FINAL REPORT

BBRO PROJECT 04/01

OPTIMIZING YIELD BENEFITS FROM

TRIAZOLE AND STROBILURIN FUNGICIDES

MAY 2008

Optimizing yield benefits from triazole and strobilurin fungicides

CONTENTS

1. EXECUTIVE SUMMARY

1. In general, triazole and strobilurin fungicides applied at full recommended rates at the end of July gave significant, cost-effective yield responses in the presence or absence of disease.

2. There was no evidence, over the [*three*] years of trials, of an interaction between fungicide treatments and harvest date, i.e. that some treatments were better suited to early or late harvests.

3. Very early (early June, before canopy closure) application of triazole/strobilurin fungicides led to enhanced disease susceptibility and reduced yields compared with normal treatments. There was evidence that this was due to an adverse physiological effect on plants.

4. Half-rates of fungicdes failed to give adequate control of mildew particularly on susceptible varieties. However, half-rate mixtures with non-triazoles tended to perform as well as, though not better than a full rate of their triazole component. In disease-free trials, half rates of triazoles (either alone or in mixtures with the non-triazole, Fortress) generally gave equivalent yield increases to full rates; their physiological effect was not reduced.

5. On some recently introduced, very susceptible varieties artificially inoculated with mildew, fungicides applied in late July failed to control the disease much beyond 4 weeks. A second application, 4 weeks after the first, significantly increased yield over a single treatment, by an average (over several trials) of 8 adjusted tonnes.

6. Spyrale and Punch C generally gave the best control of mildew with the largest yield responses. Fortress gave good mildew control but no physiological yield boost. Cabaret showed poor persistence against mildew.

7. Spyrale and Cabaret gave the best control of rust. Fortress gave no significant control of this disease. Significant yield benefits were obtained from controlling this disease, particularly with a two-spray programme.

2. AIMS, CONDUCT AND FINDINGS OF THE RESEARCH

PART 1. DISEASE CONTROL.

Objective 1.
Carry out trials (in collaboration with British Sugar) in the three beet growing regions to compare the effect of triazoles, strobilurins and other approved fungicides, applied at different stages of crop growth, on disease control and yield and quality in early and late harvested plots.

Objective 2.
Compare reduced rates and mixtures of triazoles and other fungicides to establish the most cost-effective treatments for disease control.

Trials were carried out in each of the years 2004 – 8 to address these objectives. Treatments and approaches evolved according to previous year's data, and to accommodate changes in varieties, available fungicide products and beet growing areas during the course of the 4 – year project.

2004

1. Fungicide application timings and harvest dates

(a) Aims:

Collaborative trials in the three beet growing regions were established to compare the effect of triazoles, strobilurins and other approved fungicides, applied at different stages of crop growth, on disease control, yield and quality in early and late harvested plots.

(b) Methods:

Three identical trails were established in growers' crops at Broom's Barn, Suffolk (cv. Roberta); Pattingham, Shropshire (cv. Latoya); and Hibaldstow, Lincs (cv. Cinderella). Plots were marked out as 4 duplicate pairs of randomized blocks, one of each pair to be harvested early and the other late. The standard plot size for spraying was 6 rows (3m) x 12m long. The same fungicide treatments (Table 1) were applied to all three trials in 200 l/ha using an Oxford precision plot sprayer. In this particular set of trials, sprays were applied at (1) approx. 20% leaf cover (early June) or (2) late July (corresponding to when powdery mildew was generally first observed in the trial area) and (3) on both occasions. The objective here was to examine whether very early fungicide applications could give benefits either by controlling disease or through direct physiological effects in the early stages of crop development.

At Broom's Barn, field inoculation with powdery mildew was carried out by distributing infected plants from the glasshouse throughout the trial

area on 12 July. 25 mm irrigation was supplied on 1 July and 3 August. Disease assessments on all trials were conducted 4 and 7 weeks after the 'normal' spray treatments had been applied in late July/early August. On each occasion, the level of disease (powdery mildew, rust and ramularia) was estimated on 5 randomly selected plants from each of the central four rows in each plot. Disease was recorded on a 0-6 scale and later converted to '% leaf area infected per plant' using a standard in-house transformation equation.

Half of the plots in each trial were machine harvested (4 rows x 8.65 m per plot at Broom's Barn; 3 rows x 9 m by British Sugar at outside sites) early and the other half later. Samples from all plots were tarehoused at Broom's Barn and root yield, sugar content, amino-N, Na and K concentrations determined. All data were statistically analysed by Rothamsted's Biomathematics Unit using Genstat 6 and are presented in summary form.

(c) Results:

Disease levels in all trials were particularly low in 2004 (Table 2) probably largely due to the wet conditions (23 days with rain were recorded in August alone at Broom's Barn). No disease was recorded at Hibaldstow. Some mildew developed on the inoculated plots at Broom's Barn and rust, but no mildew, was observed at low levels at Pattingham in late September.

Early (June) applications of the triazole and strobilurin fungicides increased susceptibility to both powdery mildew and rust, whether compared with 'normal' applications or the untreated controls. This effect was not evident with the non-triazole, Fortress. Among 'normal' applications, Cabaret did not give such persistent control of mildew as the other products. The low levels of rust were well controlled by all products except Fortress.

Yields in adjusted tonnes per hectare increased significantly between the two harvest dates at Hibaldstow, but not at Broom's Barn or Pattingham. Because there was no significant interaction between the various fungicide treatments and harvest date at any site, the data from the two harvests were combined (Table 3).

At Broom's Barn, where there was some late-developing but low level mildew, 'normal' applications of the triazole fungicides gave yield increases over the untreated control of *ca*. 4.8 adjusted tonnes. 'Early' applications gave substantially reduced yields. This damaging effect was not evident with the non-triazole, Fortress. At the high yielding disease free site at Hibaldstow, 'normal' triazole applications increased yields over the untreated by 5-7 adjusted tonnes, though these did not achieve statistical significance in this rather variable trial. However, there were large and statistically significant reductions when 'early' and 'normal' applications of the triazoles were compared. At Pattingham,

yields were generally low and the trial was innately very variable so that no significant differences between treatments were detected.

Quality*:* Some small statistically significant differences between treatments were occasionally found in quality traits (sugar content, amino-N, Na and K levels) but these were not consistent across all trials and are therefore not reviewed here.

Table 1. Treatments applied to the Collaborative Fungicide Trials in 2004

	Product	Active ingredient/s	Rate (l/ha)	Spray Timing [+]	Harvested*
1.	Punch C	Flusilazole + carbendazim	0.625	Early (E)	Early (E)
2.				Early (E)	Late (L)
3.				Normal (N)	E
4.				Normal (N)	L
5.				Early + Normal (E+N)	E
6.				Early + Normal (E+N)	L
7.	Cabaret	Cyproconazole	0.25	E	E
8.				E	L
9.				N	E
10.				N	L
11.				E + N	E
12.				E + N	L
13.	Opera	Pyraclostrobin + epoxiconazole	1.0	E	E
14.				E	L
15.				N	E
16.				N	L
17.				E + N	E
18.				E + N	L
19.	Fortress	Quinoxyfen	0.2	E	E
20.				E	L
21.				N	E
22.				N	L
23.				E + N	E
24.				E + N	L
25.	Untreated			-	E
26				-	L

[+]Spray timings: 'Early' = 20% leaf cover (Broom's Barn, 3rd June; Hibaldstow, 7th June; Pattingham, 8th June)
'Normal' = when disease was first seen, or equivalent (BB, 26th July; Hibaldstow, 31st July; Pattingham, 5th Aug)

*Harvest dates: 'Early' = BB, 22nd Oct; Hibaldstow, 30th Sept; Pattingham, 6th Oct.
'Late = BB, 15th Dec; Hibaldstow, 25th Nov; Pattingham, 24th Nov.

Table 2. Disease levels recorded on the Collaborative Fungicide Trials in 2004 (% leaf area infected)

		Broom's Barn		Pattingham		
	Application	Mildew		Mildew		Rust
Treatment	**Time**	**23/8**	**16/9**	**2/9**	**28/9**	**28/9**
Punch C	Early (E)	2.9[+]	10.1	0	0	7.6
	Normal (N)	0	0.1	0	0	1.5
	(E+N)	0	1.5	0	0	2.4
Cabaret	E	3.0	17.6	0.1	0	4.9
	N	0	7.9	0	0	1.5
	E+N	0	15.3	0.1	0	3.3
Opera	E	2.2	10.1	0.1	0	7.0
	N	0	0.2	0	0	1.3
	E+N	0	2.7	0	0	1.3
Fortress	E	0.5	0.6	0.1	0	9.6
	N	0	0.8	0	0	9.4
	E+N	0	0	0	0	10.5
Untreated		1.4	4.0	0	0	9.0
5% LSD		1.8	4.8	NS	NS	4.3

[+]Data are mean of 8 plots per treatment, 20 plants per plot.
NS = No significant difference between treatments
No disease was recorded at Hibaldstow.

Table 3. Yields (adjusted tonnes per hectare) of the Collaborative Fungicide Trials, 2004. Data from early and late harvests combined.

Treatment	Application time	Broom's Barn	Hilbaldstow	Pattingham
Punch C	E	83.5[+]	89.7	58.3
	N	92.4	100.4	59.5
	E+N	94.1	99.3	58.6
Cabaret	E	84.5	88.4	55.9
	N	92.4	99.3	60.1
	E+N	88.1	95.3	55.2
Opera	E	87.4	96.1	56.6
	N	92.2	102.9	60.4
	E+N	95.0	99.0	57.9
Fortress	E	87.9	97.4	56.8
	N	88.0	94.4	57.7
	E+N	89.2	95.4	56.4
Untreated		87.5	95.6	58.8
5% LSD		4.9	7.7	NS*
CV%		5.5	8.0	9.0

[+] Data are means of 8 plots
* No significant difference between treatments

2. Reduced rates and mixtures of fungicides

(a) Aims:

To examine, in a single, inoculated trial at Broom's Barn, (1) half rates of Punch C, Cabaret, Opera or Fortress, designed to minimize costs (2) mixtures of half rates of Punch C and Cabaret with a half rate of Fortress, designed to maximize the spectrum of disease control, and (3) both a reduced or a full rate of Punch C applied when mildew first seen, followed by a half or a full rate of Cabaret to control later developing rust, designed to maximize the duration of disease control.

(b) Methods:

The trial was laid out in a uniform area of cv. Roberta at Broom's Barn and mildew infected plants introduced from the glasshouse on 12 July. Treatments (Table 4) were applied as 5 randomized complete blocks with a plot size of 6 rows x 12m. 25mm irrigation was supplied on 6 July and disease assessments were carried out 4 and 7 weeks after the first sprays were applied on 27 July. The trial was machine harvested (4 rows x 8.65m per plot) on 3 November and tarehoused at Broom's Barn. Statistical analysis of disease, yield and quality data was carried out at Rothamsted using Genstat 6.

(c) Results:

Despite artificial inoculation, mildew developed slowly in the trial because of the wet conditions so that, at the first assessment on 24 August only 22% of the leaf area was infected on untreated plots and no disease was apparent on any of the treated plots. By 17 September mildew had developed on most plots (Table 5), particularly on those treated with Cabaret and Opera. The most persistent and effective treatments for mildew control at this stage were Fortress (both full and half rate) and full rate Punch. The 2 spray programme (full rates) also showed good control at this stage as the second spray had been applied only 3 weeks earlier.

Yield over the untreated control was increased significantly by all treatments except half rates of Punch, Cabaret and Fortress. The highest yield increases (15-18%) were obtained from Opera (1.0 and 0.65 l/ha) and the half-rate Punch+Cabaret mix. Reduced and full-rate mixtures and sequences all gave yield improvements that were not significantly different from their components applied at the full rate. Of the impurities, amino-N and Na were significantly reduced by all fungicide treatments compared with the unsprayed control. K levels, though generally reduced, did not improve significantly with half rates of Punch and Cabaret.

Table 4. Treatments applied to Reduced Rates and Mixtures of Fungicides trial in 2004.

	Treatment	Rate (l/ha)	Timing*
1	Untreated		
2	Punch C	Full (0.625)	1
3	Cabaret	Full (0.25)	1
4	Fortress	Full (0.2)	1
5	Opera	Full (1.0)	1
6	Punch C	Half (0.31)	1
7	Cabaret	Half (0.125)	1
8	Fortress	Half (0.1)	1
9	Opera	Reduced (0.65)	1
10	Punch C + Cabaret	Half (0.31) Half (0.125)	1
11	Punch C + Cabaret	Reduced (0.5) Half (0.125)	1
12	Punch C followed by Cabaret	Full (0.625) Full (0.25)	1 2
13	Punch C followed by Cabaret	Reduced (0.5) Half (0.125)	1 2

* 1 = 27 July, 2 = 26 August

Table 5. Disease levels, yield and quality components in the Reduced Rates and Mixtures of Fungicides trial, 2004

Treatments	**Mildew levels** (% Leaf area infected, 17/9)	**Yield** (adj. tonnes/ha)	**Quality components:**		
			Amino-N	**Na**	**K**
			(mg/100 g sugar)		
1 Untreated	31.5	75.9	57	71	843
2 Punch 0.625 (1)	3.3	85.4	42	56	809
3 Cabaret 0.25 (1)	20.7*	85.5	45	59	803
4 Fortress 0.2 (1)	0	84.4	49	58	788
5 Opera 1.0 (1)	10.0	89.5	43	50	773
6 Punch 0.31 (1)	6.1	82.0*	43	56	824
7 Cabaret 0.125 (1)	28.5*	81.6*	48	59	833
8 Fortress 0.1 (1)	1.4	79.8*	46	56	789
9 Opera 0.65 (1)	14.2	87.2	46	61	813
10 Punch 0.31 + Cabaret 0.125 (1)	9.4	87.6	44	53	816
11 Punch 0.5 + Cabaret 0.125 (1)	9.2	84.4	43	54	775
12 Punch 0.625 (1) Cabaret 0.25 (2)	0.1	84.0	42	49	756
13 Punch 0.5 (1) Cabaret 0.125 (2)	8.8	85.8	43	53	777
5% LSD	11.9	6.2	7	9	49

* Not significantly different from untreated

3. General conclusions from 2004 trials

1. Application of triazole and strobilurin fungicides in early June, before canopy closure, increased susceptibility to disease and reduced yields compared with untreated controls or Fortress (Fig. 1). This was *via* a direct effect on the physiology of the plant (see Fig. 2 and later in report).

2. With normal, late-July fungicide applications, there was no evidence of an interaction with harvest date, i.e. that some treatments were better suited to early or late harvests.

3. Full rate applications of fungicides increased yields in the presence of disease whereas half-rate applications did not (Fig. 3).

4. Cabaret (cyproconazole) showed poor persistence against powdery mildew.

5. Fortress (quinoxyfen) gave poor control of rust.

6. Mixtures gave yield increases equivalent to, but not significantly better than their components applied at full rates.

Figure 1. Effects of early June (E) and late July (N) applications of fungicides in the Collaborative Fungicide Trials (2004) on (A) mildew levels in late September and (B) final yields at Broom's Barn, and (C) yields in the disease-free trial at Hibaldstow.

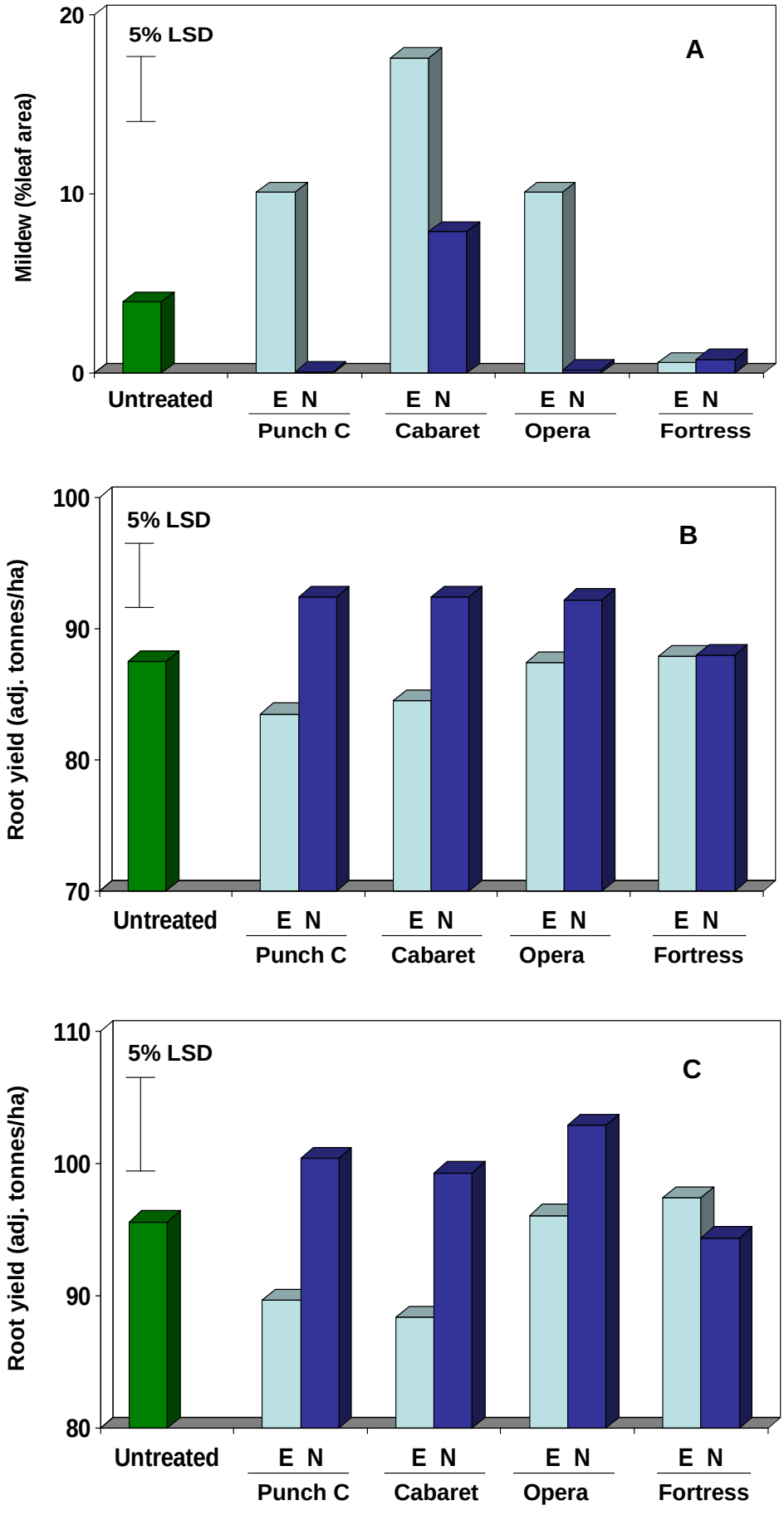
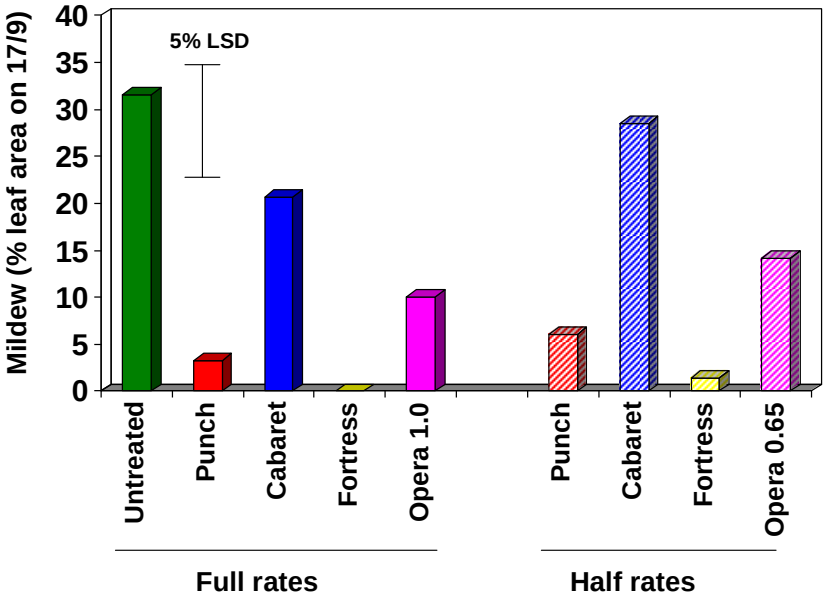
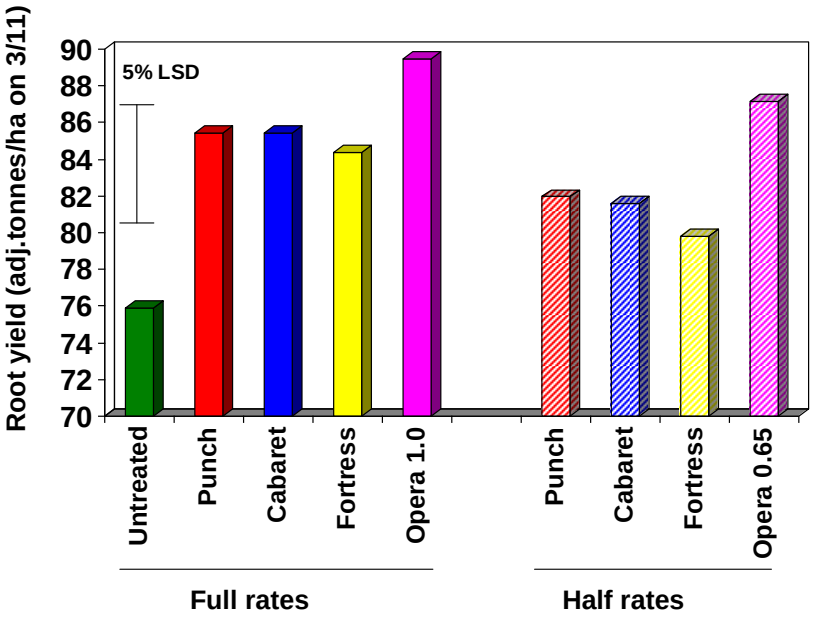


Figure 2. Darker green plots treated with triazoles or strobilurins, one week after spraying on 3 June, 2004.

Figure 3. Effect of full and half rates of fungicides applied on 27 July, 2004 on mildew levels and final yield in an inoculated trial at Broom's Barn





2005

1. Fungicide products, reduced rates and mixtures *vs* harvest dates

(a) Aims:

To examine, at three sites and on varieties differing in mildew susceptibility, a range of fungicide products, along with reduced rate mixtures and sequential applications, for their effects on disease control, yield and quality in early and late harvested plots.

(b) Methods:

As in 2004, three identical collaborative trials were established in growers' crops at Broom's Barn, Hibaldstow (Lincs) and Pattingham (Shrops). Varieties with different levels of mildew susceptibility were used, viz. Aspect (NIAB resistance rating = 2), Dominika (rating = 8) and Gandalf (rating = 4). The trials were designed as previously with five randomized blocks, duplicated to allow for early and late harvests. At Broom's Barn, mildew infected plants were introduced into the trial area on 11th July and 25mm irrigation was supplied on 23rd June and 20th July. The first fungicide applications were made when mildew was first seen on the trial plots (or at an equivalent time when no disease had developed on the other trials) and disease assessments made 4 and 7 weeks after this, using methods previously described. The full list of treatments applied is shown in Table 6. Trials were harvested both 'early' and 'late' and all samples tarehoused at Broom's Barn for analysis of yield and quality components. Statistical analysis of the data was carried out at Rothamsted, using Genstat 6. Because of variable crop establishment at Broom's Barn, yield data were subjected to covariance analysis against root numbers per plot.

(c) Results:

Disease levels: At Broom's Barn, where the highly mildew susceptible variety Aspect (rhizomania resistant) was inoculated in mid-July, disease control was not complete on any treatment when assessed three weeks after spraying on 23rd August (Table 7). The untreated plots were very severely affected with an average 48% leaf area covered by mildew. By 14th September, significant re-invasion had occurred on all plots receiving single, full rate applications; Cabaret showed particularly poor persistence. Half rate mixtures of Fortress with a triazole were most effective at this stage. No disease was recorded on either assessment date at Hibaldstow and Pattingham.

Yield: Again, there was no evidence of a statistical interaction between fungicide treatments and harvest date at any site so data from the two harvests were combined to improve the precision of results. At Broom's Barn, where high yields were recorded, all

treatments except Fortress significantly increased yield above the untreated control. Yield increases of 11-14% were achieved with Punch C, Cabaret and Opera. Apart from Fortress, there was no significant difference between any treatment, mixture or sequence; all were equally effective in improving yields in this trial. At Hibaldstow and Pattingham (Table 8) yields were, in general, slightly lower and, in the absence of disease, there was little benefit from treatments when compared with the untreated. Full rate Fortress, which has no physiological effects, was the lowest yielding treatment in both trials. When compared with this treatment, half rate triazoles in mixtures with Fortress showed significant yield enhancement, indicating that their physiological effects were evident even at these reduced rates.

Quality: Of the quality components, only amino-N values were significantly affected in these trials. At Broom's Barn, amino-N was reduced by all fungicide treatments except Punch C, Fortress and the half-rate mix of these products. At Hibaldstow, Fortress and the Punch C/Fortress mix again failed to reduce amino-N. Apart from these effects there were no other marked significant differences between treatments.

Table 6. Treatments applied to Collaborative Fungicide Trials in 2005

	Treatment (l/ha)	**Harvested**
1.	Punch C (0.625)*	Early (E)‡
2.	Punch C (0.625)	Late (L)
3.	Cabaret (0.25)	E
4.	Cabaret (0.25)	L
5.	Opera (1.0)	E
6.	Opera (1.0)	L
7.	Opera (0.75)	E
8.	Opera (0.75)	L
9.	Fortress (0.2)	E
10.	Fortress (0.2)	L
11.	Punch C (0.31) + Opera (0.5)	E
12.	Punch C (0.31) + Opera (0.5)	L
13.	Punch C (0.31) + Opera (0.1)	E
14.	Punch C (0.31) + Opera (0.1)	L
15.	Cabaret (0.125) + Fortress (0.1)	E
16.	Cabaret (0.125) + Fortress (0.1)	L
17.	Punch C (0.31) followed by Cabaret (0.125) †	E
18.	Punch C (0.31) followed by Cabaret (0.125)	L
19.	Fortress (0.1) followed by Cabaret (0.125)	E
20.	Fortress (0.1) followed by Cabaret (0.125)	L
21.	Opera (0.5) followed by Opera (0.5)	E
22.	Opera (0.5) followed by Opera (0.5)	L
23.	Untreated	E
24.	Untreated	L

*First (T1) fungicide applications : Broom's Barn, 26th July; Hibaldstow, 11th Aug; Pattingham, 10th Aug.

†Second (T2) fungicide applications : Broom's Barn, 23rd Aug; Hibaldstow, 8th Sept; Pattingham 7th Sept.

‡ Harvest dates: 'Early' = Broom's Barn, 12th Oct; Hibaldstow, 5th Oct; Pattingham, 27th Oct
'Late' = Broom's Barn, 29th Nov; Hibaldstow, 1st Dec; Pattingham, 29th Nov.

Table 7. Significant disease levels, yield and quality factors recorded at Broom's Barn in the Collaborative Fungicide Trials : 2005

Treatments	**% L.A. infected with mildew**		**Yield**	**Amino-N**
	23/8	**14/9**	**(adj.t/ha)**	**(mg/100g sugar)**
1 Punch C (0.625)	1.3	15.1	96.3	59.2*
2 Cabaret (0.25)	6.7	30.0*	99.5	49.5
3 Opera (1.0)	0.5	17.7	99.4	48.2
4 Opera (0.75)	1.8	19.2	98.6	47.9
5 Fortress (0.2)	7.9	10.7	87.3*	57.5*
6 Punch C (0.31) + Opera (0.5)	1.1	14.2	99.3	49.8
7 Punch C (0.31) + Fortress (0.1)	2.0	3.6	96.5	58.1*
8 Cabaret (0.125) + Fortress (0.1)	1.5	6.6	98.2	50.1
9 Punch C (0.31) fb.Cabaret (0.125)	5.8	12.0	100.0	48.4
10 Fortress (0.1) fb.Cabaret (0.125)	8.6	9.7	96.1	51.1*
11 Opera (0.5) fb. Opera (0.5)	4.6	2.9	97.8	45.6
12 Untreated	48.1	31.7	87.1	58.0
5% LSD	4.6	5.3	4.3	7.3
CV %	-	-	4.5	-

Data are mean of 8 plots (2 harvests combined)
* Not significantly different from untreated

Table 8. Significant yield and quality factors recorded at the disease-free sites of Hibaldstow and Pattingham in the Collaborative Fungicide Trials : 2005

Treatments	**Hibaldstow**		**Pattingham**
	Yield (adj.t./ha)	**Amino-N (mg/100g sugar)**	**Yield (adj.t./ha)**
1 Punch C (0.625)	81.2*	32.7	74.3*
2 Cabaret (0.25)	83.7*	33.0	76.9
3 Opera (1.0)	85.9*	30.1	76.3
4 Opera (0.75)	81.5*	32.9	75.8
5 Fortress (0.2)	77.2*	41.3*	72.0*
6 Punch C (0.31) + Opera (0.5)	81.7*	30.1	76.4
7 Punch C (0.31) + Fortress (0.1)	83.3*	36.8*	74.6*
8 Cabaret (0.125) + Fortress (0.1)	83.2*	29.4	77.4
9 Punch C (0.31) fb.Cabaret (0.125)	80.7*	32.4	76.7
10 Fortress (0.1) fb.Cabaret (0.125)	81.3*	35.4	74.5*
11 Opera (0.5) fb. Opera (0.5)	87.9	30.6	73.7*
12 Untreated	82.5	41.1	71.6
5% LSD	5.2	5.4	3.2
CV %	6.3	-	4.3

Data are mean of 8 plots (2 harvests combined)
* Not significantly different from untreated

2. Reduced rates and mixtures of fungicides

(a) Aims:

Similar to the 2004 trial, the objectives were to compare half-rates with full rates of the major products, plus reduced rate mixtures and sequences at reduced rates, but using a mildew susceptible variety.

(b) Methods:

The trial area (cv. Aspect, NIAB resistance rating = 3) was inoculated by introducing mildew infected plants from the glasshouse on 11th July. The 11 treatments plus untreated plots (Table 9) were laid out in five randomized blocks. First sprays were applied on 26th July and follow-up sprays (where specified) on 23rd August. 25mm irrigation was supplied on 22nd June, 29th June and 18th July. Disease assessments were performed 4 and 7 weeks following the first spray application and the trial was machine harvested (4 rows x 8.3m) on 8th November. Full yield and quality analysis was carried out at Broom's Barn and statistical analysis of the data at Rothamsted Research.

(c) Results:

Mildew developed rapidly on the susceptible variety but, apart from Cabaret, all treatments were still fully effective four weeks after treatment (Table 10). By seven weeks, however, control had completely broken down in all the half-rate treatments, in the full rate of Cabaret and in the half-rate Cabaret/Fortress mix. Even the full rate Punch C and Opera plots had been significantly re-invaded by mid-September on this mildew susceptible variety.

Yields at harvest reflected this, with half-rate treatments, Cabaret and the Cabaret/Fortress mixture all failing to yield significantly more than the untreated plots. Punch C, Opera and Fortress gave yield increases of 8-9% whereas the two spray programme of Punch C followed by Cabaret (both at full rates) gave a substantial 12.7 adj. t/ha increase (15%) on this susceptible variety. Even sequential half-rates of these two products gave an additional 10.0 adj. tonnes (12%).

Amino-N values were significantly reduced by all treatments except half-rates of Punch and Fortress; lowest values were obtained with the two spray programmes.

Table 9. Treatments applied to Reduce Rates and Mixtures of Fungicides trial in 2005

	Treatment	Rate (l/ha)	Timing*
1.	Untreated		
2.	Punch C	Full (0.625)	1
3.	Cabaret	Full (0.25)	1
4.	Opera	Full (1.0)	1
5.	Fortress	Full (2.0)	1
6.	Punch C	Half (0.31)	1
7.	Cabaret	Half (0.125)	1
8.	Opera	Half (0.5)	1
9.	Fortress	Half (0.1)	1
10.	Punch C + Fortress	Half (0.31) Half (0.1)	1 1
11.	Cabaret + Fortress	Half (0.125) Half (0.1)	1 1
12.	Punch C followed by Cabaret	Full (0.625) Full (0.25)	1 2
13.	Punch C followed by Cabaret	Half (0.31) Half (0.125)	1 2

*1 = 26th July, 2 = 23rd August.

Table 10. Mildew levels, yield and quality components in the Reduced Rates and Mixtures of Fungicides trial, 2005

	Treatments	% leaf area infected 22/8	% leaf area infected 13/9	Yield (adj. t/ha)	Amino-N (mg/100g sugar)
1.	Untreated	35.6	43.7	83.7	93.6
2.	Punch C (0.625)	0	37.8	90.5	77.3
3.	Cabaret (0.25)	0.7	52.7*	89.2*	72.5
4.	Opera (1.0)	0	38.5*	91.4	75.8
5.	Fortress (0.2)	0.7	8.6	90.4	76.8
6.	Punch C (0.31)	0.3	43.5*	90.2*	84.0*
7.	Cabaret (0.125)	6.0	46.5*	85.6*	79.4
8.	Opera (0.5)	0.3	47.0*	85.7*	78.0
9.	Fortress (0.1)	0.2	15.0	90.3	84.2*
10.	Punch C (0.31)+ Fortress (0.1)	0	10.5	89.6*	76.5
11.	Cabaret (0.125)+ Fortress (0.1)	0.1	41.6*	87.2*	74.1
12.	Punch C (0.625) followed by Cabaret (0.25)	0	19.1	96.4	65.7
13.	Punch C (0.31) followed by Cabaret (0.125)	0.2	31.2	93.7	68.3
5% LSD		5.5	6.0	6.5	10.8

*Not significantly different from untreated.

3. General conclusions from 2005 trials

1. As in 2004, there was no evidence for an interaction between fungicide treatments and harvest date.

2. Mildew control in inoculated plots of a very susceptible variety was generally good four weeks after spraying but had failed after seven weeks (Fig. 4). Cabaret was the least persistent.

3. Significant yield increases (8-14%) were obtained with single applications of full rate Punch C and Opera in both trials on the susceptible variety (Fig. 5).

4. In the one inoculated trial in which it was tested, a second fungicide application, four weeks after the first, significantly increased yield over a single treatment on a susceptible variety (Fig. 5). Two sprays also gave the lowest amino-N values. Sequential treatments on susceptible varieties need to be investigated further.

5. Half rates of fungicides failed to give sufficient disease control and yield benefits on the susceptible variety.

6. However, in the absence of disease, half-rates of triazoles gave an equivalent yield boost to full-rate applications (Fig. 6).

Figure 4. Mildew levels in an inoculated trial on a susceptible variety at Broom's Barn in the Collaborative Trials (2005), 4 and 7 weeks after fungicide treatments had been applied. Selected treatments only.

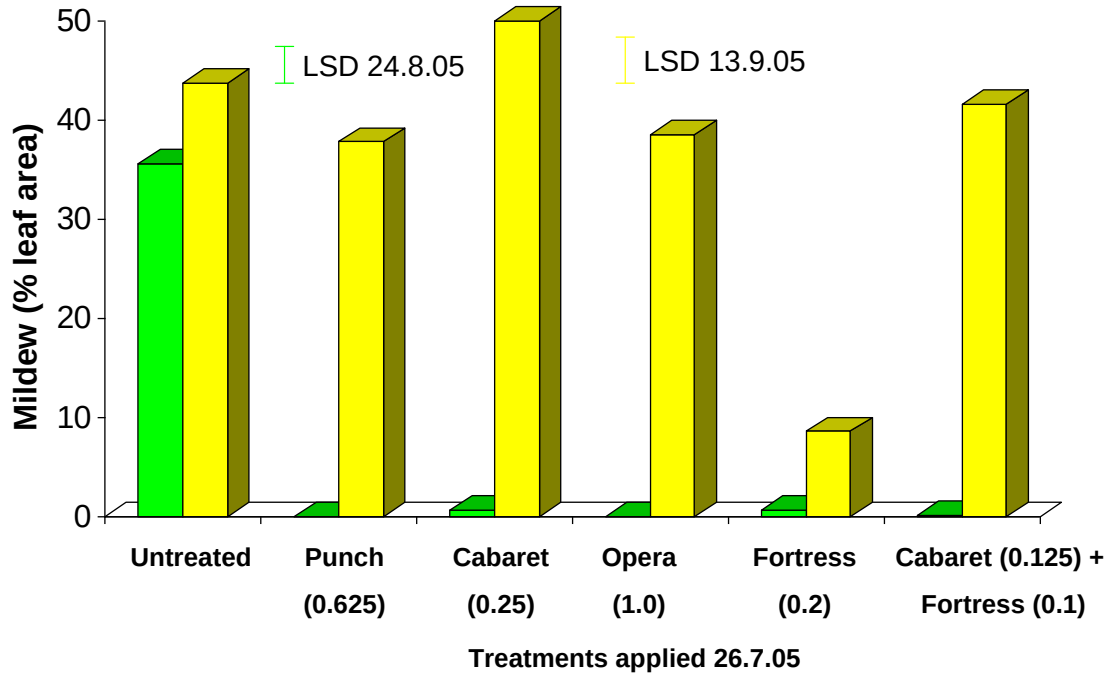


Figure 5. Yields (early and late harvests combined) in the mildew trial at Broom's Barn in the Collaborative Trials in 2005. Selected treatments only.

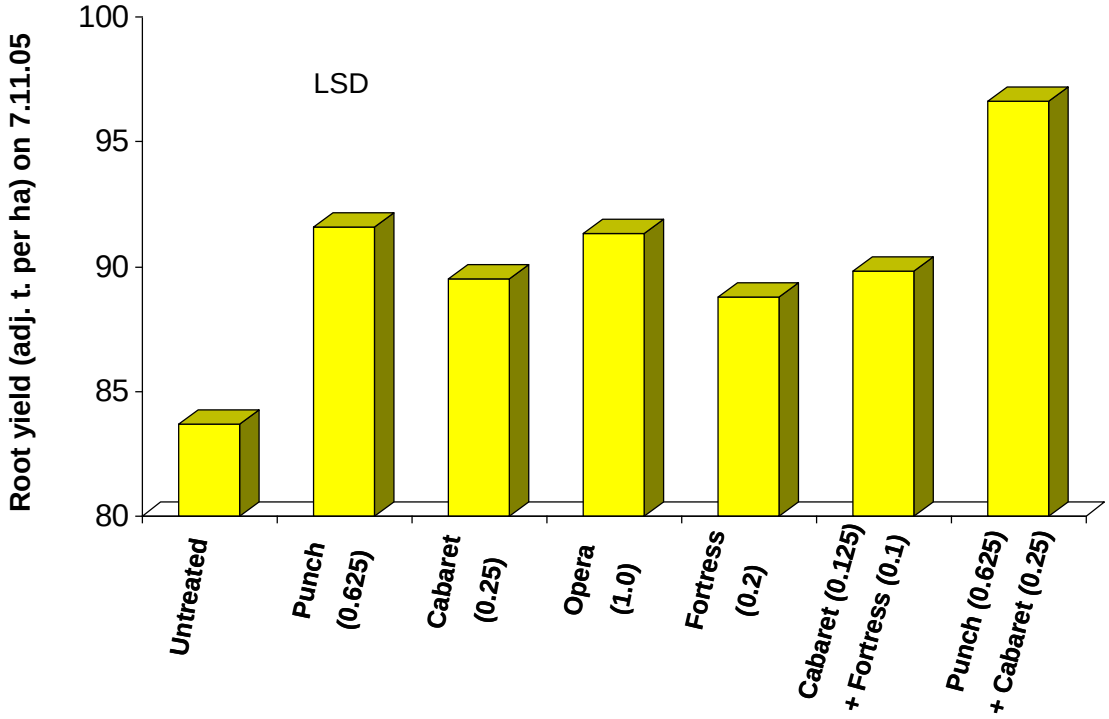
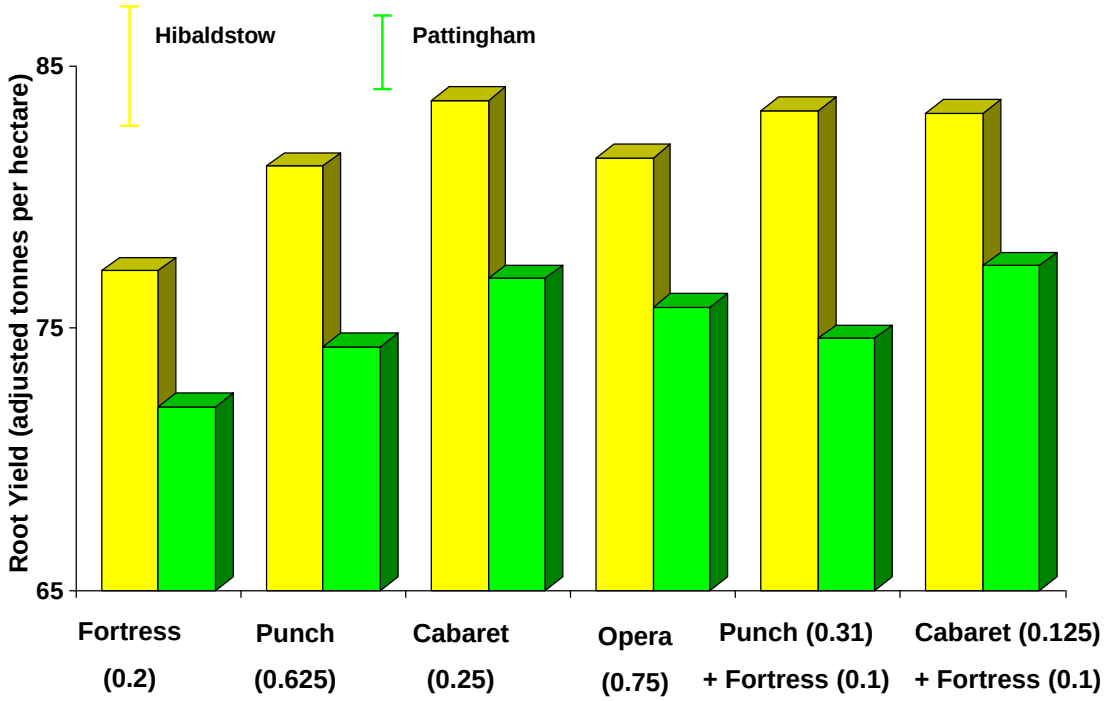


Figure 6. Yields (early and late harvests combined) at the disease-free sites of Hibaldstow and Pattingham in the Collaborative Trials in 2005. Selected treatments only.



2006

1. Fungicide products, reduced rates and mixtures *vs* harvest dates

(a) Aims:

To examine, on sites selected for (i) powdery mildew (ii) rust and (iii) no disease, the performance of fungicide products, along with selected reduced-rate mixtures and sequential applications, in early and late harvested plots.

(b) Methods:

This year, three sites were selected for the collaborative trials, targeted at a specific disease or no disease. A mildew trial was sited at Broom's Barn, using the susceptible variety Harry (NIAB rating for mildew resistance = 1) and introducing infected plants in July to generate the disease. A trial to examine rust control was carried out at Bardwell, Suffolk, a site known to be prone to this disease, using the rust susceptible variety Aspect (NIAB rust resistance rating = 1). Finally, the third trial was sited at Hibaldstow, known to be relatively disease-free, using the mildew resistant variety Dominika. At Broom's Barn, plots were inoculated on 10th July and 25mm irrigation applied on the 12th and 20th July. The first fungicide applications were made when mildew was first seen in the plots (or at an equivalent time in the other trials) and disease assessment made four and seven weeks after this. The treatments applied to all trials are shown in Table 11. Trials were split for 'early' and 'late' harvests and all samples tarehoused at Broom's Barn with chemical and statistical analyses conducted as in previous years.

(c) Results:

Disease levels. Mildew developed rapidly following inoculation of the Broom's Barn trial and by 22nd August untreated plots had 68% of the leaf area affected (Table 12). Under this severe disease pressure, all fungicide treatments had significant mildew infection at this stage with full-rate Spyrale and the Spyrale + Fortress half-rate mixture giving the best control. By the second assessment date significant further re-infection of treated plots had occurred; Spyrale and the Punch/Cabaret sequence were giving the best control at this stage. At Bardwell, rust development began in late August but had only reached 1% of leaf area on the untreated plots by the time of the first assessment on 5th September (data not shown). By the second assessment date this had increased to 19% and significant differences between treatments were recorded (Table 13). No powdery mildew was observed. Spyrale and Cabaret gave the best control of rust with Opera and, particularly, Fortress giving significantly poorer control. All the mixtures gave good control and the sequential treatment, with the second spray, Cabaret, having been applied only three weeks earlier, was the most effective.

No mildew was recorded at Hibaldstow and rust reached only very low levels; at an assessment on 21st September only 6% of the leaf area was affected on the untreated and only traces were observed on treated plots.

Yield. At Broom's Barn, significant yield increases from mildew control were achieved with all treatments except half-rate Punch. Highest yields (12-16% over untreated) were obtained with full-rate Punch and Spyrale, and all the mixtures and sequences tested. Fortress yielded significantly less than any of these.

At Bardwell, controlling the relatively late appearing rust gave significant yield increases over the control with all treatments except full-rate Fortress and the reduced rates of Opera and Punch. The best treatment was the half-rate Punch/Cabaret sequence which gave an additional 12 adj. tonnes (19%) more than the untreated. At Hibaldstow, where there was no significant disease, yields were significantly increased by all triazoles and triazole mixtures. Fortress alone, which is known to have no physiological effect, failed to enhance yield. As in 2005, however, yields were improved even where triazoles were used at half rates in mixtures with Fortress.

Quality components are only highlighted where significant differences were found between treatments. In the mildew trial, Na levels were reduced by full-rate Punch, Opera and Spyrale but at disease-free Hibaldstow all triazole treatments (but not Fortress) reduced the levels of this impurity when compared with the untreated samples. Amino-N values were also reduced at Hibaldstow by all treatments except Fortress and Opera (0.75).

Table 11. Treatments applied to the Collaborative Fungicide Trials in 2006

	Treatment (l/ha)	**Harvested**
1.	Punch C (0.625)*	Early (E)‡
2.	Punch C (0.625)	Late (L)
3.	Cabaret (0.25)	E
4.	Cabaret (0.25)	L
5.	Opera (1.0)	E
6.	Opera (1.0)	L
7.	Opera (0.75)	E
8.	Opera (0.75)	L
9.	Fortress (0.2)	E
10.	Fortress (0.2)	L
11.	Spyrale (1.0)	E
12.	Spyrale (1.0)	L
13.	Punch C (0.31)	E
14.	Punch C (0.31)	L
15.	Punch C (0.31) + Opera (0.5)	E
16.	Punch C (0.31) + Opera (0.5)	L
17.	Cabaret (0.125) + Fortress (0.1)	E
18.	Cabaret (0.125) + Fortress (0.1)	L
19.	Spyrale (0.5) + Fortress (0.1)	E
20.	Spyrale (0.5) + Fortress (0.1)	L
21.	Punch C (0.31) followed by Cabaret (0.125) †	E
22.	Punch C (0.31) followed by Cabaret (0.125)	L
23.	Untreated	E
24.	Untreated	L

*First (T1) fungicide applications : Broom's Barn, 25th July; Bardwell 8th Aug; Hibaldstow, 4th Aug.

†Second (T2) fungicide applications : Broom's Barn, 22nd Aug; Bardwell 5th Sept; Hibaldstow 2nd Sept.

‡ Harvest dates: 'Early' = Broom's Barn, 4th Oct; Bardwell, 9th Oct; Hibaldstow, 9th Oct
'Late' = Broom's Barn, 6h Dec; Bardwell, 20th Nov; Hibaldstow, 30th Nov.

Table 12. Significant disease levels, yield and quality factors recorded at Broom's Barn in the Collaborative FungicideTrials: 2006

Treatments	**% L.A. infected with mildew**		**Yield**	**Na**
	22/8	**11/9**	**(adj.t/ha)**	**(mg/100g sugar)**
1 Punch C (0.625)	17.3	34.6	91.4	84.1
2 Cabaret (0.25)	48.5	42.1*	87.6	91.2*
3 Opera (1.0)	31.0	41.4*	85.5	86.6
4 Opera (0.75)	36.2	42.4*	87.0	89.4*
5 Fortress (0.2)	12.3	27.8	85.0	95.9*
6 Spyrale (1.0)	7.4	20.0	90.2	78.9
7 Punch(0.31)	31.0	40.4*	84.8*	88.0*
8 Punch C (0.31) + Opera (0.5)	18.7	32.1	90.1	85.1
9 Cabaret (0.125) + Fortress (0.1)	11.8	38.0	93.1	93.3*
10 Spyrale (0.5) + Fortress (0.1)	6.4	27.5	91.1	90.4*
11 Punch C (0.31) fb. Cabaret (0.125)	36.4	19.5	91.6	90.1*
12 Untreated	68.2	44.1	80.1	97.9
5% LSD	5.6	4.7	4.6	10.3
CV %	-	-	5.1	-

Data are mean of 8 plots (2 harvests combined)
* Not significantly different from untreated

Table 13. Significant disease levels, yield and quality factors recorded at Bardwell and Hibaldstow in the Collaborative Trials : 2006

	Bardwell		Hibaldstow		
	% leaf area infected with rust 25/9	Yield (adj. t/ha)	Yield (adj. t/ha)	Amino-N (mg./100g. sugar)	Na
1 Punch C (0.625)	3.0	67.4*	65.3	90.1*	127.0
2 Cabaret (0.25)	1.3	70.0	65.9	79.5	128.0
3 Opera (1.0)	2.1	69.1	67.6	84.5*	121.8
4 Opera (0.75)	6.8	68.0*	68.2	77.1	129.5
5 Fortress (0.2)	12.7	65.2*	57.3*	94.4*	168.7*
6 Spyrale (1.0)	1.1	69.4	65.7	83.9	136.0
7 Punch(0.31)	5.1	64.5*	66.2	82.2	136.3
8 Punch C (0.31) + Opera (0.5)	1.7	70.2	70.5	78.2	120.6
9 Cabaret (0.125) + Fortress (0.1)	2.9	70.8	67.7	83.7	130.3
10 Spyrale (0.5) + Fortress (0.1)	2.3	69.3	69.2	80.4	137.5
11 Punch C (0.31) fb. Cabaret (0.125)	0.3	76.9	68.2	71.8	118.0
12 Untreated	19.3	64.8	59.3	94.5	160.3
5% LSD	3.7	3.8	6.4	10.6	22.2
CV %	-	5.6	9.7	-	-

Data are means of 8 plots (2 harvests combined)
*Not significantly different from untreated

2. Reduced rates, mixtures and sequences of fungicides

(a) Aims:

As in previous years, the objectives were to compare full and half rates of products (including the newly introduced product, Spyrale) along with half-rate mixtures and sequential applications, on a susceptible variety.

(b) Methods:

The variety Harry (NIAB resistance rating = 1) was inoculated on 10th July by introducing mildew infected plants throughout the trial area at Broom's Barn. 25mm irrigation was supplied on the 12th and 20th July. The 16 treatments (Table 14) were laid out as five randomized blocks and the first sprays applied on 25th July. Disease assessments were carried out 4 and 7 weeks after this and the trial was machine harvested (4 rows x 8.3m) on 7th November.

(c) Results:

Mildew development was rapid, reaching an average 57% of leaf area on the untreated plots by 23rd August (Table 14). Plots sprayed with Cabaret (0.25 and 0.125 l/ha), Opera (0.75 and 0.5 l/ha) and half-rate Punch showed significant levels of disease at this stage. By seven weeks after treatment, significant re-invasion had occurred with almost all products. On plots receiving a single fungicide application, only full-rate Punch, Spyrale and Fortress had significantly less mildew than the untreated control. As would be expected, the most effective control at this time was achieved with the two-spray programme of full-rate Spyrale (or Punch) followed by Cabaret.

The yield of this very susceptible variety was increased significantly by single applications of full-rate Opera and Spyrale but not by Punch, Cabaret or Fortress. Spyrale gave the highest yield increase, 9.7 adj. tonnes (11%) more than the untreated. Cabaret + Fortress mixtures increased yields but Punch + Cabaret did not. All three sequences increased yields by, on average, a further 8 adjusted tonnes more than a single application. The two doses of full-rate Spyrale gave the largest response, an increase of 18.2 adj. tonnes (21%) over the untreated and 8.5 adj. tonnes more than a single dose. Of the quality components significantly affected by the treatments, amino-N levels were reduced by full-rate Cabaret and Spyrale and by all the sequences. Lowest levels were achieved with full-rate Punch followed by full-rate Cabaret and by two applications of full-rate Spyrale. Na levels were also most reduced by these two treatments; the non-triazole Fortress had the highest Na level.

Table 14. Mildew levels, yield and quality components in the Reduced Rates and Mixtures of Fungicides trial, 2006

Treatments (l/ha)†	Powdery Mildew % Leaf area infected		Yield at harvest (adj.t/ha)	Impurities (mg/100g sugar)	
	23/8	14/9		Amino-N	Na
1. Untreated	56.8	29.9	86.3	48.4	127
2. Punch (0.625)	12.1	23.7*	89.0*	42.3*	122*
3. Cabaret (0.25)	25.6	32.6*	88.9*	38.5	106
4. Opera (0.75)	28.6	34.8*	94.2	43.6*	117*
5. Spyrale (1.0)	10.5	18.4	96.0	40.3	112*
6. Fortress (0.2)	6.4	18.0	88.8*	42.1*	143*
7. Punch (0.31)	23.1	28.2*	94.7	47.0*	129*
8. Cabaret (0.125)	44.3	33.4*	89.9*	44.5*	120*
9. Opera (0.5)	30.1	33.5*	90.4*	51.1*	119*
10. Fortress (0.1)	21.8	26.6*	87.4*	47.2*	137*
11. Punch (0.31) + Cabaret (0.125)	14.9	27.8*	89.1*	40.1	123*
12. Cabaret (0.125) + Fortress (0.1)	10.6	32.1*	93.4	44.8*	123*
13. Cabaret (0.125) + Fortress (0.2)	2.4	25.7*	93.5	43.9*	120*
14. Punch (0.31) fb. Cabaret (0.125)‡	17.4	13.4	97.0	41.6	109*
15. Punch (0.625) fb. Cabaret (0.25) ‡	9.3	5.2	96.2	34.3	104
16. Spyrale (1.0) fb. Spyrale (1.0)	4.5	0	104.5	33.8	98
5% LSD	8.1	6.7	6.6	6.7	20
CV	-	-	5.6	-	-

† First applications: 25th July
‡ Second applications: 22nd August
* Not significantly different from untreated

3. General Conclusions from 2006 trials

1. There was no significant interaction between fungicide treatments and harvest dates.

2. When a susceptible variety was inoculated with mildew in mid-July, a single application of the most effective fungicide in late-July failed to control disease beyond about 4 weeks (Fig. 7). A second fungicide application was economically worthwhile, increasing yields by a further 8 adj. tonnes on average in one trial (Table 14).

3. Spyrale, Fortress and Punch C gave the most effective control of mildew under severe disease pressure but, in general, Fortress gave the smallest yield improvement over the untreated control (Fig. 8), probably because it lacked the physiological activity of the triazoles (see Fig. 11).

4. Half rates of fungicides failed to control disease adequately but this was not always accompanied by an equivalent yield penalty.

5. Rust was effectively controlled by all the triazoles but not by Fortress (Fig. 9). Of the individual fungicides, Cabaret and Spyrale gave the best control. Overall, the most effective control of rust was achieved with a half rate of Punch C followed by a half rate of Cabaret 4 weeks later; this gave a yield response of 12 adj. tonnes (Fig. 10).

6. In the absence of disease, yields were increased significantly by all triazoles and half-rate triazole mixtures with Fortress.

Figure 7. Mildew levels in an inoculated trial on a highly susceptible variety at Broom's Barn in the Collaborative Trials (2006), 4 and 7 weeks after fungicides applied. Selected treatments only.

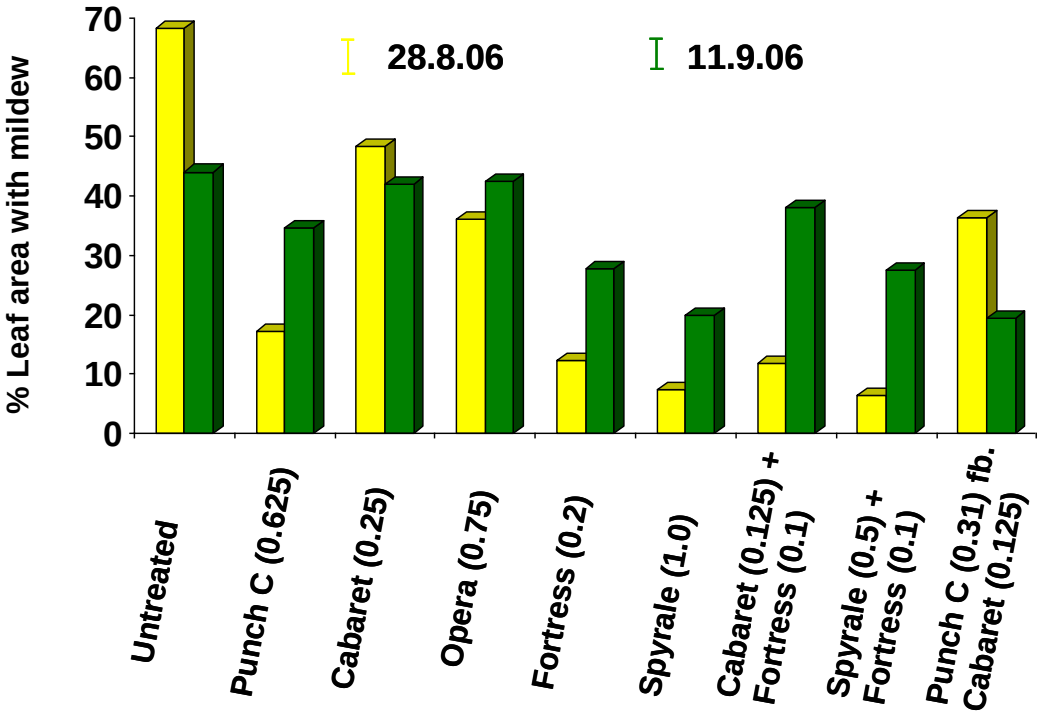


Figure 8. Yields (early and late harvest combined) in the mildew trial at Broom's Barn in the Collaborative Trials (2006). Selected treatments only.

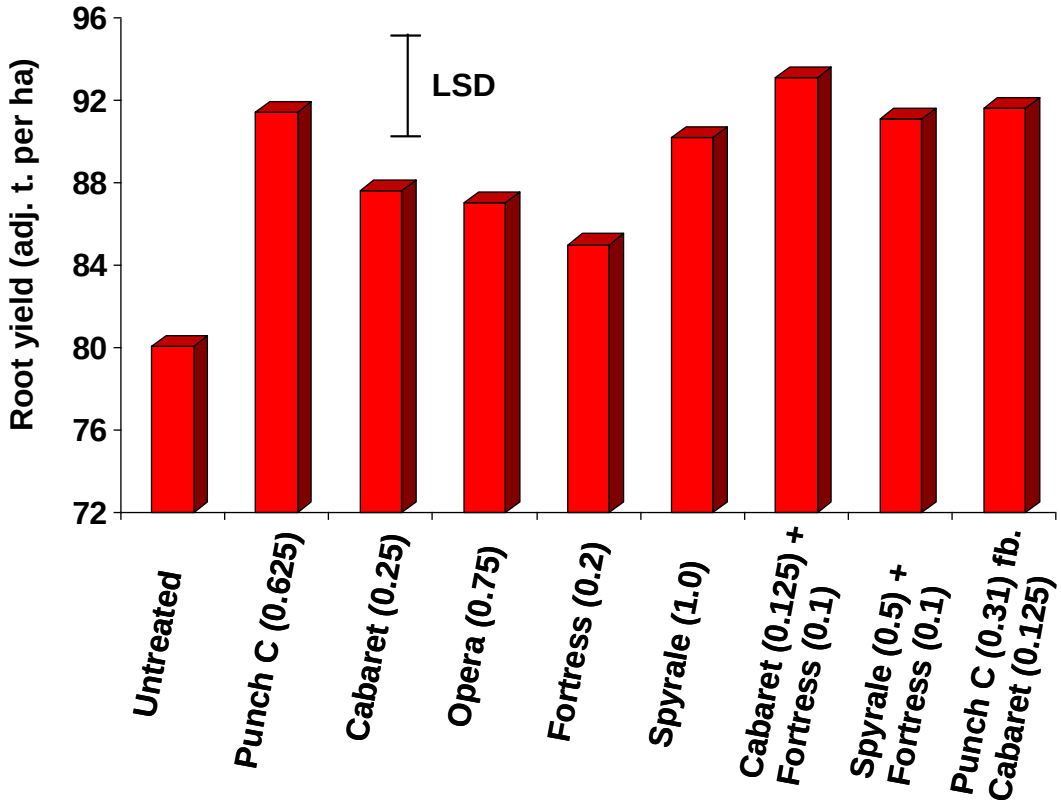


Figure 9. Levels of rust on a susceptible variety at the end of September at Bardwell, in the Collaborative Trials (2006). Selected treatments only.

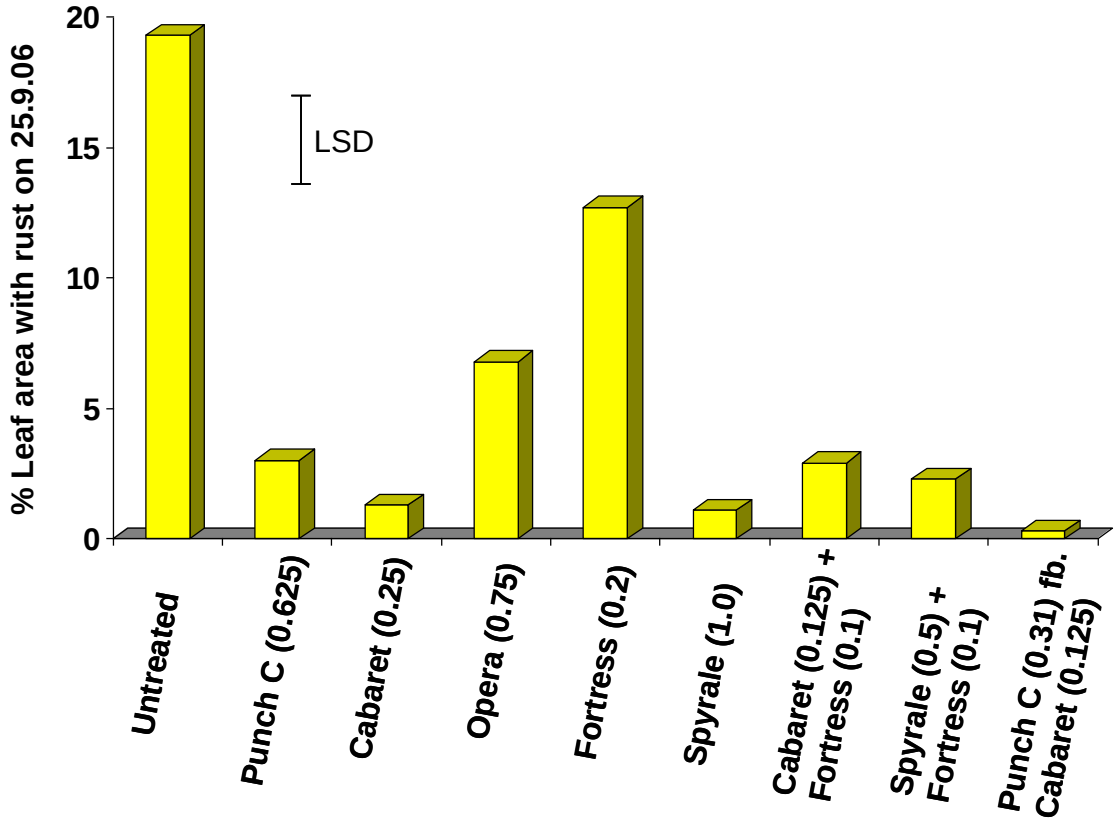


Figure 10. Yields (early and late harvests combined) in the rust trial at Bardwell, in the Collaborative Trials (2006). Selected treatments only.

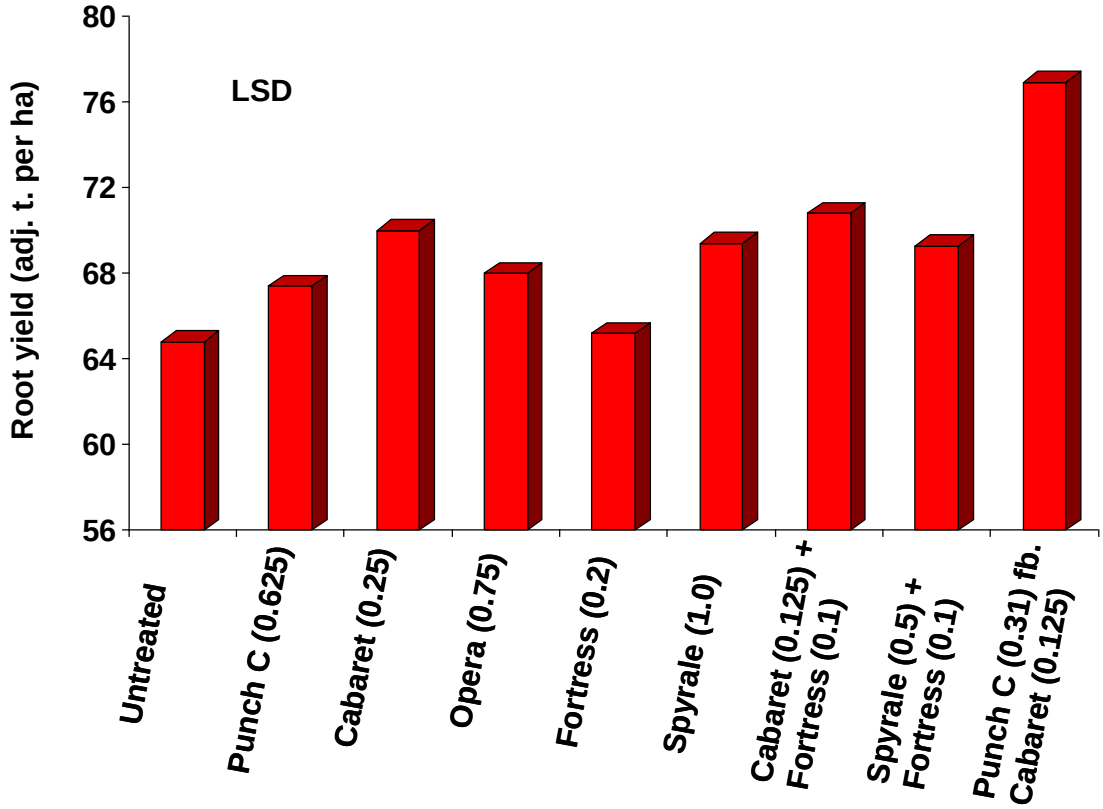
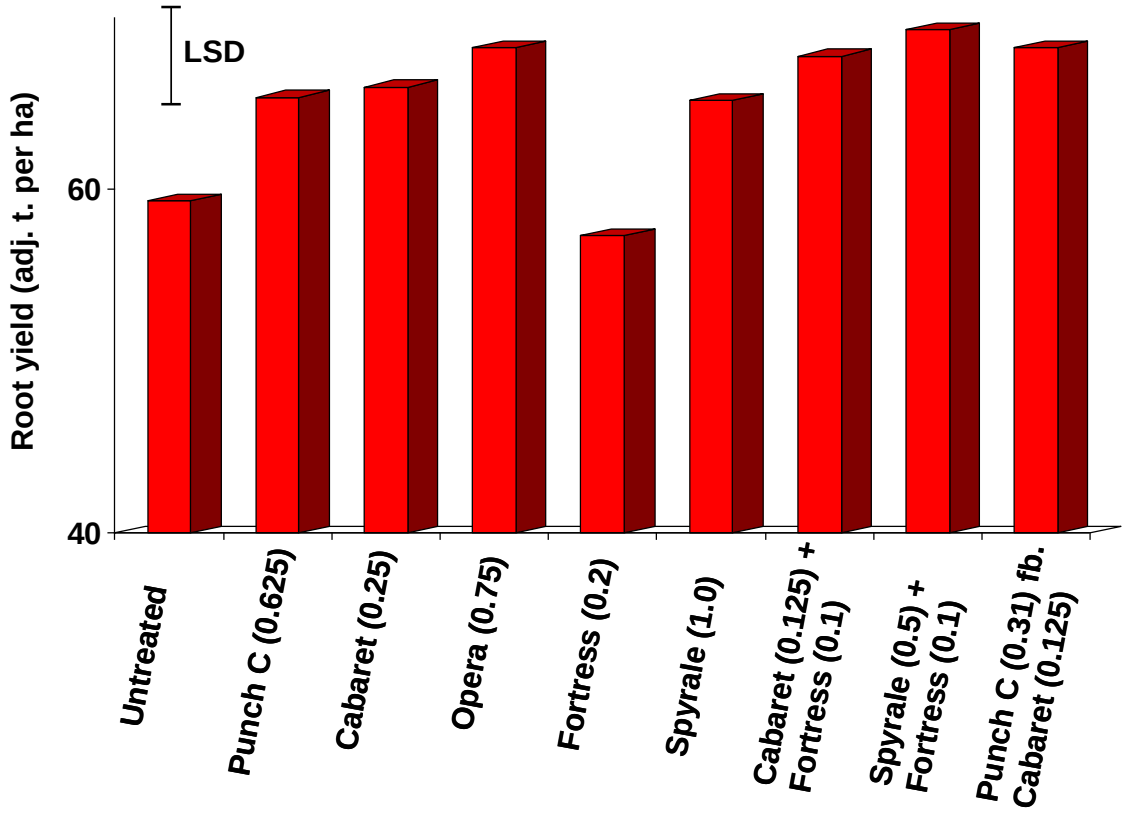


Figure 11. Yields (early and late harvests combined) in the disease-free trial at Hibaldstow, in the Collaborative Trials (2006). Selected treatments only.



2007

1. **Fungicide products, reduced rates and mixtures *vs.* harvest dates**
2. **Reduced rates, mixtures and sequences of fungicides**
3. **General conclusions from 2007 trials**

Part 1: Discussion and conclusions

PART 2. PHYSIOLOGICAL EFFECTS.

3. NUMBER OF STAFF YEARS AND COSTS (2007/8)

Planned Expenditure:

Actual Expenditure:

Planned scientific staff input (years):

Actual scientific staff input (years):

4. ACHIEVEMENTS

- The relative efficacy of the different fungicide products in controlling powdery mildew and rust has been established and the resulting yield benefits highlighted
- The yield boost from triazole and strobilurin fungicides in the absence of disease has been confirmed
- The strengths and weaknesses of reduced rates, mixtures and sequential applications of fungicides have been explored
- The requirements for the effective protection of susceptible varieties from mildew and rust have been established and the benefits of two spray programmes on these varieties highlighted
- Data from the trials has been widely disseminated in articles and presentations, along with advice to inform on-farm decision making
- The ongoing results of this project have contributed to the increasing usage of triazole fungicides nationally. The 70% of the national area sprayed with a triazole in 2006 would have given an additional yield of at least 300K adjusted tonnes (6%)

5. INTELLECTUAL PROPERTY

?

6. FURTHER RESEARCH

To be completed

7. COMMUNICATION OF RESEARCH RESULTS

(a) Articles and Papers

Asher, M. (2005). Fungicides for 2005. *British Sugar Beet Review* **73** (2), 28-32.

Asher, M.J.C. and Ober, E. (2005). Fungicides for the control of foliar diseases in sugar beet: fungicidal and physiological effects. In: Production and Protection of Sugar Beet and Potatoes, *Aspects of Applied Biology* **76**, 27-33.

Asher, M. (2006). Maximizing yield potential with fungicides. *British Sugar Beet Review* **74** (2), 44-47.

Stevens, M., May, M. and Asher, M. (2007). Fungicides for 2007. *British Sugar Beet Review* **75** (2), 19-22.

(b) Presentations at meetings

2006	'Foliar disease control'	BBRO meeting Spalding	24 Jan
		BBRO meeting Newmarket	25 Jan
		BBRO meeting York	26 Jan
		BBRO meeting Norwich	31 Jan
		BBRO meeting Telford	1 Feb
		BBRO meeting Newark	2 Feb
2007	'Crop Protection under a changing climate and sugar regime'	BBRO meeting Newmarket	1 Feb
		BBRO meeting Lincoln	6 Feb