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WINTER OILSEED RAPE: EVALUATION OF FUNGICIDE SPRAY PROGRAMMES

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WINTER OILSEED RAPE: EVALUATION OF FUNGICIDE SPRAY PROGRAMMES

by

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WINTER OILSEED RAPE: EVALUATION OF FUNGICIDE SPRAY PROGRAMMES

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Abstract

A series of 6 replicated plot scale trials was done in 1990/91 to evaluate the effect of differently timed single and multiple sprays of prochloraz (Sportak) and iprodione plus thiophanate-methyl (Compass) on disease control and yield of winter oilseed rape.

The 6 sites were Fonmon (S Glamorgan), Hawkinge (Kent), High Mowthorpe EHF (N Yorks), Neston (Wilts), Terrington EHF (Norfolk), and Threekingham (Lincs).

Fungicides were applied as either

(a) single sprays of Sportak (1.25 l/ha) at the following timings: autumn (aut), mid-February (mF), mid-March (mM), early stem extension (se), early-mid flowering (emf), and end of flowering (ef).

(b) two 2-spray programmes; Sportak in the autumn plus at early stem extension, or, Sportak at early stem extension plus Compass (3.0 l/ha) at the end of flowering.

(c) a 3-spray programme of Sportak at autumn and early stem extension plus Compass at the end of flowering.

Disease levels were low to moderate at most sites with significant pod invasion occurring only at Neston and Threekingham.

Light leaf spot (Cylindrosporium concentricum, perfect stage Pyrenopeziza brassicae) was the most common disease encountered. Control of this disease was significant ($p = 0.05$) in the spring with autumn and early spring applications at High Mowthorpe and Neston.

Phoma leaf spot (Phoma lingam, perfect stage Leptosphaeria maculans) developed at low levels at all sites except Fonmon. Disease incidence was significantly ($p = 0.05$) reduced at Neston (early flowering assessment) by single sprays applied at mid-March and early stem extension, and by the autumn plus stem extension programme. Stem canker developed to moderate levels at Hawkinge and Neston with very low levels at High Mowthorpe. Both programmes with an autumn plus stem extension spray gave good reduction in disease severity at Hawkinge, but so did single sprays applied in mid-February and mid-March with the latter being the best treatment. At Neston, the incidence of stem canker was significantly ($p = 0.05$) reduced by all of the spray programmes, as well as the mid-February, mid-March, and stem extension sprays, but again, the mid-March spray was the best treatment.

Sclerotinia (Sclerotinia sclerotiorum), a rarity in most seasons, was found, albeit at low levels, at High Mowthorpe, Neston and Threekingham. Alternaria pod spot (Alternaria brassicae and

Alternaria brassicicola) was found at trace levels at Neston, and moderate levels at Threekingham. End-of-flowering sprays of Sportak or Compass gave significant control of pod spot at Threekingham. Ringspot (Mycosphaerella brassicicola) affected the pods quite severely at Neston, but no treatment gave significant reduction in disease levels.

The mean untreated yield from the 6 sites was 2.95t/ha. Significant ($p = 0.05$) yield increases were obtained at two sites; at High Mowthorpe from sprays applied in mid-February , mid-March and early flowering and from all of the spray programmes. At this site the biggest response was from the 3-spray programme. At Neston, significant responses were obtained from both spray programmes that included an end of flowering spray of Compass. Positive responses were obtained at four sites. There was however no obvious relationship between disease control and yield. At individual sites very few treatments would have been profitable if the value of the seed was £130/t. At £240/t the most economic timing (meaned across the sites) would be the mid-March application.

Objective

To evaluate the effect of the timing of single and multiple sprays of a fungicide on disease levels and yield.

Introduction

ADAS surveys for the past 8 seasons (unpublished, except Hardwick et al., 1989, covers 1986-88 season) have shown light leaf spot to be the dominant pod disease with the exception of harvest year 1990 when at pod-ripening Botrytis cinerea was most common, but generally as a result of pest damage. The incidence of most diseases has been high, but the severity has been low, with total pod disease being about five per cent pod area annually. There is evidence that autumn fungicide sprays are more effective in

controlling light leaf spot than spring treatments (Rawlinson et al., 1984) but yield responses to autumn treatments in commercial crops have been inconsistent (Anon, 1985) since the epidemic often failed to develop. Good control of light leaf spot and yield responses have been achieved in ADAS trials using spring sprays applied shortly after symptom development (Giltrap, 1986). Rawlinson et al. (1989) have shown that where light leaf spot and Alternaria are prevalent and severe it is possible to obtain yield responses of between 0.96 to 1.58 t/ha from fungicidal control. This trial was designed to evaluate the performance of Sportak applied from the autumn through to the end of flowering as single sprays for the control of disease and effect on yield. In addition, three spray programmes were included in which the end of flowering spray (Sportak in the previous three years of the trial, unpublished) was Compass.

Materials and Methods

Sites

Details of trial sites and of crops on trial plots are given in Tables 1 and 2.

Table 1. Soils and Soil Management at Trial sites

Details	Fonmon	Hawkinge	High Mowthorpe	Neston	Terrington	Threekingham
Soil Series:	Ston Easton	Batcombe	Andover	Sherbourne	Agney	Ragdale Association
Soil Texture:	Clay	Clay loam with flints	Silty clay loam	Sandy clay loam	Silty clay loam	Clay loam
Drainage:	Moderate	Very good	Good	Well drained	Good	Free
Soil Analysis:						
pH	7.9	7.0	7.2	7.7	7.9	7.2
P index	3	1	4	3	4	2
K index	3	2	3	3	3	3
Mg index	2	1	1	1	4	3
Previous cropping:						
1990	WB	WB	WOSR	WB	WB	WW
1989	WW	WW	WOSR	WW	WW	WW
1988	WW	WBe	WOSR	WW	WW	SB
Previous crop residues:	Ploughed	Baled	Ploughed	-	Baled	Burnt
Previous cultivations:	Gramoxone Power harrowed & rolled	Disc and press x 2 .Power harrowed,drill + ring roll	Pressed & rolled	Plough power harrow and rolled	Chisel ploughed Disced & rolled Spike rotavated	Disc & power harrowed

SB = Sugar Beet
WB = Winter Barley
WBe = Winter Beans
WOSR = Winter Oilseed Rape
WW = Winter Wheat
- = Not available

Table 2. Details of crops on trial plots

Details	Fonmon	Hawkinge	High Mowthorpe	Neston	Terrington	Threekingham
Cultivar	Lictor	Falcon	Cobra	Lictor	Libravo	Falcon
Sowing date	23.8.90	21.8.90	29.8.90	21.8.90	23.8.90	25.8.90
Seed rate (kg/ha)	9.00	5.56	6.40	6.75	6.75	6.5
Fertiliser (kgN/ha)	110 (28/1) 110 (1/2) 110 (11/3)	24 (8/10) 115 (25/2) 91 (15/3)	70 (28/2) 182 (26/3/91)	115 (19/2) 86 (13/3)	50 (27/8) 240 (11/3)	70 (14/2) 120 (14/3)
Herbicides	Fusilade(1/10) Fortrol(20/10)	Butisan plus Fusilade(5/12) Kerb (12/10)	Benazolox(29/10) Fortrol (17/12)	Pilot(3/9)	Butisan(23/8) Butisan plus Fusilade(7/11)	Fusilade(30/9)
Fungicides*	Sportak Alpha (1/10)	Nil	Sportak 45 (12/4)	Sportak Alpha(13/3)	Nil	Nil
Insecticides	Draza at drilling	Decis(12/12)	Decis (8/5) Hostathion (24/6)	Decis (8/10)	Hostathion(24/6)	Cypermethrin (15/10) Cypermethrin (1/4)
Plant growth regulators	Nil	Nil	Nil	Nil	Nil	Nil
Harvest	Direct	Direct	Swathed(5/8)	Challenge(19/7) Direct (8/8)	Direct	Direct
Harvest date	6 August	9 August	12 August	8 August	8 August	9 August

* to surrounding crop

Design

The experiment was of a randomised block design with 4 replicate blocks. The size of plots differed from site to site, within the range 72-144m^2.

Husbandry

Plots were located in a commercial crop of winter oilseed rape. All treatments other than fungicides were as per farm practice.

Fungicides

Table 3. Fungicides, active ingredients (a.i.) and dose rates

Fungicide	a.i.	Amount a.i. in product (g/l)	Dose rate product/ha
Sportak	prochloraz	400	1.25 l
Compass	iprodione + thiophanate-methyl	167+ 167	3.0 l

Treatments

Table 4. Details of fungicides and their timing

Autumn	mid-February	mid-March	early stem extension	early-mid flowering	End of flowering
-	-	-	-	-	-
Sp	-	-	-	-	-
-	Sp	-	-	-	-
-	-	Sp	-	-	-
-	-	-	Sp	-	-
-	-	-	-	Sp	-
-	-	-	-	-	Sp
Sp	-	-	Sp	-	-
-	-	-	Sp	-	Co
Sp	-	-	Sp	-	Co

Sp = Sportak, Co = Compass.

Fungicide Applications

The spraying date and equipment used are listed in Table A in Appendix 1.

Assessments

The percentage area of leaves, stems and pods affected by each disease was assessed at key stages throughout the season. In addition, untreated plants were assessed at regular intervals throughout the season to build up a picture of disease development.

Growth stages were recorded using the provisional key produced by Sylvester-Bradley and Makepeace (1984). NIAB keys were used for assessment of disease severity on leaves and pods. Plots were direct combine-harvested and yields corrected to 91% dry matter. Assessments of the degree of ripening and lodging were made as appropriate before harvest.

Statistical Analysis

Data were subjected to Analysis of Variance. Treatment means were separated using Duncan's Multiple Range Test where the variance ratio was significant ($p = 0.05$). Where data were skew they were transformed prior to Analysis of Variance, and Duncan's Multiple Range Test was performed on the transformed data where the ratio was significant ($p = 0.05$).

Results

Disease and disease control

Fonmon

Light leaf spot and powdery mildew (Erysiphe cruciferarum) were both found at trace levels in November. Neither disease developed significantly during the period of the trial and by the end of flowering less than 1% of the leaf area was affected by each disease (Table A). No further assessments were made on the trial as the trial area had become inaccessible due to extensive

crop growth and lodging. An assessment of the surrounding crop (25 June GS 6.3) showed that no other diseases were present.

Hawkinge

Trace levels of powdery mildew, downy mildew (Peronospora parasitica), Phoma leaf spot and light leaf spot were present in December. Powdery mildew was the prevalent disease (72% plants affected at 0.2% leaf area) but declined over the winter and was absent in the summer assessments. Both light leaf spot and Phoma leaf spot were present throughout the season and, although a substantial percentage of plants became affected (44%, 8 March), the severity of each disease remained low (< 1% leaf area). Low levels of slight canker were found on the stems in early June (Table B).

Significant control of moderate levels of stem canker was achieved by spray programmes that included an autumn plus a stem extension spray, also by single sprays applied in February and March (Table C, disease assessment 8 July).

High Mowthorpe

Downy mildew, light leaf spot, Phoma, Alternaria and Botrytis were present in the crop on 21 November, but disease levels remained very low throughout the winter. Light leaf spot became the most severe foliar disease affecting 9.1% leaf area on 51% of plants on 3 April (GS 2.01, Table D). Phoma leaf spot developed to affect 49% of plants by this time, but was only present at low levels and was not controlled by early sprays (Tables D and E). Foliar disease levels declined thereafter.

Light leaf spot was reduced in the spring by early sprays. At early stem extension, autumn, mid-February and mid-March sprays reduced foliar disease severity from 9.1% to approximately 1% leaf area affected. These results could not be analysed as the

data were skew and could not be transformed (Table E). The effect of early sprays was still obvious during May (Table F).

Light leaf spot affected the stems during June and July. All of the single spray timings (except the end of flowering treatment), and the autumn plus stem extension spray, significantly reduced the severity of stem light leaf spot during June (Table G). The mid-March, stem extension, and the spray programmes with an autumn treatment were still effective at the final assessment (Table H, GS 6.4, 17 July).

Phoma, Botrytis, Sclerotinia and light leaf spot affected the stems at low levels at the final assessment. Pods were affected by trace levels of Phoma, Alternaria, and light leaf spot, and low levels of Botrytis (Table D), but there were no treatment effects at this stage.

Neston

Powdery mildew was the predominant disease in the autumn and winter; also present were Phoma leaf spot and ringspot which had spread in from the adjacent kale game cover. Light leaf spot was not recorded until early March and developed to affect most plants by the end of May. Symptoms of light leaf spot were found on the stems but not the pods. Ringspot was readily found from late flowering and developed to infect the pods causing large black lesions. A complex of diseases was found on the stems at the final assessment. Sclerotinia, Botrytis and stem canker were all present and causing premature ripening (Table I).

Disease assessments on 27 April (GS 4.2, early to mid-flowering) revealed trace levels of downy mildew on most plants. Ringspot and Phoma leaf spot were present but not severe ($\leq$ 0.1% leaf area affected on untreated plots). The incidence of Phoma leaf spot was significantly ($p = 0.05$) reduced from 60% plants affected (untreated) to approximately 20% by the mid-March and early stem

extension sprays, and the autumn plus early stem extension programme. The same treatments were very effective in reducing the incidence of ringspot with some effect coming from earlier (autumn and mid-February [1 March]) sprays (Table J).

Light leaf spot was the most severe disease on 27 April affecting 5.4% of the leaf area and 90% of the plants (mean figures, untreated plots). Disease incidence and severity was significantly ($p = 0.05$) reduced by mid-March and early stem extension sprays, and the 2-spray programme (autumn plus stem extension) (Table J). Assessment towards the end of flowering (22 May GS 4.7) showed that the severity of light leaf spot had increased on untreated plots (11.3% mean leaf area affected) (Table K). There was little difference between autumn treated and untreated plots on 27 April (Table J) but there was significantly less disease on autumn treated plots one month later (Table K). The mid-February and mid-March sprays and the 2-spray programme remained effective at this stage.

The final disease assessment was made on 19 July, three weeks before harvest. Phoma stem canker affected 62% of plants in untreated plots. Single spray treatments applied in mid-February, mid-March, and early stem extension and all spray programmes resulted in significant ($p = 0.05$) reductions in stem canker incidence. The most effective treatment was the single spray applied in mid-March. The autumn spray was not effective. The common factor in the spray programmes was the stem extension spray. The incidence of plants affected by cankers of different severity (Index 1, 2, or 3 plus 4) was not significantly affected by any treatment within each class, but the most effective sprays were autumn plus stem extension, mid-March and mid-February respectively (Table L).

Sclerotinia affected the stems at low levels (4.8% of plants in untreated plots). The lowest disease levels occurred where end of flowering sprays were applied singly or in programmes but

these results were not significantly different from the untreated. These results are too variable for conclusions to be drawn regarding spray timing for Sclerotinia control, ie significantly higher disease levels occurred where an autumn plus stem extension spray or a stem extension spray alone were applied. Similar variability occurred with the final stem Botrytis assessments (Table M). Light leaf spot affected the stems at low severity (6.5% stem area untreated). Significant reduction in disease severity was afforded by single sprays applied in mid-February, mid-March and early stem extension and by the three spray programmes (Table M).

Pods were affected by low levels of powdery mildew Alternaria and Botrytis (Table I). Ringspot was severe, affecting 100% of plants with 32.5% of the pod area affected in the untreated plots. There was no significant effect of treatment on incidence or severity of this disease. The lowest severity occurred where the 3-spray programme had been applied but this was not attributable to any one of the spray timings (Table M).

Terrington

Disease levels were extremely low in this crop. The first assessment in December (7 December, GS 1.3-1.4) revealed low levels of downy and powdery mildew (3% and 0.3% leaf area on 92% and 28% of plants respectively). At early flowering (9 May, GS 4.2-4.3) only trace amounts of Phoma leaf spot were found on occasional plants with sparse downy mildew on the untreated plots. Low levels of Sclerotinia were found in late July (1% plants affected) following unsettled weather during June.

Threekingham

Trace levels of light leaf spot affected the crop from late January to mid-March (early stem extension). The disease did not develop onto the upper leaves or the pods. Phoma leaf spot was

recorded at low levels from November to March but was not apparent after April. Alternaria appeared late, trace levels were recorded on lower leaves on 28 June, with moderate development on the pods in mid-July (11% pod area). End of flowering sprays of Sportak alone, or Compass as part of a programme, gave significant (p = 0.05) control of pod Alternaria reducing disease severity to approximately 6 and 2% pod area respectively. Low levels of downy mildew and Botrytis were recorded on the pods, with no significant differences between treatments (Table N).

Yields

Yields from individual sites are shown in Table 5.

Table 5. Yield (t/ha)

Fungicide applied at:						Site					
aut	mf	mM	se	emf	ef	Fon	Haw	H.Mow	Nest	Terr	Thre
-	-	-	-	-	-	2.77	2.45	2.06a	3.11a	3.48	3.82
Sp	-	-	-	-	-	3.06	2.75	2.22abc	3.36abc	3.53	3.87
-	Sp	-	-	-	-	3.14	2.63	2.27bcd	3.25a	3.53	3.84
-	-	Sp	-	-	-	2.99	2.71	2.35cd	3.35abc	3.52	3.91
-	-	-	Sp	-	-	3.17	2.79	2.24abc	3.26a	3.52	3.81
-	-	-	-	Sp	-	3.14	2.57	2.45de	3.20a	3.51	3.82
-	-	-	-	-	Sp	2.93	2.72	2.13ab	3.34ab	3.54	3.76
Sp	-	-	Sp	-	-	3.06	2.76	2.37cde	3.35ab	3.52	3.96
-	-	-	Sp	-	Co	2.92	2.70	2.32bcd	3.61c	3.63	3.91
Sp	-	-	Sp	-	Co	3.14	2.95	2.55e	3.58bc	3.57	3.90
SED (dF)						NS	NS	0.09(27)	0.12(27)	NS	NS
CV (%)						10.2	8.0	5.6	4.9	3.4	4.7

Sp = Sportak
Co = Compass
NS = Not significant (p = 0.05)
Values followed by the same letter within a column do not differ significantly (p = 0.05)

Mean yields, yield increases and relative yields are shown in Table 6. The same trial series was carried out between 1988 and 1990 and the mean data for 1988 to 1991 is included for comparison. (26 sites).

Table 6. Mean yields, yield increases and relative yields (untreated = 100%)

Fungicides applied at:						1991			1988 - 91		
aut	mF	mM	se	emf	ef	Yield (t/ha)	Yield increase (t/ha)	Relative yield(%)	Yield (t/ha)	Yield increase (t/ha)	Relative yield (%)
-	-	-	-	-	-	2.95	0.00	100	3.11	0.00	100
Sp	-	-	-	-	-	3.13	0.18	106	3.28	0.17	105
-	Sp	-	-	-	-	3.11	0.16	105	3.27	0.16	105
-	-	Sp	-	-	-	3.14	0.19	106	3.26	0.15	105
-	-	-	Sp	-	-	3.13	0.18	106	3.25	0.14	104
-	-	-	-	Sp	-	3.12	0.17	106	3.23	0.12	104
-	-	-	-	-	Sp	3.07	0.12	104	3.17	0.06	102
Sp	-	-	Sp	-	-	3.17	0.22	107	3.30	0.19	106
-	-	-	Sp	-	Co	3.18	0.23	108	3.25	0.14	104
Sp	-	-	Sp	-	Co	3.28	0.33	111	3.33	0.22	107

Sp = Sportak
Co = Compass

The results show that all treatments produced a yield increase when averaged across 6 sites. The largest increase came from the 3-spray programme (11%). The mean data for 1988 - 1991 shows that for single sprays the yield increase declines the later the treatment is applied.

The mean yield of untreated plots (t/ha) and yield increases for each site are given in Table 7. Significant yield responses (Table 5, p = 0.05) were obtained at two sites. At High Mowthorpe single sprays applied in mid-February, mid-March and at early to mid-flowering produced significant yield responses as did all of the spray programmes. At Neston, only the 3-spray programme and the stem extension plus end of flowering programme produced yields that were significantly greater than the untreated.

Table 7. Mean yield of untreated (t/ha) and yield increases from individual sites

Fungicides applied at:						Site					
aut	mf	mM	se	emf	ef	Fon	Haw	H.Mow	Nest	Terr	Thre
-	-	-	-	-	-	2.77	2.45	2.06	3.11	3.48	3.82
Sp	-	-	-	-	-	0.29	0.30	0.16	0.25	0.05	0.05
-	Sp	-	-	-	-	0.37	0.18	0.21	0.14	0.05	0.02
-	-	Sp	-	-	-	0.22	0.26	0.29	0.24	0.04	0.09
-	-	-	Sp	-	-	0.40	0.34	0.18	0.15	0.04	-0.01
-	-	-	-	Sp	-	0.37	0.12	0.39	0.09	0.03	0.00
-	-	-	-	-	Sp	0.16	0.27	0.07	0.23	0.06	-0.06
Sp	-	-	Sp	-	-	0.29	0.31	0.31	0.24	0.04	0.14
-	-	-	Sp	-	Co	0.15	0.25	0.26	0.50	0.15	0.09
Sp	-	-	Sp	-	Co	0.37	0.50	0.49	0.47	0.09	0.08

Sp = Sportak

Co = Compass

Prior to the introduction of area payments the yield responses obtained at four of the sites would mostly be profitable (Table 8). At the sites where there was very little disease (Terrington and Threekingham) the application of fungicides at any timing was not economic. The most profitable treatment meaned across the sites was the single spray applied in mid-March (£21/ha).

Table 8. Profitability @ £240/t

Fungicide applied at:						Profit £/ha Site						
aut	mf	mM	se	emf	ef	Fon	Haw	H.Mow	Nest	Terr	Thre	- x
-	-	-	-	-	-	0	0	0	0	0	0	0
Sp	-	-	-	-	-	45	47	13	35	-13	-13	19
-	Sp	-	-	-	-	64	18	25	9	-13	-20	14
-	-	Sp	-	-	-	28	37	45	33	-15	-3	21
-	-	-	Sp	-	-	71	57	18	11	-15	-27	19
-	-	-	-	Sp	-	64	4	69	-3	-18	-25	15
-	-	-	-	-	Sp	13	40	-8	30	-11	-39	4
Sp	-	-	Sp	-	-	20	24	24	8	-40	-16	3
-	-	-	Sp	-	Co	-14	10	12	70	-14	-28	6
Sp	-	-	Sp	-	Co	14	45	43	38	-53	-56	5

Sp = Sportak 1.25 l/ha
Co = Compass 3.0 l/ha

£ = £ profit (average t/ha response - cost of fungicide application/ha using oilseed rape @ £240*/t and the cost of a single spray approximately £25/ha). This does not include the cost of application or wheeling damage.

\- x = mean of 6 sites.

* Nix (1989)

The yield responses obtained were also evaluated at a reduced price of £130/t (Table 9).

Table 9. Profitability @ £130/t

Fungicide applied at:						Profit £/ha Site						
aut	mf	mM	se	emf	ef	Fon	Haw	H.Mow	Nest	Terr	Thre	$\bar{x}$
-	-	-	-	-	-	0	0	0	0	0	0	0
Sp	-	-	-	-	-	13	14	-4	8	-19	-19	-1
-	Sp	-	-	-	-	23	-2	2	-7	-19	-22	-4
-	-	Sp	-	-	-	4	9	13	6	-20	-13	0
-	-	-	Sp	-	-	27	19	-2	-6	-20	-26	-1
-	-	-	-	Sp	-	23	-9	26	-13	-21	-25	-3
-	-	-	-	-	Sp	-4	10	-16	5	-17	-33	-9
Sp	-	-	Sp	-	-	-13	-10	-10	-19	-45	-32	-22
-	-	-	Sp	-	Co	-31	-18	-16	15	-31	-38	-20
Sp	-	-	Sp	-	Co	-27	-10	-11	-14	-63	-65	-32

Sp = Sportak 1.25 l/ha

Co = Compass 3.0 l/ha

£ = £ profit (average t/ha response - cost of fungicide application/ha using oilseed rape @ £130/t and the cost of a single spray approximately £25/ha). This does not include the cost of application or wheeling damage.

$\bar{x}$ = mean of 6 sites.

Under the new price arrangements for oilseed rape in harvest year 1992 very few treatments would be profitable (proposed price approximately £130/t, G Sansome, pers comm). The single sprays applied up to early flowering at Fonmon produced profits ranging from £4 to £23 but the yields were not significantly different from the untreated. No profits were made at Terrington or Threekingham. The mid-March timing was the most consistent producing profits at four of the six sites. None of

the spray programmes produced a profit. Meaned across the sites, none of the treatments would be profitable.

Glucosinolates

Glucosinolates were measured at three sites on a bulk sample of the untreated plots. Levels were variable at Neston, Hawkinge, and Terrington being 13, 22 and 34 μmol/g respectively.

Discussion

Disease control

The severity of disease was low to moderate at most sites throughout the season. Very little foliar or stem disease developed at Fonmon, Terrington and Threekingham, and of these three sites only Threekingham was affected by significant levels of pod disease. The most common disease was light leaf spot.

Pod disease developed at three of the sites. Trace levels of Phoma, Alternaria and light leaf spot and low levels of Botrytis were found on the pods at High Mowthorpe. At Neston, pods were affected by low levels of powdery mildew and light leaf spot and trace levels of Alternaria. Ringspot was severe at Neston affecting 32.5% of the pod area of untreated plants in July but there was no significant effect of any treatment on the incidence or severity of this disease. Low levels of downy mildew and Botrytis affected the pods at Threekingham in July, with 11.4% of the pod area in the control plots affected by Alternaria. End of flowering sprays of Sportak alone, or Compass as part of a programme, gave significant control of pod Alternaria reducing disease severity to approximately 6 and 2% respectively.

Light leaf spot affected the stems at High Mowthorpe and Neston. Disease severity was reduced from 3.0% stem area to 0.6% or less by the mid-March and stem extension sprays and the spray programmes with an autumn treatment at High Mowthorpe in July. Sprays applied between mid-February (1 March) and early stem extension, and all of the spray programmes gave significant reduction of stem light leaf spot at Neston where 6.5% stem area was affected in the control plots during July.

Phoma stem canker developed at Hawkinge, High Mowthorpe (trace levels only), and Neston. Significant control of moderate levels of stem canker (Index 1.45, 100% plants affected) at Hawkinge was obtained by spray programmes that included an autumn plus stem extension spray, and also by single sprays applied in February and March when assessed in July. The most effective treatment was the mid-March spray which reduced canker severity to Index 0.4. Sixty-two per cent of plants in untreated plots were affected by stem canker at Neston in July. Single spray treatments applied between mid-February (1 March) and early stem extension plus all of the spray programmes gave a significant reduction in the incidence of stem canker. As with the Hawkinge site, the best treatment was the mid-March spray reducing canker incidence to 20%. The common spray timing in all of the programmes which were effective at both sites was the stem extension treatment. The severity of stem canker at Neston ranged from Index 1 to Index 4 with approximately 50% of affected plants being in the Index 1 category for most treatments. There was no significant effect of any treatment within a particular class.

Sclerotinia infection of the stems was found at High Mowthorpe, Neston, and Terrington. Disease severity and incidence was low, such that there was no detectable difference between treated and untreated plots. Botrytis was found on the stems at High Mowthorpe and Neston and was not affected by fungicide treatment.

Foliar diseases were diverse and occurred at trace levels at several sites. Light leaf spot was the most common foliar disease. Control of light leaf spot at High Mowthorpe was achieved in the spring with autumn, mid-February and mid-March sprays which reduced foliar disease severity from 9.1% to approximately 1% leaf area affected. These results could not be analysed as the data was skew.

At Neston, light leaf spot affected 90% of plants at 5.4% leaf area by the end of April. Disease incidence and severity was significantly reduced by sprays applied in mid-February and mid-March and the autumn plus stem extension programme. By the end of May the disease had developed to affect 11.4% leaf area when the treatments were still effective.

Phoma leaf spot developed at low levels at all sites except Fonmon. At Hawkinge 44% of plants became affected by early March but only at trace levels. This was sufficient for canker to develop on 100% of plants by July. At Neston, the mid-March, early stem extension, and the autumn plus early stem extension programmes gave significant control of Phoma leaf spot by early flowering, reducing it from 60% to approximately 20% plants affected (albeit at trace levels). The same treatments were very effective in reducing the incidence of foliar ringspot; 60% of untreated plants had trace levels of ringspot, this was reduced to 5% or less by mid-March and stem extension sprays, and the autumn plus stem extension programme.

Yield

Significant yield responses occurred at High Mowthorpe and Neston. Sprays applied in mid-February, mid-March and at early to mid-flowering, plus all of the spray programmes produced yields significantly greater than the untreated. At Neston, both of the programmes that included an end of flowering spray of Compass produced significant yield responses.

The mean yields across the sites showed responses of between 4 and 6% for single sprays applied between autumn and the end of flowering, and 7 to 11% for the spray programmes. Meaned across the sites, the most economic timing @ £240/t would be the mid-March application.

Conclusions

1. Sportak reduced low levels of foliar light leaf spot in the spring at High Mowthorpe and Neston, with treatments applied in mid-February and mid-March at both sites, in the autumn at High Mowthorpe and autumn plus stem extension at Neston.

2. Low levels of stem light leaf spot were reduced in the summer at High Mowthorpe by the mid-March and stem extension sprays and both programmes that included an autumn treatment. This also occurred at Neston with sprays applied between mid-February and early stem extension and all spray programmes.

3. The incidence of Phoma leaf spot at Neston in the spring was significantly reduced by the mid-March, stem extension and autumn plus stem extension programme. The mid-March spray was the most effective treatment in reducing the incidence of stem canker at this site. The mid-February (1 March) and stem extension treatments and all of the spray programmes were also effective in reducing the incidence of stem canker.

4. At Hawkinge the severity of stem canker was significantly reduced by spray programmes that included an autumn plus stem extension spray, and also by single sprays applied in February and March. The most effective treatment was, as at Neston, the mid-March spray.

5. There were no significant yield responses at Hawkinge. All of the single sprays gave a positive response, but neither of the 2 - spray programmes gave an additional response. The 3 - spray programme did however, possibly as a result of the autumn plus end of flowering components.

6. At Neston the incidence of foliar ringspot was reduced significantly at early flowering by sprays applied in mid-March, stem extension, and by the autumn plus stem extension programme. There was however no significant effect of any treatment on pod infection which was severe at this site in July.

7. Significant yield responses were obtained at Neston only from two of the multiple application programmes although there was a positive trend from all of the treatments. The 3 - spray programme was no better than the 2 - spray programme of stem extension plus end of flowering. Of the individual spray components in the programmes only that applied at stem extension gave significant control of disease (foliar ringspot, Phoma leaf spot and stem canker) and none gave a significant yield response. Since disease control achieved by single applications sometimes exceeded that from 2 and 3 - spray programmes it is impossible to attribute yield response to disease control.

8. At Threekingham infection of the pods by Alternaria was significantly reduced by end of flowering sprays of Sportak alone, or Compass as part of two of the spray programmes. There were no resultant yield increases, this could be attributable to the late development of the disease.

9. At Terrington yield responses were also very low and sometimes negative, but this was not surprising in the absence of any significant disease.

10. At Fonmon there was a high degree of variation in the yield responses obtained which although sometimes large had no pattern to them. In the absence of disease no conclusions could be drawn.

11. At High Mowthorpe, significant yield responses were obtained from single sprays applied mid-February, mid-March and early to mid-flowering, and also from the spray programmes, although none of the individual spray components gave a significant response. The autumn spray gave significant control of foliar light leaf spot. Very low levels of infection on the stem were reduced by the autumn and stem extension sprays and by programmes containing these timings. It is very unlikely that control of such low levels of stem disease could be responsible for the yield responses obtained.

12. Despite significant yield responses being obtained at two sites with a positive trend coming from four sites there was no obvious relationship between disease control and yield.

13. At individual sites, very few of the treatments would be profitable at £130/t, and meaned across the sites there were no profits to be made.

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Table A. Fonmon

Disease assessments at the end of flowering (GS 4.9)

Fungicides applied at: 19/11 aut	19/2 mF	13/3 mM	12/4 se	2/5 emf	4/6 ef	Mean % leaf area Light leaf spot	Powdery Mildew
-	-	-	-	-	-	0.80	0.66
Sp	-	-	-	-	-	0.10	0.20
-	Sp	-	-	-	-	0.15	0.37
-	-	Sp	-	-	-	0.32	0.39
-	-	-	Sp	-	-	0.17	0.20
-	-	-	-	Sp	-	0.11	0.36
-	-	-	-	-	Sp	-	-
Sp	-	-	Sp	-	-	0.26	0.26
-	-	-	Sp	-	Co	-	-
Sp	-	-	Sp	-	Co	-	-

Table B. Hawkinge

Disease assessments on untreated control plots

Date	G.S.	Disease	Mean % affected Plants	Leaf area
7 Dec	1.6	powdery mildew	72	0.2
		downy mildew	8	<0.1
		phoma	16	<0.1
		light leaf spot	4	<0.1
18 Jan	1.7	downy mildew	8	<0.1
		alternaria	4	<0.1
		phoma	32	0.11
22 Feb	1.8	powdery mildew	16	<0.1
		downy mildew	8	<0.1
		phoma	28	<0.1
		light leaf spot	8	<0.1
8 Mar	2.1	downy mildew	40	0.2
		phoma	44	<0.1
		light leaf spot	44	0.6
5 June	6.1	downy mildew	8	<0.1
		phoma leaf spot	8	<0.1
		light leaf spot	3	<0.1
		phoma canker	13	0.1*

*phoma canker index = 0.1

Table C. Hawkinge

Disease assessment 8 July (GS 9.5 - 9.9)

Fungicide applied at: 14/11 aut	19/2 mF	14/3 mM	4/4 se	8/5 emf	5/6 ef	Phoma stem index
-	-	-	-	-	-	1.45 d
Sp	-	-	-	-	-	1.05 bcd
-	Sp	-	-	-	-	0.73 abc
-	-	Sp	-	-	-	0.40 a
-	-	-	Sp	-	-	1.00 bcd
-	-	-	-	Sp	-	1.03 bcd
-	-	-	-	-	Sp	1.13 cd
Sp	-	-	Sp	-	-	0.63 ab
-	-	-	Sp	-	Sp	1.15 cd
Sp	-	-	Sp	-	Sp	0.65 ab

SED (27 d.f.)	0.20
CV (%)	30.7

Values followed by the same letter (within a column) do not differ significantly (p = 0.05).

Table D. High Mowthorpe

Disease assessments on untreated control plots - Mean % incidence and (severity+)

	Assessment Date and Growth Stage										
Disease	21 Nov 1.05	5 Dec 1.05	19 Dec 1.06	27 Feb 1.06	13 Mar 1.07	3 Apr 2.01	9 Apr 3.6	1 May 3.6	22 May 4.5	19 June 4.8	17 Jul 6.4
D. Mildew	t (t)	3 (t)	-	-	1(t)	6(0.6)	-	3(t)	-	-	-
LLS	t (t)	-	-	3(t)	-	51(9.1)	63(3.8)	75(3.8)	78(5.1)	**63(3.6)	**53 (3.0)
Phoma	t (t)	34 (2)	13 (t)	31(0.4)	30(t)	49(2.5)	31(1.2)	19(t)	5(t)	* 5(0.1)	* 5 (0.8)
Botrytis	t (t)	-	-	-	-	-	-	8(t)	-	*20(0.2)	*21 (0.5)
Alternaria	t (t)	14(0.9)	-	-	-	-	-	-	-	-	-
Sclerotinia	-	-	-	-	-	-	-	-	-	* 3(0.03)	* 3(0.03)

\+ mean % leaf area
t trace
* stems and stem index
** Stems and stem area

NB. Pod infection, 17 July

	% pods	Pod area
Light leaf spot	5.0	t
Botrytis	10.0	5.2
Alternaria	7.5	t

Table E. High Mowthorpe

Disease assessment, 3 April (GS 2.01)

Fungicide applied at: 9/11 Aut	25/2 mF	13/3 mM	Mean % leaf area (transformed data*) Light leaf spot**	Phoma leaf spot
-	-	-	9.1	2.5 (7.9)
Sp	-	-	1.2	3.3 (9.9)
-	Sp	-	0.9	6.2 (13.1)
-	-	Sp	1.1	1.1 (4.6)
SED (9 d.f)			-	- NS
CV (%)			-	- (56.8)

NS = Not significant (p = 0.05)
(-) = Data skew

** Light leaf spot data could not be transformed to restore normality .·. statistical analysis was not performed

* Arcsine transformation

Table F. High Mowthorpe

Disease assessments

Fungicide applied at: 9/11 aut	25/2 mF	13/3 mM	12/4 se	Light leaf spot Mean % leaf area (transformed data*) GS 3.6, 1 May		GS 4.5, 22 May	
-	-	-	-	3.8	(10.9)b	5.1	(12.5)b
Sp	-	-	-	0.3	(3.1)a	0.2	(2.1)a
-	Sp	-	-	0.5	(3.7)a	2.0	(7.7)ab
-	-	Sp	-	0.4	(3.4)a	1.1	(5.9)a
-	-	-	Sp	2.1	(8.2)b	2.8	(8.0)ab
SED (12 d.f)				-	(1.4)	-	(2.5)
CV (%)				-	(34.1)	-	(49.7)

(-) = Data skew

* Arcsine transformation

Values followed by the same letter (within a column) do not differ significantly (p = 0.05)

Table G. High Mowthorpe

Disease assessment, 19 June (GS 4.8)

Fungicide applied at:					Mean % stem area	
9/11	25/2	13/3	12/4	23/5	(transformed data*)	
aut	mF	mM	se	emf	Light leaf spot	
-	-	-	-	-	3.6	(10.6)b
Sp	-	-	-	-	1.3	(5.4)a
-	Sp	-	-	-	0.5	(3.9)a
-	-	Sp	-	-	0.9	(4.8)a
-	-	-	Sp	-	0.8	(4.9)a
-	-	-	-	Sp	3.2	(10.0)b
Sp	-	-	Sp	-	0.2	(1.9)a
SED (18 d.f)					(-)	(2.9)
CV (%)					(-)	(48.2)

(-) = Data skew

* Arcsine transformation

Values followed by the same letter (within a column) do not differ significantly (p = 0.05)

Table H. High Mowthorpe

Final Disease assessment, 17 July (GS 6.4)

Fungicide applied at:						Mean % stem area
9/11	25/2	13/3	12/4	23/5	24/6	
aut	mF	mM	se	emf	ef	Light leaf spot
-	-	-	-	-	-	3.6bc
Sp	-	-	-	-	-	1.3ab
-	Sp	-	-	-	-	1.1ab
-	-	Sp	-	-	-	0.6a
-	-	-	Sp	-	-	0.5a
-	-	-	-	Sp	-	4.1c
-	-	-	-	-	Sp	2.0ab
Sp	-	-	Sp	-	-	0.0a
-	-	-	Sp	-	Co	1.0ab
Sp	-	-	Sp	-	Co	0.1a
SED (27 d.f)						1.3
CV (%)						91.8

Values followed by the same letter (within a column) do not differ significantly (p = 0.05)

Table I. Neston Disease Development on untreated discard plots: % Plants (Plant area)

Date	GS	Downy Mildew	Phoma Leaf	Phoma stem	Powdery mildew	Ringspot	Alternaria	Light leaf spot Leaf	Light leaf spot Stem	Light leaf spot Pod	Botrytis Stem	Botrytis Pod
27/11	1.12	0	5(t)	0	100(23.3)	32 (0.2)	0	0	0	-	-	-
17/12	1.14	0	4(t)	0	100(23.2)	12 (t)	0	0	0	-	-	-
1/3	1.18	0	4(t)	0	72 (1.3)	20 (t)	0	24(0.2)	0	-	-	-
15/3	2.2	0	47(0.2)	0	13 (t)	93 (0.8)	0	27(2.4)	0	-	-	-
27/3	2.5	68(0.3)	48(0.1)	0	0	48 (0.1)	0	16(0.7)	0	-	-	-
25/4	4.2	92(0.5)	36(0.1)	0	0	36 (t)	0	76(5.7)	12(0.9)	-	-	-
22/5	4.7	16(t)	24(0.2)	4	0	36 (t)	0	100(11.7)	44(1.5)	16(0.2)	-	-
3/6	4.9	12(t)	16(t)	0	0	20 (t)	0	96 (8.2)	76(5.3)	32(0.5)	-	-
19/7	6.4	-	-	80a/56b	32(1.6)p	96 (19.0)p	24(0.1)p		56(3.0)	20(0.5)	28(0.9)	16(0.5)

a = aerial stem canker incidence

b = basal stem canker incidence

p = pod

t = trace

NB: 8% of plants had Sclerotinia stem rot on 19 July (Index 0.24)

Table J. Neston

Disease assessment, 27 April (GS 4.2)

Fungicide applied at: 27/11 aut	1/3 mF	14/3 mM	27/3 se	Mean % plants affected Ringspot	Phoma	LLS	Mean % leaf area LLS
-	-	-	-	60.0c	60.0b	90.0b	5.4b
Sp	-	-	-	35.0b	57.5b	70.0b	5.3b
-	Sp	-	-	25.0b	40.0ab	20.0a	0.9a
-	-	Sp	-	5.0a	17.5a	32.5a	1.5a
-	-	-	Sp	0.0a	22.5a	87.5b	4.9b
Sp	-	-	Sp	5.0a	17.5a	17.5a	1.5a
SED (15 d.f)				6.6	11.9	9.9	1.5
CV (%)				43.0	46.8	26.3	64.2

Values followed by the same letter (within a column) do not differ significantly (p = 0.05)

Table K. Neston

Disease assessment, 22 May (GS 4.7)

Fungicide applied at:					Mean % leaf area
27/11 aut	1/3 mF	14/3 mM	27/3 se	26/4 emf	Light leaf spot
-	-	-	-	-	11.3c
Sp	-	-	-	-	4.0ab
-	Sp	-	-	-	4.8ab
-	-	Sp	-	-	3.0a
-	-	-	Sp	-	8.8bc
-	-	-	-	Sp	17.5d
Sp	-	-	Sp	-	2.0a
SED (18 d.f)					2.3
CV (%)					43.8

Values followed by the same letter (within a column) do not differ significantly (p = 0.05)

Table L. Neston

Disease assessment, 19 July (GS 6.4)

Fungicide applied at:-							% plants affected		
27/11	1/3	14/3	27/3	26/4	31/5		Phoma stem canker		
aut	mF	mM	se	emf	ef	Total	Index 1	Index 2	Index 3/4
-	-	-	-	-	-	62.0e	28.0	17.0	17.0
Sp	-	-	-	-	-	55.0de	22.0	23.0	10.0
-	Sp	-	-	-	-	40.0bcd	22.0	14.0	4.0
-	-	Sp	-	-	-	20.0a	14.0	1.0	5.0
-	-	-	Sp	-	-	42.0bcd	19.0	11.0	12.0
-	-	-	-	Sp	-	48.0cde	27.0	11.0	10.0
-	-	-	-	-	Sp	56.0de	19.0	16.0	21.0
Sp	-	-	Sp	-	-	38.0bc	13.0	11.0	14.0
-	-	-	Sp	-	Co	31.0ab	14.0	8.0	9.0
Sp	-	-	Sp	-	Co	35.0abc	15.0	11.0	9.0
SED (27 d.f)						7.1	NS	*	NS
CV (%)						23.5	40.5	76.6	64.9

NS = Not significant (p = 0.05)

*Date skew and not transformable

Values followed by the same number (within a column) do not differ significantly (p = 0.05)

Table M. Neston

Disease assessment, 19 July (GS 6.4)

Fungicide applied at:						% plants affected [+]		% area affected	
27/11 aut	1/3 mF	14/3 mM	27/3 se	26/4 emf	31/5 ef	Sclerotinia	Botrytis (stems)	Light leaf spot (stems)	Ringspot (pods)
-	-	-	-	-	-	4.8abc	12.0bcd	6.5b	32.5
Sp	-	-	-	-	-	8.8cd	12.0bcd	4.5b	31.2
-	Sp	-	-	-	-	4.8abc	17.0cd	1.6a	28.7
-	-	Sp	-	-	-	8.8cd	17.0cd	2.2a	23.2
-	-	-	Sp	-	-	10.0d	8.0abc	1.5a	30.0
-	-	-	-	Sp	-	3.5ab	19.0d	6.5b	27.5
-	-	-	-	-	Sp	1.3a	5.0ab	6.3b	25.0
Sp	-	-	Sp	-	-	6.5bcd	12.0bcd	0.8a	31.2
-	-	-	Sp	-	Co	1.0a	0.0a	2.4a	25.5
Sp	-	-	Sp	-	Co	2.3ab	1.0a	1.4a	12.5
SED (27 d.f)						2.3	4.1	0.9	NS
CV (%)						62.3	56.8	39.2	29.8

[+] Whole plot method

NS = Not significant (p = 0.05)

Values followed by the same letter (within a column) do not differ significantly (p = 0.05)

Table N. Threekingham

Disease assessment, 23 July (GS 6.7)

Fungicide applied at:							% pod area affected		
27/11 aut*	23/1 mJ	25/2 mF	12/3 mM	19/3 se	14/5 emf	2/7 ef	Alternaria	Downy Mildew	Botrytis
-	-	-	-	-	-	-	11.4d	1.1	0.7
Sp	-	-	-	-	-	-	11.3d	0.8	0.9
-	Sp	-	-	-	-	-	8.7cd	1.3	0.8
-	-	Sp	-	-	-	-	9.4cd	1.6	0.4
-	-	-	Sp	-	-	-	10.0cd	1.3	0.4
-	-	-	-	Sp	-	-	9.8cd	1.6	0.5
-	-	-	-	-	Sp	-	10.4cd	1.5	0.4
-	-	-	-	-	-	Sp	6.5bc	1.6	0.7
-	Sp	-	-	Sp	-	-	11.5d	1.3	0.2
-	-	-	-	Sp	-	Co	2.2a	0.8	0.2
-	Sp	-	-	Sp	-	Co	2.5ab	0.7	0.6
SED (27 d.f)							2.0	NS	NS
CV (%)							33.5	41.7	73.0

* = Additional treatment

NS = Not significant (p = 0.05)

Appendix 1

Table A - Details of Fungicide application

Details	Fonmon	Hawkinge	High Mowthorpe	Neston	Terrington	Threekingham
Sprayer	Oxford Precision	Solo Knapsack	Oxford Precision till mid-March Hardi thereafter	Oxford Precision	Tractor-mounted	MDM modified
Volume of water (l/ha)	250	220	200 400 emf and ef	250 350 emf and ef	220	240 300 ef
Pressure (kPa)	276	300	200	200	250	200
Date of spray:						
Autumn (a)	19 November	14 November	9 November	27 November	3 December	23 January
mid-February (mF)	19 February	19 February	25 February	1 March	1 March	25 February
mid-March (mM)	13 March	14 March	13 March	14 March	13 March	12 March
Early stem extension(se)	12 April	4 April	12 April	27 March	12 April	29 March
Early mid-flowering (emF)	2 May	8 May	23 May	26 April	10 May	14 May
End of-flowering (eF)	4 June	5 June*	24 June	31 May	28 June	2 July

* Sportak, not Compass