest disease infection yielded the lowest, Apex an average of 3.08 t/ha and Bristol 3.83 t/ha. Synergy gave the highest yield of 4.20 t/ha. In general, crops grown from home-saved seed yielded as well as crops grown from certified seed, irrespective of source or fungicide treatment to parent crop (Figure 19). The exception to this was the variety Apex (low resistance to light leaf spot), where the crop grown from certified seed out-yielded the home-saved seed by 0.47 t/ha. In many cases, crops from the home-saved seed yielded better than those from certified seed. Home-saving the restored hybrid variety Pronto or the varietal association Synergy tended not to increase disease and did not compromise yield. However, it should be noted that home-saving hybrids is not permitted.

Light leaf spot levels throughout the season are shown in Appendices 19 & 20.

Figure 17. Relationship between parental seed source and severity of light leaf spot in early spring 2003 (in-field assessment)

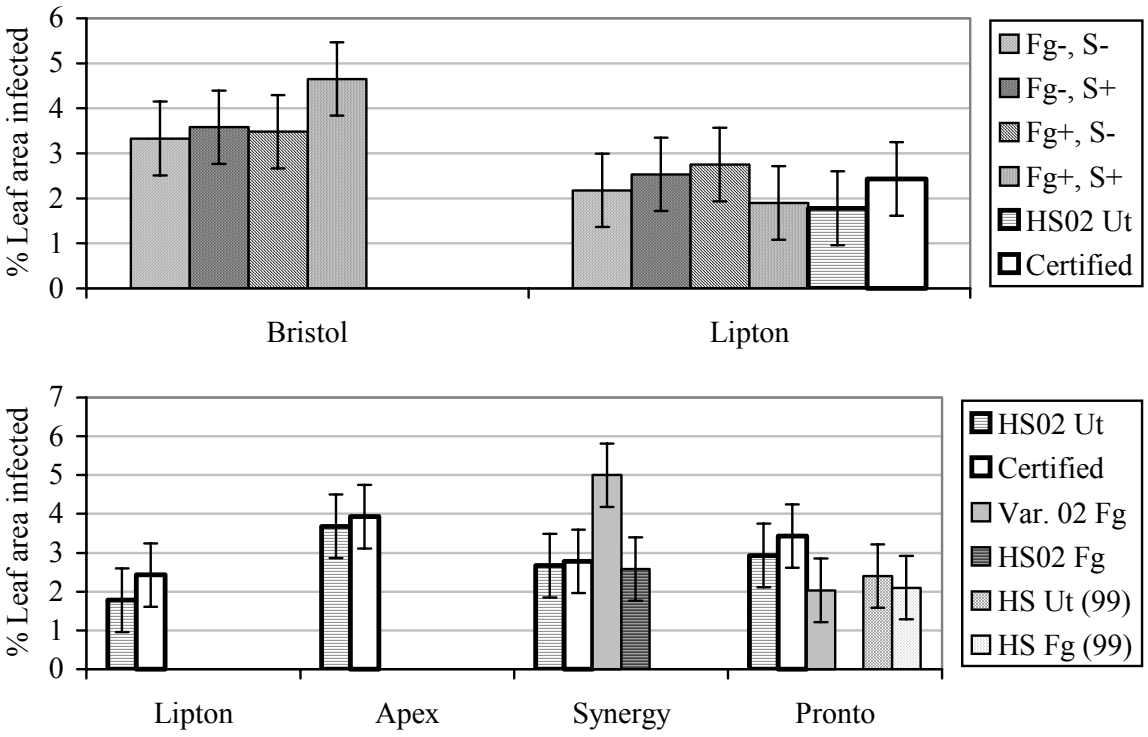


Figure 18. Relationship between parental seed source and incidence and severity of light leaf spot at stem-extension 2003 (laboratory assessment)

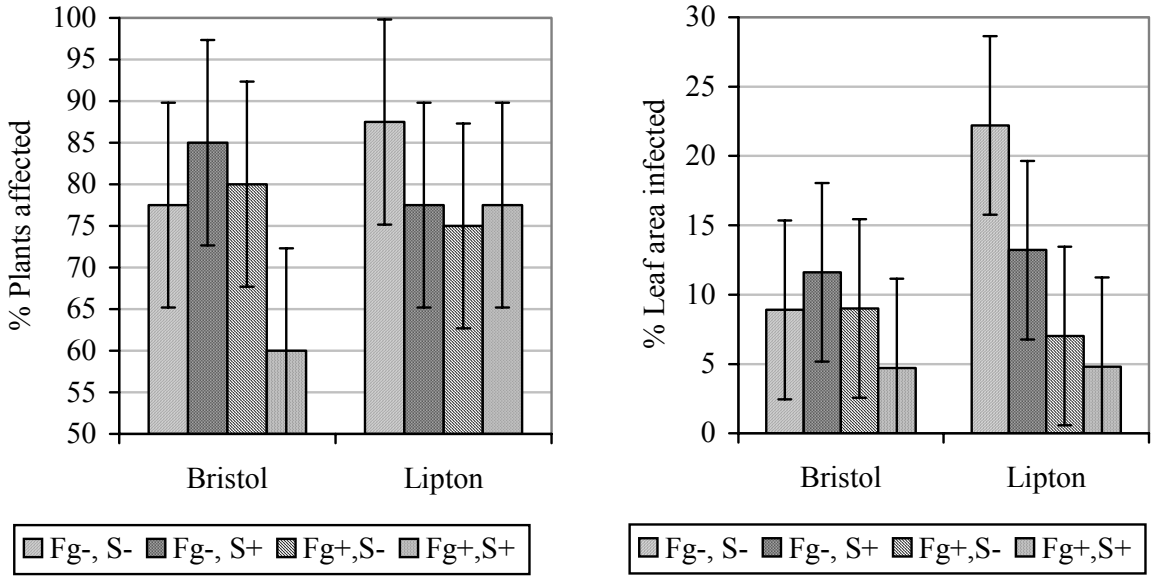
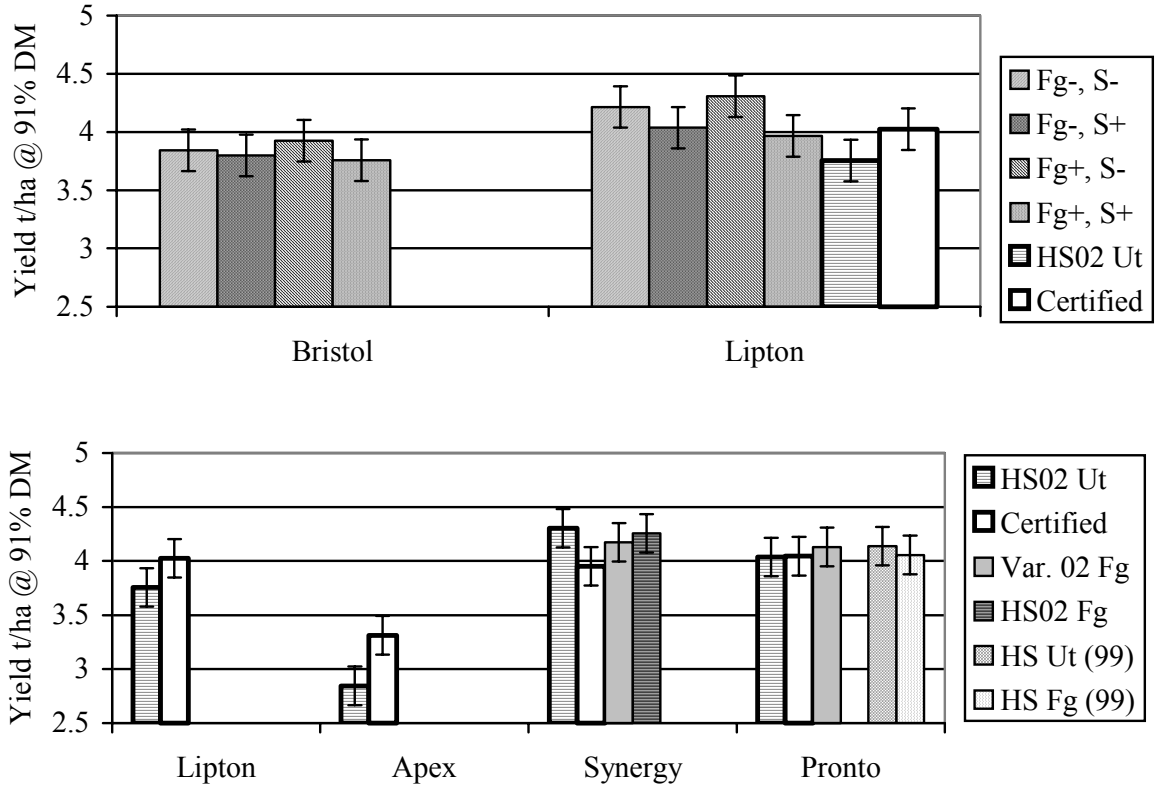


Figure 19. Relationship between parental seed source and yield of oilseed rape 2003



Agronomic Characteristics

In Year 1, 2000/2002, seed source had very little significant affects on agronomic characteristics of individual varieties (Appendix 16). Synergy and Pronto showed poorer establishment due to the lower sowing rates. The main differences were seen in the light leaf spot susceptible variety Apex, where the crop grown from the certified seed showed improved emergence and establishment (score of 7.75 and 8.25) compared with the home-saved seed from a parent crop untreated (score 7.25 and 7.25) or treated with fungicide (score 7.25 and 8.00). However, a crop grown from certified seed flowered later and was shorter in height by 7-8 cm than the crops grown from the home-saved seed. Also, certified Synergy seed tended to exhibit reduced initial establishment compared with crops grown from the home-saved seed.

In Year 2, 2001/02, most agronomic characteristics had high scores, 7.0 or above (Appendix 18). Seed source had no effect on emergence, establishment or vigour in the autumn and where standing ability of the crop was reduced by some treatments to the parent crop, as in Apex and Synergy, the scores were still very good (>7.5) in the reduced treatment. In Year 3, 2002/03, emergence, establishment and vigour were again unaffected by seed source (Appendix 20). In the variety Apex, the use of certified seed significantly improved winter hardiness from 5.0 to 7.0 and crop maturity pre-harvest from 5.75 to 7.50 compared with using home-saved seed. However, in the variety Synergy the same two characteristics and crop height were reduced by growing a crop from certified seed rather than home-saved seed. Home-saving seed had no effect on the characteristics shown by Lipton and Pronto.

Summary of results

Although on individual assessment dates in any particular year there were some significant differences in levels of light leaf spot, yields and agronomic characteristics within the varieties, over the three year period 2000 – 2003 the source of seed, or the treatment applied to the parent crop, did not influence the levels of light leaf spot developing on the daughter crop not did it affect yield or agronomic characteristics of the crop. Results from this observational work does not support the theory that light leaf spot is transmitted via the seed to the daughter crop. Results also show the use of home-saved seed does not put the crop at a disadvantage over a crop grown from certified seed. In these small plot experiments home-saving the varieties Pronto and Synergy did not lead to a loss of heterosis which may be associated with hybrids. It must be stressed, however, that home-saving of hybrid varieties is not permitted on-farm.

DISCUSSION

If light leaf spot is transmitted via the seed then application of fungicides to a growing crop would be expected to reduce disease levels and hence reduce light leaf spot within the seed. Disease levels in daughter crops grown from this seed would subsequently be lower than in daughter crops grown from seed harvested from a non-fungicide treated parent crop. Results from this study showed that light leaf spot levels in crops

grown from certified seed, which are treated with a robust fungicide programme to maintain disease free crops, were not significantly different to those in crops grown from home-saved seed. Also, levels of light leaf spot in crops grown from home-saved seed harvested from fungicide treated or untreated parent crops were similar. Results therefore do not suppoert the theory that light leaf spot is transmitted via the seed.

Application of sulphur to the parent crop had no effect in reducing light leaf spot levels in the daughter crop. Results from Section 1 of this report showed that application of soil sulphur to oilseed rape increased the glucosinolate content of the seed. The presence of glucosinolates in leaves are important in defence against all diseases of oilseed rape, including light leaf spot (Kirkegaard *et al*, 1996). If light leaf spot was carried in the seed, then raising the glucosinolate content of the seed would be expected to reduce the presence of light leaf spot in this seed and hence reduce the light leaf spot showing up in the daughter crop. This did not happen.

The source of the seed, that is, the site it was grown on, again did not affect disease levels. However, it must be noted that the incidence of light leaf spot in daughter crops at stem extension were very high, almost 100%. According to the HGCA funded Forecasting Light Leaf Spot on Winter Oilseed Rape project (Project report No. OS41, Steed & Fitt (2000)), any crop with >25% plants infected with light leaf spot at stem extension (irrespective of the % leaf area infected) was deemed to have a severe infection of light leaf spot. Obviously over the three years of this project light leaf spot epidemics were very severe and it is possible that such severe epidemics masked any differences that may have been present due to seed source, fungicide treatment to parent crop or application of sulphur to the soil. However, natural light leaf spot epidemics in Aberdeenshire are the most severe in the UK so any evidence of transmission of light leaf spot via the seed would be expected in this region. It must therefore be concluded that light leaf spot is not transmitted via the seed.

Results showed that home-saving hybrid varieties or varieties with a varietal association did not adversely affect agronomic characteristics such as emergence, establishment, crop vigour and yield. However, it is recognised that growing such varieties in small plots ($40m^2$), where there is a plentiful supply of pollen from other varieties in surrounding plots, is not a true reflection of what might happen in a field situation. The results shown in this report give an indication of the potential for home-saving hybrid varieties and varieties with a varietal association but the authors of this report would not recommend extrapolating results from these experiments into the field. It should also be noted that the British Society of Plant Breeders indicate that growers are not permitted to home-save seed from hybrids.

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Appendix 1. Soil analyses of Aberdeen and Inverness sites

Determination	Aberdeen			Inverness		
	Year1	Year 2	Year 3	Year 1	Year 2	Year 3
Soil pH	6.0	6.1	6.6	5.5	5.9	5.3
Lime requirement (t/ha)	3.0	2.0	0	6.0	3.0	6.0
P (mg/l)	5.7	6.2	16.1	6.7	7.4	10.6
	(mod)	(mod)	(high)	(mod)	(mod)	(mod)
K (mg/l)	158.0	168.0	211	55.0	55.1	113.0
	(mod)	(mod)	(high)	(low)	(low)	(mod)
Mg (mg/l)	80.0	71.7	270	76.9	88.5	41.2
	(mod)	(mod)	(high)	(mod)	(mod)	(low)
S (mg/l)	13.5	18.5	10.4	14.9	8.8	21.8
	(high)	(high)	(high)	(high)	(mod)	(high)
Organic matter (LOI) (%)	10.8	10.2	8.9	8.2	6.9	5.9
Previous crop	w.barley	grass	w.barley	grass	w. oats	s. barley

Appendix 2. Dates of sowing and application dates of fertiliser and pesticides

Application	Aberdeen			Inverness		
	2000/01	2001/02	2003/04	2000/01	2001/02	2002/03
Date of sowing	29 Aug 00	28 Aug 01	01 Sep 02	29 Aug 00	28 Aug 01	11 Sep 02
Basal Fertiliser (kg/ha N:P:K)	29 Aug 00 15:72:72	28 Aug 01 15:72:72 + 18 kg SO_3	01 Sep 02 10:63:63 + 6 kg SO_3	29 Aug 00 15:72:72	28 Aug 01 15:72:72 + 18 kg SO_3	11 Sep 02 25:62:62 + 6 kg SO_3
Herbicide 1 (l/ha)	01 Sep 00 1.25 l Butisan S	01 Sep 01 1.5 l Butisan S	02 Sep 02 2.5 l Butisan S	02 Sep 00 1.5 l Butisan S	01 Sep 01 1.5 l Butisan S	02 Sep 02 1.25 Butisan S
Herbicide 2 (l/ha)	-	14 Nov 01 2.25 l Laser + 0.8% Fyzol	-	09 Oct 00 2.3 l Benazalox	14 Nov 01 2.25 l Laser + 0.8 % Fyzol	30 Oct 02 0.6 kg Benazalox + 1.25 l Butisan S
Slug Pellets (kg/ha)	04 Sep 00 4.0 kg Metarex green	03 Sep 01 4.0 kg Metarex green	06 Sep 02 4.0 kg Metarex green	05 Sep 00 4.0 kg Metarex green	05 Sep 01 4.0 kg Metarex green	-
Autumn Sulphur (kg S/ha)	-	11 Sep 01 50 kg S	11 Oct 02 50 kg S	-	11 Sep 01 50 kg S	08 Oct 02 50 kg S
Autumn Fungicide (l/ha)	11 Apr 01 0.4 l Punch C	02 Nov 01 0.4 l Punch C	28 Nov 02 0.4 l Punch C	08 Jan 01 0.4 l Punch C	02 Nov 01 0.4 l Punch C	19 Nov 02 0.4 l Punch C
Spring N1 (kg N/ha)	20 Mar 01 100 kg	12 Mar 02 100 kg N	03 Mar 03 30 kg N	08 Mar 01 100 kg N	12 Mar 02 100 kg N	05 Mar 03 100 kg N
Spring N2 (kg N/ha) To half the plots only	04 Apr 01 100 kg N	08 Apr 02 100 kg N	20 Mar 03 30 kg N	05 Apr 01 100 kg N	08 Apr 02 100 kg N	19 Mar 03 100 kg N
Spring Sulphur (kg S/ha) To half the plots only	04 Apr 01 100 kg S	12 Mar 02 50 kg S	20 Mar 03 50 kg S	20 Mar 01 100 kg S	12 Mar 02 50 kg S	19 Mar 03 50 kg S
Spring Fungicide (l/ha)	27 May 01 0.5 l/ha Folicur	08 Apr 02 0.4 l Punch C	20 Mar 03 0.4 l Punch C	26 Apr 01 0.4 l Punch C	08 Apr 02 0.4 l Punch C	19 Mar 03 0.4 l Punch C

Appendix 3. Incidence and severity of light leaf spot on leaves of winter oilseed rape (except where indicated), Aberdeen, 2000/01

				% Incidence			% Severity						% Sev. stem
Variety	Fg	S kg/ha	N kg/ha	11 Dec 1.10-1.11	05 Apr 3.1	18 May 4.0/4.1	11 Dec 1.10-1.11	05 Apr 3.1	18 May 4.0/4.1	05 Jun 6.2	13 Jul 6.2	19 Jul 6.3	13 Jul 6.2
Bristol	-	0	100	7.5	81.8	100.0	0.35	11.52	3.51	5.75	1.50	5.75	1.83
	-	0	200	-	74.3	100.0	-	7.46	4.95	2.25	1.71	5.25	1.75
	-	100	100	-	92.5	100.0	-	14.63	5.42	8.75	0.98	7.25	2.25
	-	100	200	-	85.4	100.0	-	16.53	5.30	7.25	2.19	6.73	2.25
	+	0	100	-	-	90.0	-	-	2.12	8.50	1.12	7.57	1.25
	+	0	200	-	-	85.0	-	-	5.14	6.50	2.17	6.75	1.58
	+	100	100	-	-	100.0	-	-	4.07	4.00	1.17	4.00	1.66
	+	100	200	-	-	85.0	-	-	2.54	6.25	1.50	6.17	1.25
Lipton	-	0	100	7.5	87.6	97.5	0.30	17.80	6.41	7.50	1.46	7.25	1.75
	-	0	200	-	92.5	97.5	-	12.17	7.07	10.25	1.63	10.17	2.08
	-	100	100	-	92.1	100.0	-	19.07	5.84	9.50	1.17	8.50	2.42
	-	100	200	-	89.4	100.0	-	11.89	6.37	5.00	1.62	5.92	1.16
	+	0	100	-	-	92.5	-	-	2.82	6.00	1.04	5.00	1.17
	+	0	200	-	-	92.5	-	-	3.22	5.25	1.96	6.40	1.50
	+	100	100	-	-	82.5	-	-	2.48	3.75	1.21	6.50	1.33
	+	100	200	-	-	92.5	-	-	5.19	5.25	1.88	6.60	1.42
LSD				22.50	15.34	17.01 (10.93)	1.276	7.822	2.875 (2.851)	5.890 (4.499)	0.595 (0.627)	4.152 (3.703)	0.793 (0.802)
df				3	53	42	3	53	42	42	42	42	42
significance				ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

Figures in brackets are when comparing means with the same levels of Fg, Fg*Var, Fg*S, Fg*N**,** Fg*Var*S, Fg*Var*N and Fg*S*N

ns = not significant

Appendix 4. Incidence and severity of light leaf spot on leaves of winter oilsee rape, Inverness 2000/01

Variety	Fg.	S	N	% Incidence				% Severity			
				20 Dec	27 Feb	30 Mar	26 Apr	20 Dec	27 Feb	30 Mar	26 Apr
		kg/ha	kg/ha	GS 1.05	GS 3.0	GS 3.3	GS 3.5	GS 1.05	GS 3.0	GS 3.3	GS 3.5
Bristol	-	0	100	15.0	0	7.5	0	0.10	0	0.38	0
	-	0	200	-	0	0	0	-	0	0	0
	-	100	100	-	0	7.5	0	-	0	0.3	0
	-	100	200	-	0	12.5	0	-	0	0.62	0
	+	0	100	-	0	15.0	0	-	0	0.70	0
	+	0	200	-	0	0	0	-	0	0	0
	+	100	100	-	0	2.5	0	-	0	0.12	0
	+	100	200	-	0	10.0	0	-	0	0.5	0
Lipton	-	0	100	5.0	0	0	0	0.02	0	0	0
	-	0	200	-	0	2.5	0	-	0	0.25	0
	-	100	100	-	0	7.5	0	-	0	0.38	0
	-	100	200	-	0	0	0	-	0	0	0
	+	0	100	-	0	0	0	-	0	0	0
	+	0	200	-	0	0	0	-	0	0	0
	+	100	100	-	0	7.5	0	-	0	0.50	0
	+	100	200	-	0	0	0	-	0	0	0
LSD				34.47	-	11.19 (11.50)	-	0.247	-	0.549 (0.563)	-
df				3	-	42	-	3	-	42	-
significance				ns	-	ns	-	ns	-	ns	-

Figures in brackets are when comparing means with the same levels of Fg, Fg*Var, Fg*S, Fg*N**,** Fg*Var*S, Fg*Var*N and Fg*S*N

ns = not significant

Appendix 5. Incidence and severity of light leaf spot on leaves of winter oilseed rape (except where indicated), Aberdeen, 2001/02

Var.	Fg	S kg/ha	N kg/ha	% Incidence						% Severity								
				03 Dec 1.9-1.10	04 Mar 3.1	08 Apr 3.3-3.5	18 May 4.0-4.1	12 Jun 6.1-6.2	12 Jun stems	03 Dec 1.9-1.10	04 Mar 3.1	08 Apr 3.3-3.5	18 May 4.0-4.1	12 Jun 6.1-6.2	13 Jul 6.3	12 Jun stems	13 Jul stems	13 Jul pods
Bristol	-	0	100	8.75	51.2	100.0	92.5	65.0	95.0	0.03	3.65	14.91	4.16	2.71	1.67	3.50	1.58	3.50
	-	0	200	-	-	-	100.0	77.5	100.0	-	-	-	3.54	6.57	1.40	4.92	1.75	2.25
	-	100	100	7.50	50.0	100.0	92.5	85.0	100.0	0.05	2.09	9.39	5.20	6.79	1.36	4.05	1.42	3.00
	-	100	200	-	-	-	95.0	92.5	97.5	-	-	-	5.38	7.10	1.38	5.42	1.25	3.00
	+	0	100	0	20.0	75.0	95.0	47.5	85.0	0	0.80	3.25	3.29	1.90	1.34	2.08	1.83	1.62
	+	0	200	-	-	-	97.5	62.5	85.0	-	-	-	3.35	2.14	1.67	2.15	1.92	2.00
	+	100	100	1.25	25.0	75.0	95.0	52.5	72.5	0.001	0.41	4.61	3.58	1.48	1.12	1.82	1.75	2.00
	+	100	200	-	-	-	95.0	75.0	72.5	-	-	-	5.18	3.45	1.25	1.85	1.50	0.88
Lipton	-	0	100	3.75	36.2	75.0	97.5	100.0	90.0	0.01	0.83	13.46	4.12	7.92	1.31	3.95	1.75	1.75
	-	0	200	-	-	-	87.5	95.0	97.5	-	-	-	4.69	8.65	2.25	2.90	1.66	1.50
	-	100	100	2.50	38.8	88.8	92.5	100.0	87.5	0.002	2.94	13.63	4.64	8.77	1.21	2.98	1.58	2.75
	-	100	200	-	-	-	87.5	100.0	97.5	-	-	-	5.77	7.45	1.71	3.48	2.17	2.50
	+	0	100	2.50	21.2	71.2	95.0	77.5	67.5	0.03	1.06	4.10	4.49	2.71	1.21	1.72	1.42	0.88
	+	0	200	-	-	-	97.5	60.0	85.0	-	-	-	6.25	1.98	1.84	1.78	1.50	1.38
	+	100	100	1.25	17.5	62.5	100.0	75.0	75.0	0.001	0.22	3.73	4.65	3.88	1.67	1.30	2.16	1.38
	+	100	200	-	-	-	95.0	72.5	65.0	-	-	-	4.18	2.24	1.92	1.32	1.42	1.38
LSD				5.948	19.95	52.45 (26.35)	22.24 (11.57)	28.30 (24.94)	17.85 (17.31)	0.048	2.406	11.298 (6.158)	4.262 (3.099)	3.025 (2.843)	0.698 (0.738)	0.944 (0.998)	1.106 (0.838)	1.448 (1.417)
df				50	50	50	42	42	42	50	50	50	42	42	42	42	42	42
significance				ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

Figures in brackets are when comparing means with the same levels of Fg, Fg*Var, Fg*S, Fg*N**,** Fg*Var*S, Fg*Var*N and Fg*S*N

ns = not significant

Appendix 6. Incidence and severity of light leaf spot on leaves of winter oilseed rape, Inverness, 2001/02

				% Incidence				% Severity			
Var.	Fg	S kg/ha	N kg/ha	13 Nov 1.06	31 Jan 1.08	09 Apr 3.3	12 May 4.1-4.3	13 Nov 1.06	31 Jan 1.08	09 Apr 3.3	12 May 4.1-4.3
Bristol	-	0	100	0	10.0	100.0	100.0	0	0.09	11.40	9.33
	-	0	200	-	-	-	100.0	-	-	-	11.13
	-	100	100	0	5.0	100.0	100.0	0	0.08	10.61	10.07
	-	100	200	-	-	-	100.0	-	-	-	9.60
	+	0	100	-	7.5	98.8	100.0	-	0.14	4.20	3.47
	+	0	200	-	-	-	100.0	-	-	-	3.83
	+	100	100	-	7.5	98.8	97.5	-	0.15	3.81	4.83
	+	100	200	-	-	-	100.0	-	-	-	3.78
Lipton	-	0	100	0	13.8	100.0	100.0	0	0.10	16.01	18.05
	-	0	200	-	-	-	100.0	-	-	-	11.65
	-	100	100	0	11.2	100.0	100.0	0	0.18	11.74	11.20
	-	100	200	-	-	-	100.0	-	-	-	10.28
	+	0	100	-	10.0	100.0	100.0	-	0.16	5.34	4.60
	+	0	200	-	-	-	100.0	-	-	-	5.47
	+	100	100	-	8.8	95.0	100.0	-	0.08	4.18	5.20
	+	100	200	-	-	-	95.0	-	-	-	9.82
LSD				-	13.85	3.96	4.025 (3.745)	-	0.288	3.912	5.834 (6.169)
df				-	50	50	42	-	50	50	42
significance				-	ns	ns	ns	-	ns	ns	ns

Figures in brackets are when comparing means with the same levels of Fg, Fg*Var, Fg*S, Fg*N, Fg*Var*S, Fg*Var*N and Fg*S*N

ns = not significant

Appendix 7. Incidence and severity of light leaf spot on leaves of winter oilseed rape (except where indicated), Aberdeen, 2002/03

				% Incidence					% Severity				% Sev. stems	% Sev. pods
Var.	Fg	S kg/ha	N kg/ha	18 Nov 1.08-1.09	13 Jan 1.11-1.12	26 Feb 3.1	28 Apr 4.3-4.5	17 Jul 6.3	18 Nov 1.08-1.09	13 Jan 1.11-1.12	26 Feb 3.1	28 Apr 4.3-4.5	17 Jul 6.3	17 Jul 6.3
Bristol	-	0	100	0	10	67.5	90.0	-	0	0.01	4.28	4.00	7.09	1.18
	-	0	200	-	-	-	92.5	-	-	-	-	5.51	8.83	5.58
	-	100	100	0	10	56.2	92.5	-	0	0.10	2.50	3.86	7.67	1.67
	-	100	200	-	-	-	85.0	-	-	-	-	5.65	9.92	5.79
	+	0	100	-	-	71.2	100.0	-	-	-	3.80	8.30	3.88	1.57
	+	0	200	-	-	-	97.5	-	-	-	-	11.90	6.38	2.21
	+	100	100	-	-	72.5	100.0	-	-	-	5.48	10.62	5.00	1.31
	+	100	200	-	-	-	100.0	-	-	-	-	7.95	4.01	0.99
Lipton	-	0	100	0	20	53.8	82.5	-	0	0.15	2.78	3.12	4.79	0.91
	-	0	200	-	-	-	85.0	-	-	-	-	4.29	4.91	6.61
	-	100	100	0	60	50.0	85.0	-	0	7.52	2.37	3.65	4.33	0.47
	-	100	200	-	-	-	85.0	-	-	-	-	4.57	3.71	3.05
	+	0	100	-	-	71.2	100.0	-	-	-	4.52	11.17	1.79	1.11
	+	0	200	-	-	-	100.0	-	-	-	-	10.52	3.71	4.09
	+	100	100	-	-	61.2	100.0	-	-	-	6.84	11.47	1.79	2.18
	+	100	200	-	-	-	97.5	-	-	-	-	14.42	3.83	4.63
LSD				-	-	43.09	9.188 (9.087)	-	-	-	3.840	5.370 (4.895)	2.563 (2.053)	3.684 (3.232)
df				-	-	50	42	-	-	-	50	42	42	42
significance				-	ns	ns	ns	-	-	ns	ns	ns	ns	ns

Figures in brackets are when comparing means with the same levels of Fg, Fg*Var, Fg*S, Fg*N**,** Fg*Var*S, Fg*Var*N and Fg*S*N

ns = not significant

Appendix 8. Incidence and severity of light leaf spot on leaves of winter oilseed rape, Inverness , 2002/03

Var.	Fg	S kg/ha	N kg/ha	% Incidence 19 Nov 1.3-1.5	29 Nov 1.4-1.5	16 Dec 1.4-1.6	14 Feb 2.1	21 Mar 3.1	14 Apr 4.0	% Severity 19 Nov 1.3-1.5	29 Nov 1.4-1.5	16 Dec 1.4-1.6	14 Feb 2.1	21 Mar 3.1	14 Apr 4.0
Bristol	-	0	100	0	10.0	0	13.8	63.8	12.5	0	0.50	0	1.20	4.05	0.38
	-	0	200	-	-	-	-	-	22.5	-	-	-	-	-	0.58
	-	100	100	0	10.0	0	25.0	58.8	7.5	0	0.10	0	3.13	5.79	0.18
	-	100	200	-	-	-	-	-	30.0	-	-	-	-	-	0.75
	+	0	100	-	-	0	30.0	38.8	5.0	-	-	0	2.74	2.66	0.02
	+	0	200	-	-	-	-	-	15.0	-	-	-	-	-	0.52
	+	100	100	-	-	0	17.5	27.5	7.5	-	-	0	1.68	1.49	0.62
	+	100	200	-	-	-	-	-	2.5	-	-	-	-	-	0.02
Lipton	-	0	100	2.5	20.0	0	2.5	31.2	20.0	0.08	0.20	0	0.16	2.41	0.90
	-	0	200	-	-	-	-	-	17.5	-	-	-	-	-	0.78
	-	100	100	0	30.0	0	1.2	51.2	22.5	0	0.50	0	0.10	4.74	0.52
	-	100	200	-	-	-	-	-	25.0	-	-	-	-	-	0.50
	+	0	100	-	-	0	1.2	17.5	0.0	-	-	0	0.12	0.86	0
	+	0	200	-	-	-	-	-	2.5	-	-	-	-	-	0.10
	+	100	100	-	-	0	3.8	21.2	5.0	-	-	0	0.30	1.39	0.12
	+	100	200	-	-	-	-	-	10.0	-	-	-	-	-	0.12
LSD				4.00	30.46	-	12.92 (12.38)	23.47 (21.15)	17.26 (17.28)	0.120	0.865	-	1.485 (1.442)	4.192 (2.886)	0.720 (0.758)
df				9	9	-	50	50	42	9	9	-	50	50	42
significance				ns	ns	-	*	ns	ns	ns	ns	-	*	ns	ns

Figures in brackets are when comparing means with the same levels of Fg, Fg*Var, Fg*S, Fg*N**,** Fg*Var*S, Fg*Var*N and Fg*S*N

Ns = not significant

Appendix 9. Yields of winter oilseed rape, 2001 - 2003

				Yield (t/ha @ 9% MC)					
				Aberdeen			Inverness		
Var.	Fg	S kg/ha	N kg/ha	2001	2002	2003	2001	2002	2003
Bristol	-	0	100	3.038	2.445	2.996	2.179	2.023	1.775
	-	0	200	3.630	2.748	3.956	2.191	2.385	2.710
	-	100	100	2.708	2.535	2.849	2.340	1.903	1.997
	-	100	200	3.435	2.925	3.723	3.109	2.278	3.082
	+	0	100	2.278	2.768	3.096	2.240	2.285	2.620
	+	0	200	3.588	3.035	4.079	2.870	2.360	3.162
	+	100	100	3.175	2.843	3.158	2.694	2.245	2.577
	+	100	200	3.897	3.543	4.085	3.644	2.540	3.160
Lipton	-	0	100	3.143	3.055	3.049	2.195	1.823	2.448
	-	0	200	4.205	3.690	3.956	2.506	2.358	3.192
	-	100	100	3.160	3.345	3.052	2.317	2.090	2.545
	-	100	200	4.385	3.487	3.981	3.110	2.373	3.145
	+	0	100	3.618	2.610	3.022	2.296	2.283	2.642
	+	0	200	4.380	3.298	4.072	2.842	2.910	3.622
	+	100	100	3.448	2.875	3.099	2.417	2.578	2.812
	+	100	200	4.694	3.795	4.287	3.281	2.960	3.415
LSD				0.6844	0.577	0.460	0.6371	0.4321	1.7311
				(0.6421)	(0.510)	(0.335)	(0.3107)	(0.3750)	(0.6403)
df				42	42	42	42	42	42
significance				ns	ns	ns	ns	ns	ns

Figures in brackets are when comparing means with the same levels of Fg, Fg*Var, Fg*S, Fg*N**,** Fg*Var*S, Fg*Var*N and Fg*S*N

ns = not significant

Appendix 10. Effect of variety, fungicide (Fg), sulphur (S) and nitrogen (N) on levels of nutrients in leaves in spring (mean Year 1 & 2)

				Aberdeen					Inverness				
Variety	Fg	S	N	S	P	K	Ca	Mg	S	P	K	Ca	Mg
		kg/ha	kg/ha	%	%	%	%	%	%	%	%	%	%
Bristol	-	0	100	0.49	0.29	2.68	2.20	0.11	0.36	0.31	2.49	1.84	0.12
	-	0	200	0.60	0.32	2.97	2.52	0.13	0.37	0.33	2.31	2.06	0.15
	-	100	100	0.85	0.31	2.84	2.28	0.12	0.75	0.32	2.33	2.03	0.13
	-	100	200	0.82	0.30	2.98	2.46	0.12	0.70	0.30	2.24	1.98	0.14
	+	0	100	0.52	0.31	2.80	2.30	0.13	0.32	0.30	2.36	1.73	0.12
	+	0	200	0.48	0.31	2.80	2.28	0.13	0.32	0.30	2.18	1.84	0.13
	+	100	100	0.92	0.32	2.96	2.10	0.12	0.73	0.32	1.93	1.97	0.14
	+	100	200	0.80	0.31	2.90	2.29	0.12	0.77	0.34	2.30	2.22	0.17
Lipton	-	0	100	0.55	0.34	2.74	1.98	0.11	0.34	0.35	2.12	1.77	0.13
	-	0	200	0.52	0.34	2.87	2.07	0.12	0.39	0.37	2.21	1.93	0.13
	-	100	100	0.85	0.34	2.72	1.84	0.10	0.75	0.36	1.88	1.83	0.14
	-	100	200	0.82	0.38	3.16	2.16	0.12	0.76	0.40	1.87	2.09	0.17
	+	0	100	0.53	0.34	2.74	1.94	0.11	0.36	0.36	2.25	1.73	0.12
	+	0	200	0.48	0.32	2.68	2.08	0.12	0.39	0.34	2.26	1.77	0.13
	+	100	100	0.84	0.33	2.72	1.76	0.10	0.72	0.36	1.91	1.78	0.14
	+	100	200	0.80	0.36	3.05	2.07	0.12	0.74	0.37	1.84	1.94	0.15
LSD				0.103	0.044	0.312	0.213	0.015	0.100	0.060	0.464	0.264	0.032
				(0.106)	(0.044)	(0.329)	(0.212)	(0.016)	(0.104)	(0.060)	(0.444)	(0.248)	(0.030)
df				42	42	42	42	42	42	42	42	42	42
significance				ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

Figures in brackets are when comparing means with the same levels of Fg, Fg*Var, Fg*S, Fg*N**,** Fg*Var*S, Fg*Var*N and Fg*S*N

ns = not significant

Appendix 11. Glucosinolate content of leaves in spring, Aberdeen Year 1

Var.	Fg	S	N	glucoi-berin	progoi-trin	gluconap-oleiferin	gluco-napin	glucobrass-icanapin	gluco-brassicin	gluco-nasturtiin	neogluco-nasturiin	Total glucosinolate
		Kg/ha	Kg/ha	µmol/g	µmol/g	µmol/g	µmol/g	µmol/g	µmol/g	µmol/g	µmol/g	µmol/g
Bristol	-	0	100	0.07	0.41	0.56	0.30	1.99	0.98	0.34	0.01	4.71
	-	0	200	0.08	0.48	0.46	0.24	1.60	1.20	0.30	0.02	4.35
	-	100	100	0.08	0.54	0.44	0.33	1.84	1.25	0.32	0.02	4.82
	-	100	200	0.05	0.74	0.51	0.30	1.71	1.79	0.26	0.03	5.40
	+	0	100	0.10	0.27	0.23	0.17	0.97	0.43	0.28	0.06	2.52
	+	0	200	0.17	0.40	0.33	0.20	1.22	0.72	0.23	0.04	3.31
	+	100	100	0.13	0.44	0.35	0.30	1.46	0.71	0.26	0.04	3.70
	+	100	200	0.10	0.36	0.34	0.17	1.03	0.63	0.29	0.06	2.98
Lipton	-	0	100	0.12	0.51	0.25	0.50	1.78	0.53	0.25	0.02	3.95
	-	0	200	0.14	0.95	0.38	0.47	1.78	0.74	0.26	0.02	4.72
	-	100	100	0.09	0.47	0.18	0.51	1.51	0.40	0.33	0.06	3.55
	-	100	200	0.02	1.00	0.50	0.47	1.93	1.01	0.27	0.02	5.13
	+	0	100	0.06	0.68	0.21	0.46	1.21	0.34	0.28	0.04	3.30
	+	0	200	0.17	0.54	0.21	0.32	1.11	0.45	0.27	0.04	3.10
	+	100	100	0.17	0.76	0.23	0.53	1.27	0.41	0.28	0.06	3.67
	+	100	200	0.02	0.64	0.20	0.33	0.92	0.35	0.29	0.04	2.80
LSD				0.209 (0.080)	0.328 (0.277)	0.183 (0.140)	0.183 (0.176)	0.673 (0.695)	0.117 (0.123)	0.117 (0.123)	0.052 (0.022)	1.550 (1.533)
df				42	42	42	42	42	42	42	42	42
significance.				ns	ns	ns	ns	ns	ns	ns	*	ns

Figures in brackets are when comparing means with the same levels of Fg, Fg*Var, Fg*S, Fg*N**,** Fg*Var*S, Fg*Var*N and Fg*S*N

ns = not significant

* = significant at $p<0.05$

Appendix 12. Glucosinolate content of leaves in spring, Inverness Year 1

Var.	Fg	S	N	glucoi-berin	progoi-trin	gluconap-oleiferin	gluco-napin	glucobrass-icanapin	gluco-brassicin	gluco-nasturtiin	neogluco-nasturiin	Total glucosinolate
		Kg/ha	Kg/ha	µmol/g	µmol/g	µmol/g	µmol/g	µmol/g	µmol/g	µmol/g	µmol/g	µmol/g
Bristol	-	0	100	0	0.92	0.90	0.32	3.02	0.62	0.29	0.02	5.20
	-	0	200	0	1.27	1.14	0.31	3.71	0.66	0.34	0.02	6.30
	-	100	100	0	2.07	1.15	0.69	5.06	0.80	0.42	0.02	9.06
	-	100	200	0	1.99	1.14	0.66	4.60	0.74	0.52	0.03	8.54
	+	0	100	0	1.17	0.96	0.32	3.28	0.63	0.30	0.03	5.73
	+	0	200	0	1.08	0.85	0.32	3.02	0.50	0.28	0.02	5.21
	+	100	100	0	1.93	1.07	0.69	4.68	0.82	0.49	0.03	8.64
	+	100	200	0	1.73	0.92	0.64	4.00	0.66	0.44	0.02	7.49
Lipton	-	0	100	0	1.99	0.90	0.67	4.36	0.60	0.56	0.03	8.20
	-	0	200	0	1.61	0.80	0.45	3.49	0.51	0.63	0.02	6.71
	-	100	100	0	2.32	0.94	0.94	5.08	0.85	0.60	0.03	9.80
	-	100	200	0	1.68	0.89	0.73	3.84	0.61	0.35	0.03	7.24
	+	0	100	0	1.02	0.64	0.44	2.67	0.22	0.32	0.02	4.69
	+	0	200	0	1.12	0.67	0.36	2.64	0.32	0.28	0.03	4.75
	+	100	100	0	1.61	0.83	0.68	3.75	0.44	0.48	0.02	6.98
	+	100	200	0	1.13	0.74	0.58	3.10	0.35	0.30	0.02	5.47
LSD				-	0.686 (0.647)	0.251 (0.233)	0.200 (0.180)	1.164 (1.050)	0.291 (0.277)	0.222 (0.197)	0.012 (0.012)	2.262 (2.112)
df				-	42	42	42	42	42	42	42	42
significance				-	ns	ns	ns	ns	ns	ns	ns	ns

Figures in brackets are when comparing means with the same levels of Fg, Fg*Var, Fg*S, Fg*N**,** Fg*Var*S, Fg*Var*N and Fg*S*N

Appendix 13. Glucosinolate (GSL) content of seed, Aberdeen (mean Years 1 & 2)

Var.	Fg	S	N	glucoiberin	progoitrin	EPI	gluconapoleiferin	gluconapin	4-hydroxyglucobrassicin	glucobrassicanapin	glucobrassicin	gluconasturtiin	neoglucobrassicin	Total GSL
		kg/ha	kg/ha	µmol/g	µmol/g	µmol/g	µmol/g	µmol/g	µmol/g	µmol/g	µmol/g	µmol/g	µmol/g	µmol/g
Bristol	-	0	100	0.40	3.14	0.05	0.41	1.88	0.09	0.18	0.02	0	0.01	6.20
	-	0	200	0.39	2.69	0.04	0.30	1.43	0.06	0.17	0.03	0	0.01	5.10
	-	100	100	0.41	4.27	0.07	0.62	2.49	0.15	0.34	0.03	0.01	0.01	8.39
	-	100	200	0.50	4.52	0.08	0.59	2.46	0.13	0.36	0.05	0	0.01	8.69
	+	0	100	0.41	2.75	0.02	0.25	1.71	0.06	0.18	0.03	0	0.01	5.43
	+	0	200	0.37	2.28	0.02	0.24	1.28	0.05	0.12	0.03	0	0.01	4.40
	+	100	100	0.38	3.79	0.06	0.41	2.27	0.11	0.30	0.04	0.01	0.01	7.34
	+	100	200	0.35	4.33	0.07	0.25	2.21	0.10	0.27	0.04	0.05	0.02	7.68
Lipton	-	0	100	0.40	3.43	0.04	0.29	1.52	0.09	0.20	0.04	0	0.01	6.03
	-	0	200	0.46	3.68	0.06	0.27	1.53	0.07	0.21	0.04	0	0.01	6.33
	-	100	100	0.45	4.12	0.07	0.35	1.82	0.13	0.32	0.04	0	0.01	7.30
	-	100	200	0.48	4.74	0.08	0.35	2.03	0.12	0.27	0.05	0.01	0.01	8.14
	+	0	100	0.36	2.84	0.04	0.24	1.38	0.06	0.14	0.03	0.01	0.01	5.11
	+	0	200	0.36	3.14	0.04	0.24	1.46	0.05	0.15	0.04	0.01	0.01	5.49
	+	100	100	0.37	3.75	0.04	0.29	1.79	0.10	0.21	0.04	0	0.01	6.61
	+	100	200	0.45	4.34	0.06	0.30	2.00	0.10	0.23	0.05	0	0.01	7.53
LSD				0.115 (0.109)	0.329 (0.344)	0.022 (0.022)	0.117 (0.115)	0.261 (0.259)	0.022 (0.018)	0.063 (0.064)	0.014 (0.012)	-	-	0.613 (0.623)
df				42	42	42	42	42	42	42	42	42	42	42
significance				ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

Figures in brackets are when comparing means with the same levels of Fg, Fg*Var, Fg*S, Fg*N**,** Fg*Var*S, Fg*Var*N and Fg*S*N

Appendix 14. Glucosinolate (GSL) content of seed, Inverness (mean Years 1 & 2)

Var.	Fg.	S	N	glucoiberin	progoitrin	EPI	gluconapoleiferin	gluconapin	4-hydroxyglucobrassicin	glucobrassicanapin	glucobrassicin	gluconasturtiin	neoglucobrassicin	Total GSL
		kg/ha	kg/ha	µmol/g	µmol/g	µmol/g	µmol/g	µmol/g	µmol/g	µmol/g	µmol/g	µmol/g	µmol/g	µmol/g
Bristol	-	0	100	0.23	2.08	0.01	0.08	1.09	0.08	0.10	0.01	0	0	3.68
	-	0	200	0.07	1.06	0	0.05	0.58	0.02	0.05	0	0	0	1.84
	-	100	100	0.27	3.97	0.06	0.16	2.60	0.12	0.42	0.01	0.01	0	7.63
	-	100	200	0.18	5.11	0.07	0.14	2.68	0.14	0.41	0.02	0	0	8.75
	+	0	100	0.13	1.80	0.01	0.02	1.05	0.04	0.12	0.01	0	0	3.18
	+	0	200	0.11	0.88	0	0.01	0.50	0.02	0.02	0	0	0	1.53
	+	100	100	0.20	3.69	0.05	0.13	2.51	0.10	0.29	0.01	0	0	6.97
	+	100	200	0.24	4.87	0.06	0.08	2.81	0.12	0.31	0.01	0	0	8.50
Lipton	-	0	100	0.21	2.19	0.02	0.07	1.00	0.05	0.12	0.01	0	0	3.67
	-	0	200	0.18	1.89	0.01	0.06	0.78	0.04	0.08	0.01	0	0	3.05
	-	100	100	0.24	4.06	0.06	0.17	1.76	0.12	0.42	0.02	0	0	6.86
	-	100	200	0.45	6.19	0.09	0.16	2.55	0.15	0.44	0.06	0	0	10.09
	+	0	100	0.22	1.79	0.01	0.02	0.85	0.04	0.05	0.01	0	0	2.97
	+	0	200	0.12	1.46	0.01	0.02	0.64	0.02	0.06	0	0.01	0	2.32
	+	100	100	0.33	3.56	0.05	0.11	1.82	0.09	0.30	0.02	0	0	6.29
	+	100	200	0.23	4.14	0.06	0.08	2.04	0.10	0.24	0.02	0	0	6.92
LSD				0.175 (0.149)	0.976 (0.884)	0.033 (0.034)	0.053 (0.044)	0.660 (0.506)	0.036 (0.037)	0.106 (0.074)	-	-	-	1.777 (1.474)
df				42	42	42	42	42	42	42	42	42	42	42
significance				ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

Figures in brackets are when comparing means with the same levels of Fg, Fg*Var, Fg*S, Fg*N**,** Fg*Var*S, Fg*Var*N and Fg*S*N

Appendix 15. Light leaf spot levels on leaves(%), except where stated, in seed transmission experiment 2000/01.

Date		11 Dec		05 Apr		17 May	24 May		05 Jun	19 Jun	13 Jul	
GS		1.09 – 1.11		3.1		4.3	4.5		5.0	5.7	6.2	
Variety	Seed Source	Inc.	Sev.	Inc.	Sev.	Sev.	Inc.	Sev.	Sev.	Sev.	Leaves Sev.	Stem Sev.
Apex	Var.Trial Ut	45.0	3.87	100.0	11.68	5.00	87.5	3.52	2.75	2.75	1.58	2.17
	Var.Trial Fg	55.0	2.97	97.5	14.60	4.50	95.0	3.25	4.25	3.68	1.42	1.67
	Certified	-	-	85.0	21.03	4.25	97.5	4.67	5.00	5.00	1.66	2.17
Lipton	Var.Trial Ut	37.5	2.20	95.0	9.95	5.75	100.0	3.79	8.50	7.25	2.04	2.50
	Var.Trial Fg	27.5	0.91	100.0	17.51	5.75	92.5	4.16	6.00	5.75	1.33	1.50
	Certified	-	-	82.9	13.57	6.00	92.5	3.79	10.00	9.60	1.50	2.66
Synergy	Var.Trial Ut	-	-	87.5	16.28	6.25	97.5	5.19	3.75	3.60	1.25	1.58
	Var.Trial Fg	-	-	92.9	14.71	6.00	87.5	6.06	6.25	6.42	1.58	1.42
	Certified	-	-	82.5	16.33	6.50	95.0	4.82	7.00	7.15	1.21	1.29
Pronto	Var.Trial Ut	-	-	87.8	13.26	6.00	92.5	3.79	4.75	4.25	0.92	1.66
	Var.Trial Fg	-	-	74.8	13.84	5.75	82.5	4.87	5.00	4.92	1.54	1.83
	Certified	-	-	89.5	16.33	5.75	92.5	5.02	4.75	4.82	1.08	1.50
	HS Ut (99)	-	-	86.2	13.80	5.00	92.5	5.32	4.75	5.08	1.04	1.75
	HS Fg (99)		-	86.7	10.72	5.50	95.0	3.83	8.00	7.25	1.25	1.21
LSD (39 df)		25.96	3.837	17.19	10.619	0.862	16.77	2.937	4.197	3.988	0.706	0.887
significance		ns	ns	ns	ns	***	ns	ns	ns	ns	ns	*

ns = not significant

* = significant at $p<0.05$

*** = significant at $p\leq0.001$

Appendix 16. Agronomic characteristics in seed transmission experiment 2000/01

Date		21 Sep	21 Sep	23 Oct	17 May	17 May	24 May	19 Jun
GS		1.02	1.02	1.04	4.3	4.3	4.5	5.7
		Emergence	Establish-ment	Vigour	Look of crop	Flowering	Height	Height
Variety	Seed Source	1-9	1-9	1-9	1-9	1-9	cm	cm
Apex	Var.Trial Ut	7.25	7.25	9.00	4.00	6.00	72.47	116.3
	Var.Trial Fg	7.00	8.50	8.75	3.75	5.25	70.48	116.4
	Certified	7.75	8.25	9.00	4.00	4.75	63.72	108.0
Lipton	Var.Trial Ut	7.50	8.25	8.00	5.50	7.50	82.29	119.1
	Var.Trial Fg	7.50	7.75	8.50	5.75	8.00	79.09	121.2
	Certified	8.00	7.75	8.50	6.00	7.75	82.62	120.3
Synergy	Var.Trial Ut	7.00	6.50	7.75	5.25	7.50	79.54	128.1
	Var.Trial Fg	6.75	5.75	7.75	5.75	6.75	79.40	128.0
	Certified	6.50	5.50	7.50	5.75	7.25	76.93	124.4
Pronto	Var.Trial Ut	7.00	6.75	7.75	5.75	7.00	79.49	120.4
	Var.Trial Fg	7.25	6.75	8.00	5.00	7.25	72.93	119.9
	Certified	7.75	6.50	8.25	5.75	7.50	79.30	119.4
	HS Ut(99)	7.00	6.25	8.00	5.25	7.25	79.09	122.2
	HS Fg(99)	7.00	6.00	7.75	5.50	7.00	81.97	121.4
LSD (39 df)		0.733	0.978	0.629	1.066	0.976	6.068	5.034
significance		**	***	***	***	***	***	***

** = significant at $p<0.01$

*** = significant at $p\leq0.001$

Appendix 17. Light leaf spot levels on leaves (%), except where stated, in seed transmission experiment 2001/02, seed source light leaf spot sulphur experiment (Inverness) harvested 2001

Date		14 Dec		17 Dec	29 Mar	23 Apr		13 Jun				31 Jul
GS		1.08-1.10		1.10	2.0	3.1		6.2-6.3				6.6
Variety	Seed Source	Inc.	Sev.	Sev.	Sev.	Inc.	Sev.	Inc. Leaves	Sev. Leaves	Inc. Stems	Sev. Stems	Sev. Stems
Bristol	Fg-, S-	2.5	0.38	0.01	6.42	110.0	12.38	92.5	6.61	95.0	3.78	3.25
	Fg-, S+	0	0	0	5.17	100.0	15.50	95.0	9.02	100.0	2.98	3.75
	Fg+, S-	7.5	0.18	0.03	8.50	100.0	15.28	85.0	4.21	100.0	4.62	4.50
	Fg+, S+	5.0	0.10	0	7.91	100.0	13.80	90.0	5.12	97.5	3.58	3.75
Lipton	Fg-, S-	5.0	0.10	0	8.08	100.0	14.60	87.5	4.40	100.0	3.48	2.50
	Fg-, S+	7.5	0.10	0	5.83	100.0	13.53	90.0	4.50	95.0	3.30	2.75
	Fg+, S-	2.5	0.02	0.02	5.33	100.0	14.00	97.5	4.12	95.0	3.50	2.00
	Fg+, S+	12.5	0.29	0	8.00	97.5	18.08	80.0	4.42	97.5	3.25	4.25
LSD		11.97	0.477	0.084	2.393	2.60	7.155	16.95	5.024	8.022	1.023	2.271
df		21	21	63	63	21	21	21	21	21	21	63
significance		ns	ns	***	***	ns	ns	ns	ns	ns	ns	ns

ns = not significant

*** = significant at $p \leq 0.001$

Appendix 18. Light leaf spot levels (%) and agronomic characteristics in seed transmission experiment 2001/02, seed source NL trials (Edinburgh) harvested 2001 and certified seed.

		Light Leaf Spot			Agronomic Characteristics				
Date		17 Dec	29 Mar	31 Jul	21 Sep	21 Sep	21 Sep	30 Jul	30 Jul
GS		1.10	2.0	6.6	1.03	1.03	1.03	6.6	6.6
Variety	Seed Source	Sev. Leaves %	Sev. Leaves %	Sev. Stems %	Emergence 1-9	Establishment 1-9	Vigour 1-9	Standing ability 1-9	Crop maturity 1-9
Lipton	Var.Trial Ut	0.08	4.92	2.00	8.0	8.00	8.00	6.75	6.50
	Var.Trial Fg	0.03	9.66	4.00	8.0	7.75	7.75	6.75	7.00
	Certified	0.09	6.08	2.25	8.0	8.25	8.25	6.50	7.25
Apex	Var.Trial Ut	0.01	8.83	2.25	8.0	8.25	8.25	7.00	6.75
	Var.Trial Fg	0	9.42	2.25	8.0	8.50	8.50	8.75	7.00
	Certified	0	9.75	1.88	8.0	8.00	8.00	8.25	7.00
Synergy	Var.Trial Ut	0.01	8.92	3.50	8.0	8.00	8.00	8.00	6.75
	Var.Trial Fg	0.27	7.67	3.00	8.0	8.25	8.25	8.50	6.25
	Certified	0	8.75	3.75	8.0	8.00	8.00	9.00	7.25
Pronto	Var.Trial Ut	0.01	6.91	2.50	8.0	8.50	8.50	8.00	6.75
	Var.Trial Fg	0.35	7.25	2.75	8.0	8.75	8.75	8.00	7.00
	Certified	0	5.91	2.00	8.0	8.25	8.25	7.75	7.25
	HS Ut (99)	0	6.42	2.25	8.0	8.00	8.00	8.00	6.25
	HS Fg (99)	0.02	7.08	2.00	8.0	8.50	8.50	7.75	7.00
LSD (63 df)		0.084	2.393	2.271	-	0.980	0.804	0.923	0.909
significance		***	***	ns	-	ns	ns	***	*

ns = not significant * =significant at $p<0.05$ *** = significant at $p\leq0.001$

Appendix 19. Light leaf spot levels (%), except where stated, in seed transmission experiment 2002/03, seed source light leaf spot sulphur experiment (Inverness) harvested 2002

Date		28 Nov	16 Dec		12 Mar	24 Mar		05 May		08 May	17 Jul
GS		1.06	1.10-1.11		3.1	3.1		4.5		4.5	6.3-6.6
Variety	Seed Source	Sev.	Inc.	Sev.	Sev.	Inc.	Sev.	Inc.	Sev.	Sev.	Sev. Stems
Bristol	Fg-, S-	0.34	35.0	1.32	3.33	77.5	0.70	95.0	6.80	5.00	10.08
	Fg-, S+	0.16	35.0	1.03	3.58	85.0	0	95.0	9.30	3.75	9.50
	Fg+, S-	0.08	32.5	0.42	3.48	80.0	0.36	100.0	7.32	7.00	7.00
	Fg+, S+	0.08	37.5	0.58	4.65	60.0	0	92.5	6.30	4.25	7.42
Lipton	Fg-, S-	0	10.0	0.08	2.18	87.5	0	100.0	10.74	3.50	4.41
	Fg-, S+	0	15.0	0.57	2.53	88.5	0.40	92.5	6.59	4.25	5.08
	Fg+, S-	0	27.5	0.18	2.75	75.0	0	97.5	13.97	5.50	4.92
	Fg+, S+	0	17.5	0.21	1.90	77.5	0	92.5	6.71	2.25	4.50
LSD		0.125	18.50	1.659	1.632	24.65	0.928	10.46	7.504	4.160	2.358
df		63	21	21	63	21	21	21	21	63	21
significance		***	*	ns	**	ns	ns	ns	ns	**	***

ns = not significant

* = significant at $p<0.05$

** = significant at $p<0.01$

*** = significant at $p\leq0.001$

Appendix 20. Light leaf spot levels on leaves (%) and agronomic characteristics in seed transmission experiment 2002/03, extra varieties/seed sources.

		% Light leaf spot			Agronomic Characteristics			
Date		28 Nov	12 Mar	08 May	12 Mar	05 Jun	16 Jul	16 Jul
GS		1.06	3.1	4.5	3.1	5.5	6.3-6.6	6.3-6.6
Variety	Seed Source	Sev.	Sev.	Sev.	Winter hard.	Height	Crop Maturity	Stem Stiffness
		%	%	%	1-9	cm	1-9	1-9
Lipton	HS02 Ut	0	1.78	5.25	7.75	138.38	9.00	6.75
	Certified	0.08	2.43	4.25	7.25	144.50	8.50	8.00
Apex	HS02 Ut	0.08	3.68	14.50	5.00	119.38	5.75	8.00
	Certified	0.08	3.93	4.25	7.00	126.50	7.50	9.00
Synergy	HS02 Ut	0	2.58	4.75	7.75	149.38	7.50	8.75
	HS02 Ut	0	2.78	6.00	7.75	155.12	6.75	8.50
	HS02 Fg	0.17	2.58	5.25	6.75	136.62	6.75	8.25
	Var.02 Fg	0	5.00	6.50	7.00	151.62	6.75	8.50
	Certified	0.16	2.78	5.50	6.00	144.75	6.00	8.75
Pronto	HS02 Ut	0.08	2.93	4.25	6.50	142.88	8.00	8.75
	Var.02 Fg	0	2.03	5.75	6.50	146.62	7.75	9.00
	HS Ut (99)	0	2.40	4.50	7.75	146.25	7.50	9.00
	HS Fg (99)	0	2.10	3.75	6.75	141.62	7.00	7.50
	Certified	0	3.43	4.50	7.25	142.62	7.75	9.00
LSD (63 df)		0.125	1.632	4.160	1.635	6.894	0.997	1.271
Significance		***	**	**	ns	***	***	ns

ns = not significant * = significant at $p<0.05$ ** = significant at $p<0.01$ *** = significant at $p\leq0.001$