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Disease control programmes using triazole and strobilurin fungicides on winter wheat

by

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Contents

Abstract

The project was based upon eight experiments at various locations within Britain that were conducted to evaluate the timing of the addition of strobilurins to a three spray triazole programme in each growing season from 2002 to 2004. During this period, resistance of *Septoria tritici* to the strobilurins rose from a trace in 2002 to such an extent that in 2004 field control was severely compromised. All experiments were conducted on the winter wheat cultivar Consort which is relatively susceptible to *Septoria tritici* (HGCA Recommended List rating 4) and brown rust (*Puccinia recondita*) (HGCA Recommended List rating 4). At all sites and in all years *Septoria tritici* was the predominant foliar disease but its development between seasons and locations was diverse.

In 2002, and to a lesser extent in 2003, the optimum timing for the addition of two strobilurins was at T1 (third final leaf emerging) and T3 (mid-anthesis). This approach was identified in TAG trials in Norfolk in previous years but showed little advantage over an alternative strategy of adding strobilurins to the T2 (full flag leaf emergence) and T3 applications of triazoles. However, the T1 and T3 approach was not surpassed by any other combination of strobilurin addition to the programme in any of the national trials in 2002 and the approach was still the most robust in 2003. This strongly suggests that such an approach was appropriate nationally and there was no need for regional variations in fungicide strategy in terms of strobilurin timing.

However, the mutation that conferred resistance of *S. tritici* to the strobilurins was detected in almost 100% of isolates by the end of the 2004 season. In this year, the addition of the strobilurins did not significantly increase yields but trends suggested that they were best applied at T1 and T3 or T2 and T3. This was despite disease pressure only being significant early in the season. This suggested a change in role for any addition of the strobilurins from *S tritici* control and ear disease control to ear disease control alone. In addition, late strobilurin application has long been recognised to prolong green leaf area in the apparent absence of disease control and such a property can sometimes lead to an enhanced yield. Hence, the possible role for strobilurins in the future may be largely restricted to an application late in the season to control ear diseases, possibly supplement the triazoles on brown rust control and to prolong green leaf area. In addition, the experiments in 2004 identified the potential enhanced role of chlorothalonil in programmes where there was concern over the resistance of *S. tritici* to fungicides.

Summary

Objectives

To identify whether the differences in past results on the timing of the use of the strobilurin based treatments are due to:

i. The time interval between T1 and T2 or

ii. The intensity of the disease pressure between T1 and T2

To identify whether using strobilurin based rather than triazole based treatments on the ear provides more reliable yield responses at this timing.

To evaluate a programme that adopts a strategy of using strobilurin-based treatments at T1 and T3 and a triazole-based treatment at T2.

To evaluate the benefit of a T0 application of chlorothalonil (year 3 only).

To evaluate the addition of chlorothalonil to strobilurin based treatments at T1 and T2 (year 3 only).

Methods

Seven or eight experiments were conducted in each growing season from 2002 to 2004 at various locations (Berwickshire, Yorkshire, Norfolk, Suffolk, Cambridgeshire, Gloucestershire, Hampshire and Devon). All experiments were conducted on the cultivar Consort which is relatively susceptible to *Septoria tritici* (HGCA Recommended List rating 4) and brown rust (*Puccinia recondita*) (HGCA Recommended List rating 4). Crops were drilled as first wheats from mid September to mid October to minimise the potential impact of eyespot species and take-all (*Gaeumannomyces graminis*).

The experiments were designed to evaluate the benefit of the addition of strobilurins at two or three of the timings of a three spray programme of triazoles. Foliar treatments were applied in accordance with the treatment list which was adapted each season to reflect the rapid advancement

of *Septoria tritici* resistance to strobilurins. All experiments were conducted as a randomised block design with four replicates. The timings were typical of wheat fungicide timings, T1 was at the emergence of final leaf three (typically Zadoks GS 32), T2 was at full flag leaf emergence (GS 39) and T3 was at mid-anthesis (GS 65). In the first two years the application of the T1 treatment at ear at 1 cm (GS 31) rather than GS 32 was evaluated to measure whether the addition of strobilurins provided more persistence of disease control, thus explaining the advantage that some organisations claim from adopting their application at T1 and T2. In the final year, the role of chlorothalonil in fungicide programmes was evaluated.

At each assessment disease and or green leaf area was recorded as percentage infection on each individual leaf layer on a whole plot basis. In each year the first assessment was carried out across the whole experiment area to establish base levels of disease just prior to the first fungicide application. In all years disease and green leaf area assessments of all plots were scheduled at GS 32 (T1), GS 39 (T2), GS59 (full ear emergence) and GS 75 (milky ripe). From GS 83 (early dough) green leaf area assessments of the leaves 1 to 3 were scheduled at weekly intervals until senescence of these leaf layers was complete.

The plots were harvested and yields (t/ha at 85% dm) and specific weights (kg/hl at 85%dm) were calculated. Data was analysed using analysis of variance (ANOVA).

Key results and conclusions

<u>2002</u>

There was diverse disease pressure across the seven sites. Disease development appeared to be largely driven by rainfall during April at the time when the upper canopy leaves were emerging. Despite the diversity in disease pressure between sites a three-spray programme with strobilurin based treatments (Twist 1.0 l/ha + Opus 0.3 l/ha) at T1 (GS 32) and at T3 (GS 65), (Amistar 0.25 l/ha + Folicur 0.25 l/ha) with a triazole based treatment at T2 (GS 39), (Opus 0.75 l/ha + Bravo 1.0 l/ha) gave the greatest yield at all seven sites.

The results also suggested that the benefit of a strobilurin applied at T1 is not associated with a long time interval before T2 due to improved persistent activity but may be more related the level of control.

At two sites strobilurin based treatments at T2 and T3 produced significantly greater yields than treatments with strobilurins applied at T1 (GS 31) and T2. These sites were at Devon where there was high disease pressure throughout the season and at the low disease pressure site in Scotland, which had an extended ripening period. Consequently, despite contrasting disease pressure early in the season both sites benefited from the improved control from the strobilurin based treatments later in the season.

<u>2003</u>

In this season data from individual sites shows few statistical differences between treatments. However, the addition of strobilurin at T1 (GS 32) and T3 gave the greatest yield response at four sites. This strategy was not surpassed in yield at any site.

Disease pressure was relatively low early in the season. This may explain why there was no obvious yield penalty when T1 was applied early at GS 31 compared with a later T1 application at the emergence of final leaf three (GS 32).

<u>2004</u>

In 2004 the data clearly reflects the impact of widespread *Septoria tritici* resistance to strobilurins. In this year data at all sites suggests that strobilurins had little impact on the control of *Septoria tritici*. Yield responses to the addition of the strobilurins were small (mean response of less than 0.2 t/ha, however, responses up to 0.4 t/ha were measured at some sites) and unlikely to be cost effective at current strobilurin and grain prices. A triazole only programme performed well at all sites.

Programmes including a strobilurin at T3 preceded by strobilurin at T1 or T2 performed consistently well across all seasons and regions. In addition, there was no difference between programmes with the addition of strobilurins at T2 and T3 or T1 and T3, suggesting a change in role for strobilurins. As in previous years the addition of strobilurins at T1 and T2 gave the poorest performance at each site and in 2004 these programmes in particular benefited from the addition of chlorothalonil, both in terms of disease control and yield.

The most benefit from a T0 application at the pseudostem erect stage (GS 30) of chlorothalonil was seen where T1 was delayed due to poor weather conditions in an early disease pressure situation.

The results suggest that chlorothalonil should be considered an integral part of the programme improving control of *Septoria tritici* and to improve the anti resistance strategy and may reduce the dose of triazole required.

Implications

In all three years disease pressure was diverse across the eight UK sites and disease development appeared to be largely influenced by rainfall from April onwards, at the time when the upper canopy leaves were emerging. Despite the diversity of disease pressure between sites the most successful programmes at each site have been remarkably similar particularly with regard to the most appropriate timing of strobilurins within the programme. This suggests that fungicide strategies in terms of the timing of the addition of the strobilurins did not vary regionally across Great Britain.

In all years a strobilurin based treatment at T1 and T3 with a triazole based treatment at T2 was a consistently good treatment. In 2004 (when strobilurins had little impact on the control of *Septoria tritici*) programmes including a strobilurin at T3 either preceded by a strobilurin application at T1 or T2 performed consistently well across all sites. This indicates a changing emphasis of the role of strobilurins from *S. tritici* control, ear disease control and green leaf area retention to primarily green leaf area retention and ear disease control. However, yield responses to strobilurins were small (up to 0.4 t/ha), and unlikely to be cost effective a current product costs and grain prices. This suggests that if there is a role for strobilurins on future wheat crops they should be applied at the later timings within the fungicide strategy, particularly at T3.

This project provides evidence that strobilurin based treatment at T1 (emergence of final leaf 3) and T2 (full flag leaf emergence) and the possible use of a triazole based treatment at T3 on the ear was not the most appropriate use of strobilurin chemistry as suggested by many commentators. In addition, there was no evidence to suggest that the addition of strobilurins at T1 and T2 were beneficial when there was an extended time interval between these applications.

Whilst fungicide dose within programmes must be flexible and tailored according to variety susceptibility and disease pressure these experiments suggest a similar strategy can be employed in all major arable regions in Great Britain.

Detailed Technical Report

1. Introduction

The objectives of the experiments reported here were:

- To identify whether the differences in past results on the most appropriate timing of the strobilurin based treatments in winter wheat are due to:
    - the time interval between T1 and T2 or
    - the intensity of the disease pressure between T1 and T2
- To identify whether using strobilurin based rather than triazole based treatments on the ear provides more reliable yield responses at this timing.
- To evaluate a programme that adopts a strategy of using strobilurin-based treatments at T1 and T3 and a triazole-based treatment at T2.

In response to increasing frequency and geographic spread of *Septoria tritici* resistance to strobilurins additional objectives were set in 2004 to evaluate the benefit of a T0 application of chlorothalonil and the addition of chlorothalonil to strobilurin based treatments at T1 and T2.

Presentations at the HGCA Roadshows during the winter of 2001 suggested a common approach to the use of fungicides in winter wheat throughout Britain. This was to use a strobilurin based treatment at T1 (emergence of final leaf 3) and T2 (full flag leaf emergence) and possibly to use a triazole based treatment at T3 on the ear. However, evidence from independent experimental groups (Morley Research Centre (MRC), Scottish Agricultural College (SAC) and National Institute Agricultural Botany (NIAB)) had suggested that a common approach to the use of fungicides in winter wheat throughout Britain may not be appropriate and that the application of strobilurins at T1 and T2 may not be the best way of exploiting this chemistry.

The aims of this project are to explain the disparities in previous results, which could be due to differences in early disease pressure from *Septoria tritici* or too long a time interval between the T1 and T2 treatments favouring the use of the persistent strobilurins at T1. The experiments were also designed to determine whether the introduction of the strobilurins has increased the significance of the ear spray.

The foundations of fungicide programmes in winter wheat are built around protecting the crop from *Septoria tritici*. It has been proved by a range of research organisations that to safeguard the yield potential of the crop it is only necessary to protect the final three leaves. The introduction of strobilurin fungicides in the 1990's bought more effective and persistent control of *Septoria tritici*. However, since the beginning of this project *Septoria tritici* resistance to strobilurins has been discovered and is now frequent and widespread throughout the United Kingdom. In response to this development the treatment list was updated each year. Now that this resistance is endemic, data from 2004 shows the response to strobilurins and value of other modes of actions (triazoles and chlorothalonil) within winter wheat fungicide programmes. In the initial stages of *Septoria tritici* resistance to strobilurins the Fungicide Resistance Action Committee (FRAC) and Fungicide Resistance Action Group (FRAG) recommended that only two strobilurin applications should be made to any crop to prevent the further development of resistance to these fungicides.

Experimental data from East Anglia (Norfolk, Suffolk and Essex) and in Scotland which initially prompted this project (prior to knowledge regarding the rapid spread of *Septoria tritici* resistance to strobilurins) is typified in Table 1 and 2.

Table 1. Yields of wheat (cultivar Riband) in a fungicide programme experiment using 'conventional' treatments (triazole based) and strobilurin based treatments, Morley 1998-2000 (t/ha at 85% dm)

T1	**T2**	**T3**	**Yield**
Strobilurin	Strobilurin	Strobilurin	11.59
Strobilurin	Conventional	Strobilurin	11.52
Conventional	Strobilurin	Strobilurin	11.45
Strobilurin	Strobilurin	Conventional	11.13
Conventional	Conventional	Conventional	10.60

Data generated at MRC in Norfolk and SAC in the Scottish Borders also suggested that strobilurins at T1 and T3 may be an even more desirable approach than using strobilurins at T2 and T3 (Tables 1 and 2). However, only limited data was available from these sites and this approach required further investigation. The success of this programme was thought to be because a triazole based treatment at T2 was effectively able to bridge the gap between strobilurin based applications at T1 and T3. Perhaps strobilurins at T1 gave the crop a good start and strobilurins at T3 protected the ear and maintained green leaf area. This theory is supported by HGCA sponsored data from MRC (HGCA project 2087) which suggests that using a two spray programme of strobilurin based treatments applied at a conventional T1 timing (emergence of final leaf 3) and a delayed T2 timing at ear emergence almost matches a conventional three-spray programme on varieties with good tolerance to disease e.g. Claire.

Table 2. Yields of wheat (cultivars Riband, Aardvark and Eclipse) in a fungicide programme experiment using 'conventional' treatments (triazole based) and strobilurin based treatments, Scottish Borders 2001 (t/ha at 85% dm)

			Yield		
T1	**T2**	**T3**	**Riband**	**Aardvark**	**Eclipse**
Strobilurin	Strobilurin	Strobilurin	6.35	8.15	7.24
Strobilurin	Conventional	Strobilurin	8.64	9.12	8.12
Conventional*	Strobilurin	Strobilurin	8.05	8.88	8.28
Strobilurin**	Strobilurin	Conventional	8.44	8.91	7.91
Conventional	Conventional	Conventional	7.83	8.78	8.08

* = weak eyespot control, ** = effective eyespot control, bold figures = best yielding treatments.

In some seasons applying a strobilurin based treatment at T3 prolonged green leaf area compared with a triazole based treatment thus increasing the potential yield response from a T3 application (Tables 1 and 3).

Possible reasons for the disparity in past results between experimental groups and different parts of the UK on the most appropriate timing of the strobilurin based treatments in winter wheat include the following:

- A longer gap between the emergence of final leaf three and full flag leaf emergence in some parts of the country, thus favouring the application of the more persistent strobilurins at T1.

- The T1 spray being applied too early (i.e. prior to the emergence of leaf 3), thus favouring the application of the more persistent strobilurins at this timing.

- The areas where there has been a recorded advantage to the use of strobilurins at the T1 timing tend to be those with more intense disease pressure from *Septoria tritici* prior to application of the flag leaf treatment. This may favour the use of the more effective strobilurin based treatments at T1.

- Landmark (kresoxim-methyl + epoxiconazole) can reduce the level of eyespot when applied at T1. This is a possible explanation for the benefit of strobilurins at T1 and was not examined within this experiment, however, to reduce the potential impact of eyespot on the data all experiments were carried out on first wheats drilled from mid September. Data from other organisations suggesting the benefit of strobilurin based treatments at T1 was claimed to be consistent and therefore the occasional occurrence of eyespot may not influence yield response.

- On light soils the value of a T3 treatment may be devalued in seasons with a late drought. This may favour using strobilurins at T1 and T2. However, experiments favouring the use of strobilurins at T1 and T2 have been carried out in the West of England on well-bodied soils in wet seasons. Hence, this aspect was not examined as part of this project.

Table 3. Green leaf area (GLA), (%) of final leaves one (flag), two and three in cultivar Riband, data from a fungicide programme experiment using conventional and strobilurin based treatments, Morley 2000

			GLA of final leaves 1-3 (%)		
T1	**T2**	**T3**	**27 July**	**2 August**	**8 August**
Strobilurin	Strobilurin	Strobilurin	74	52	12
Strobilurin	Conventional	Strobilurin	77	52	11
Conventional	Strobilurin	Strobilurin	76	51	13
Strobilurin	Strobilurin	Conventional	72	37	2
Conventional	Conventional	Conventional	64	17	0

2. Materials and Methods

2.1 Sites

Eight experiments were conducted in each growing season from 2002 to 2004 at various locations within the United Kingdom (Table 4). All experiments were conducted on the cultivar Consort which is relatively susceptible to *Septoria tritici* (HGCA Recommended List rating 4) and brown rust (*Puccinia recondita*), (HGCA Recommended List rating 4). Crops were drilled as first wheats from mid September to mid October to minimise the potential impact of eyespot species and take-all (*Gaeumannomyces graminis*).

Table 4. Experimental sites and collaborators

Site No.	Location	Collaborator
1.	Whitsome, Berwickshire,	SAC
2.	Headley Hall, Yorkshire	NIAB
3.	Morley St Botolph, Norfolk	MRC/TAG*
4.	Otley, Suffolk	MRC/TAG
5.	Cambridge, Cambridgeshire	NIAB**
6.	Daglingworth, Gloucestershire	ARC/TAG*
7.	Sutton Scotney, Hampshire	ARC/TAG
8.	Seal Hayne, Devon	NIAB

* In October 2003 Arable Research Centres (ARC) and Morley Research Centre (MRC) merged to become The Arable Group (TAG).

** The Cambridgeshire experiment was abandoned in the 2001/2002 season due to over-spraying by farm operators with a foliar fungicide.

Tables 5, 6 and 7 summarise sowing date, and previous cropping at each site throughout the project.

Table 5a. Summary of experiment information, 2002

County	Berwickshire	Yorkshire	Norfolk	Suffolk
Variety	Consort	Consort	Consort	Consort
Previous cropping	Beans	Spring pulses	Beans	Beans
Sowing date	16 October 01	11 October 01	11 October 01	6 October 01

Table 5b. Summary of experiment information, 2002

County	Gloucestershire	Hampshire	Devon
Variety	Consort	Consort	Consort
Previous cropping	Oilseed rape	Set aside	Break crop species unknown
Sowing date	4 October 01	22 September 01	12 October 01

Deviations from protocol: At the Berwickshire site T1A was applied late (GS 31-32) due to unfavourable conditions for application. T1B was applied at the target growth stage (GS 32) in the afternoon of the same day.

Table 6a. Summary of experiment information, 2003

County	Berwickshire	Yorkshire	Norfolk	Suffolk
Variety	Consort	Consort	Consort	Consort
Previous cropping	Oilseed rape	Grass	Peas	Beans
Sowing date	1 October 02	27 September 02	25 September 02	3 October 02

Table 6b. Summary of experiment information, 2003

County	Cambridgeshire	Gloucestershire	Hampshire	Devon
Variety	Consort	Consort	Consort	Consort
Previous cropping	Beans	Oilseed rape	Set aside	Peas
Sowing date	23 September 02	7 October 02	3 October 02	11 October 02

Deviations from protocol: At the Cirencester site the stretched T2 treatment was applied late (GS 65) due to unfavourable conditions for application.

Table 7a. Summary of experiment information, 2004

County	Berwickshire	Yorkshire	Norfolk	Suffolk
Variety	Consort	Consort	Consort	Consort
Previous cropping	Oilseed rape	Oilseed rape	Set aside	Beans
Sowing date	25 September 03	11 October 03	30 October 03	6 October 03

Table 7b. Summary of experiment information, 2004

County	Cambridgeshire	Gloucestershire	Hampshire	Devon
Variety	Consort	Consort	Consort	Consort
Previous cropping	Oats	Set aside	Beans	Peas
Sowing date	23 September 03	2 October 03	25 September 03	8 October 03

2.2 Experimental design

A randomised block design incorporating between 10 and 12 treatments with four replicates was used for all experiments.

2.3 Data handling

Disease, green leaf area, yield and grain quality data was collected either manually or directly onto hand held computers. After collection all data was transferred to the statistical package Advanced Research Manager (ARM).

2.4 Statistical analysis

Data was analysed in ARM using analysis of variance (ANOVA).

2.5 Fungicide treatments

Foliar treatments were applied in accordance with the treatment list which was adapted each season following consultation with all collaborators to reflect the rapid advancement of *Septoria tritici* resistance to strobilurins. Fungicide treatments were applied as two, three or four spray programmes with the first application beginning at GS 30, GS 31 or GS 32. Sprays were applied in a water volume of 200 l/ha using hand-held pressurised plot spraying equipment fitted with flat fan nozzles, selected to produce a medium spray quality at 200-300 kPa pressure.

Details of fungicide treatments in each season are shown in the Tables 8, 9 and 10 below:

Table 8. Treatments in 2002

	Foliar treatment (dose in l/ha)			
Treatment No.	**GS 31**	**GS 32**	**GS 39**	**GS 65**
1.	Untreated	-	-	-
2.	-	Landmark (0.5)	Twist + Opus (1.0 + 0.3)	Amistar + Folicur (0.25 + 0.25)
3.	Opus + Bravo (0.5 + 1.0)	-	Twist + Opus (1.0 + 0.3)	Amistar + Folicur (0.25 + 0.25)
4.	Landmark (0.5)	-	Twist + Opus (1.0 + 0.3)	Folicur (0.5)
5.	-	Opus + Bravo (0.5 + 1.0)	Twist + Opus (1.0 + 0.3)	Amistar + Folicur (0.25 + 0.25)
6.	-	Landmark (0.5)	Twist + Opus (1.0 + 0.3)	Folicur (0.5)
7.	-	Landmark (0.5)	Opus + Bravo (0.75 + 1.0)	Amistar + Folicur (0.25 + 0.25)
8.	Landmark (0.5)	-	Opus + Bravo (0.75 + 1.0)	Amistar + Folicur (0.25 + 0.25)
9.	-	Landmark (0.5)	Twist + Opus (1.0 + 0.3)	-
10.	-	Opera (0.5)	Opera (0.75)	-

Table 9. Treatments in 2003

	Foliar treatment (dose in l/ha)				
Treatment No.	**GS 31**	**GS 32**	**GS 39**	**GS 55**	**GS 65**
1.	Untreated	-	-	-	-
2.	Landmark (0.5)	-	Twist + Opus (1.0 + 0.4)	-	Amistar + Folicur (0.25 + 0.25)
3.	-	Landmark (0.5)	Twist + Opus (1.0 + 0.4)	-	Amistar + Folicur (0.25 + 0.25)
4.	Opus + Bravo (0.5 + 1.0)	-	Twist + Opus (1.0 + 0.4)	-	Amistar + Folicur (0.25 + 0.25)
5.	-	Opus + Bravo (0.5 + 1.0)	Twist + Opus (1.0 + 0.4)	-	Amistar + Folicur (0.25 + 0.25)
6.	Landmark (0.5)	-	Opus + Bravo (0.75 + 1.0)	-	Amistar + Folicur (0.25 + 0.25)
7.	-	Landmark (0.5)	Opus + Bravo (0.75 + 1.0)	-	Amistar + Folicur (0.25 + 0.25)
8.	Landmark (0.5)	-	Twist + Opus (1.0 + 0.4)	-	Folicur (0.5)
9.	-	Landmark (0.5)	Twist + Opus (1.0 + 0.4)	-	Folicur (0.5)
10.	-	Landmark (0.5)		Opera (1.0)	-

Table 10. Treatments in 2004

	Foliar treatment (dose in l/ha)				
Tr't No.	**GS 30**	**GS 32**	**GS 39**	**GS 55**	**GS 65**
1.	untreated	-	-	-	-
2.	-	Opus + Bravo (0.5+1.0)	Opus + Bravo (0.75 + 1.0)	-	Folicur (0.5)
3.	-	Landmark (0.5)	Twist + Opus (1.0 + 0.75)	-	Folicur (0.5)
4.	-	Landmark + Bravo (0.5 + 1.0)	Twist + Opus (1.0 + 0.75)	-	Folicur (0.5)
5.	-	Landmark + Bravo (0.5 + 1.0)	Twist + Opus +Bravo (1.0 + 0.75 + 1.0)	-	Folicur (0.5)
6.	Bravo (1.0)	Opus + Bravo (0.5+1.0)	Twist + Opus (1.0 + 0.75)	-	Folicur + Amistar (0.25 + 0.25)
7.	-	Opus + Bravo (0.5+1.0)	Twist + Opus (1.0 + 0.75)	-	Folicur + Amistar (0.25 + 0.25)
8.	-	Opus + Bravo (0.5+1.0)	Twist + Opus +Bravo (1.0 + 0.75 + 1.0)	-	Folicur + Amistar (0.25 + 0.25)
9.	-	Opus + Bravo (0.5+1.0)	Twist + Opus +Bravo (1.0 + 0.5 + 1.0)	-	Folicur + Amistar (0.25 + 0.25)
10.	Bravo (1.0)	Landmark + Bravo (0.5 + 1.0)	Opus + Bravo (0.75 + 1.0)	-	Folicur + Amistar (0.25 + 0.25)
11.	-	Landmark + Bravo (0.5 + 1.0)	Opus + Bravo (0.75 + 1.0)	-	Folicur + Amistar (0.25 + 0.25)
12.	-	Landmark + Bravo (0.5 + 1.0)	-	Opera + Opus (1.0 + 0.35)	-

Table 11. Active ingredients of commercial products used

Product	Active ingredients (ai)	g ai/l	Formulation
Amistar	azoxystrobin	250	SC
Bravo	chlorothalonil	500	SC
Folicur	tebuconazole	250	EW
Landmark	epoxiconazole + kresoxim-methyl	125:125	SC
Opera	epoxiconazole + pyraclostrobin	50:133	SE
Opus	epoxiconazole	125	SC
Twist	trifloxystrobin	125	EC

Foliar fungicide applications were timed as closely as possible to protocol guidelines. The actual timing of applications for each experiment is shown in Tables 12, 13 and 14. All other agrochemical and fertiliser inputs were applied in accordance with Good Agricultural Practice for each site.

Table 12. Date of applications and Zadoks growth stage (ZGS, shown in brackets) in 2002

	Application timing and target ZGS					
Site	**T1A** **GS 31**	**T1B** **GS 32**	Days from T1A-T1B	**T2** **GS 39**	Days from T1A-T2	**T3** **GS 65**
Berwick	25 April (31-32)	25 April (32)	0	31 May (43)	36	24 June (65)
Yorkshire	15 April (31)	3 May (32)	17	27 May (45)	42	18 June (65)
Norfolk	19 April (31)	6 May (32-33)	17	25 May (43)	36	14 June (65)
Suffolk	23 April (31)	3 May (32)	10	21 May (39)	28	12 June (65)
Gloucs	15 April (31-32)	24 April (32)	8	27 May (55)	42	18 June (67)
Hampshire	13 April (30-31)	23 April (31)	10	16 May (39)	33	14 June (65)
Devon	26 March (30-	16 April (32)	20	31 May (55)	65	18 June (65)

Actual crop growth stage at application is shown in brackets.

Table 13. Date of applications and Zadoks growth stage (ZGS, shown in brackets) in 2003

	Application timing and target ZGS					
Site	**T1A** **GS 31**	**T1B** **GS 32**	Days from T1A-T1B	**T2** **GS 39**	Days from T1A-T2	**T3** **GS 65**
Berwick	17 April (31)	9 May (32-33)	22	29 May (39)	42	14 June
Yorkshire	22 April (31)	30 April (32)	8	25 May (39)	33	7 June (60)
Norfolk	15 April (31)	23 April (32)	8	21 May (39-	36	9 June (65)
Suffolk	17 April (30-	7 May (32)	20	27 May (39-	40	13 June
Cambridge	7 April (31)	23 April (32)	16	25 May (43)	48	13 June
Gloucs	6 May (32)	14 May (32-33)	8	27 May (49)	21	24 June
Hampshire	22 April (30)	6 May (32)	13	21 May (39)	28	9 June (65)
Devon	26 March (31)	15 April (32)	20	18 May (39)	53	12 June

Actual crop growth stage at application is shown in brackets.

GS 55 application dates for each site were; Berwickshire 5 June (GS 55), Yorkshire 31 May (GS 55), Norfolk 3 June (GS 55-59), Suffolk 3 June (GS 55-59), Cambridgeshire 5 June (GS 61), Gloucestershire 24 June (GS 65), Hampshire 30 May (GS 55) and Devon 11 June (GS 55).

Table 14. Date of applications and Zadoks growth stage (ZGS, shown in brackets) in 2004

	Application timing and target ZGS					
Site	**T0** **GS 30**	**T1** **GS 32**	**T2** **GS 39**	Days from T1-T2	**T2+** **GS 55**	**T3** **GS 65**
Berwick	8 April (30)	25 April (32)	26 May (39)	48	7 June 55	15 June (65)
Yorkshire	1 May (30)	17 May (32)	5 June (39)	15	15 June (55)	21 June (65)
Norfolk	17 April (30-31)	5 May (32)	24 May (39-41)	19	7 June (55)	14 June (65)
Suffolk	23 April (30)	13 May (32)	31 May (39)	18	9 June (55)	16 June (65)
Gloucs	8 April (23-30)	2 May (32)	24 May (39)	22	7 June (55)	22 June (65)
Cambridge	15 April (30)	13 May (32)	2 June (43)	16	9 June (57)	18 June (65)
Hampshire	7 April (30)	23 April (32)	19 May (39)	21	7 June (61)	16 June (65)
Devon	25 March (30)	14 April (32)	20 May (39)	31	1 June (55)	7 June (65)

Actual crop growth stage at application is shown in brackets.

2.6 Assessment of foliar disease and green leaf area

At each assessment disease and or green leaf area was recorded as percentage infection on each individual leaf layer on a whole plot basis. Prior to flag leaf emergence the eventual leaf number of each assessed leaf layer was ascertained either by dissection or leaf tagging and recorded. In each year the first assessment was carried out across the whole experiment area to establish base levels of disease just prior to the first fungicide application. In all years disease and green leaf area assessments of all plots were scheduled at GS 32 (T1), GS 39 (T2), GS59 (full ear emergence) and GS 75 (milky ripe). From GS 83 (early dough) green leaf area assessments of the final leaves 1 to 3 were scheduled at weekly intervals until senescence of these leaf layers was complete.

2.7 Yield assessments

The plots were harvested and yields (t/ha at 85% dm) and sometimes specific weights (kg/hl at 85%dm) were calculated.

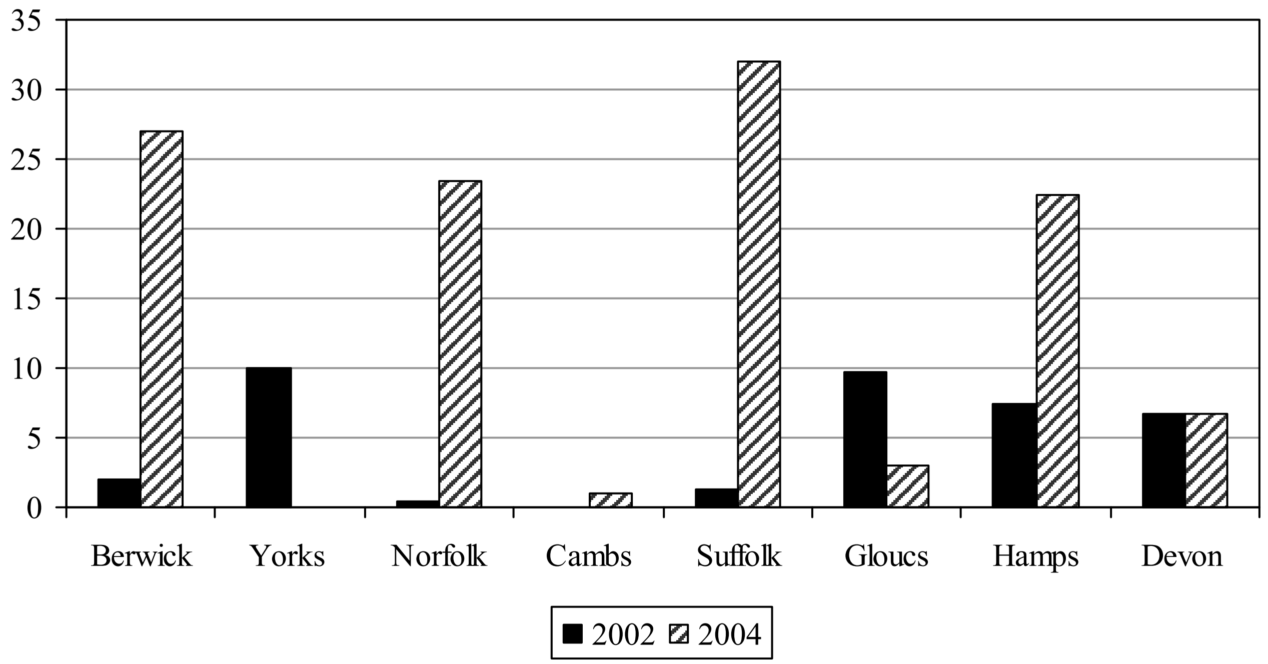
3. Results

3.1 The time interval between T1 and T2

Tables 12, 13 and 14 show the time of each application and the number of days from the first T1 application to T2. In 2002 the average interval between T1 (GS 32) and T2 (GS 39) at all sites was 29 days ranging from 18 days (Suffolk) to 45 days (Devon). In 2003 the average interval between T1 (GS 32) and T2 (GS 39) at all sites was 23 days ranging from 13 days (Gloucestershire) to 33 days (Devon) and in 2004 the average interval between T1 (GS 32) and T2 (GS 39) at all sites was 24 days ranging from 15 days (Yorkshire) to 48 days (Berwickshire). The number of days between T1 application at GS 32 and T2 application at GS 39 varied at each site from season to season.

3.2 Disease pressure at each site

Figure 1. Comparison of disease pressure at each site in 2002 and 2004. *Septoria tritici* (% leaf area) on final leaf 4 at full flag leaf emergence (GS 39) on the untreated crop



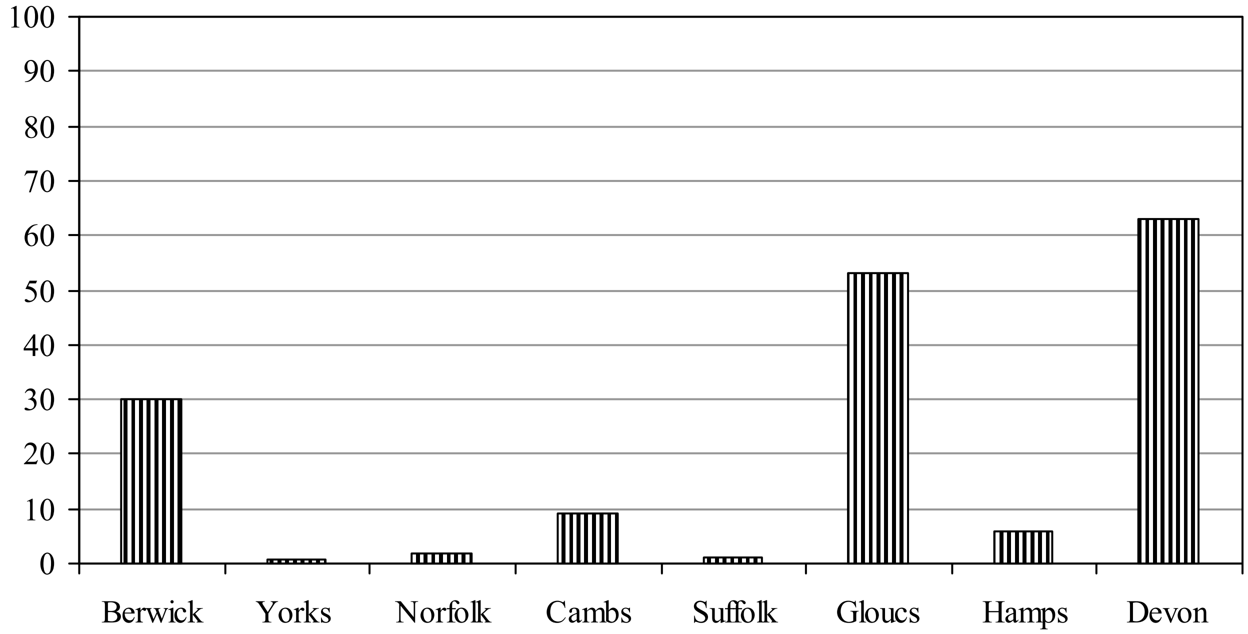
Note: The experiment at Cambridge was not conducted in 2002.

The above data demonstrates the difference in disease pressure between sites within each season and variation at each site and between sites from season to season. In 2002 disease levels on leaf 4 at flag leaf emergence suggest low early season pressure at all sites and consequently less variation between sites. In 2004 early disease pressure was relatively high compared with 2002. In 2004 there was greater variation in early disease pressure between sites and data suggests that early disease pressure was higher at the Berwickshire, Norfolk, Suffolk, Dorset and Devon sites compared with the equivalent assessment in 2002.

Unfortunately due to variability in the time of development of disease infection and hence the variable time of recording at each site data collected in 2003 does not allow the same comparison of disease pressure at GS 39 on leaf 4. However, Figure 2 below shows a comparison of disease pressure between sites on final leaf 3 during flowering (GS 61-69). At this time disease pressure was highest at the Devon, Gloucestershire and Berwick sites. Individual site data also suggests high early disease pressure at the Norfolk and Suffolk sites.

Hence at each site there was large variation in the progression and pressure of *Septoria tritici* infection from season to season particularly at the Yorkshire and Suffolk sites. However, each season disease pressure was relatively high at the Devon site.

Figure 2. Comparison of disease pressure at each site in 2003. *Septoria tritici* (% leaf area) on final leaf 3 at early to late flowering (GS 61-69) on the untreated crop



3.3 Grain yields

2002

There was diverse disease pressure across the seven UK sites (Figure 1). Disease development appeared to by largely driven by rainfall during April at the time when the upper canopy leaves were emerging. Despite the diversity in disease pressure between sites a three-spray programme with strobilurin based treatments (Twist 1.0 l/ha + Opus 0.3 l/ha) at T1 (GS 32) and at T3 (GS 65), (Amistar 0.25 l/ha + Folicur 0.25 l/ha) with a triazole based treatment at T2 (GS 39), (Opus 0.75 l/ha + Bravo 1.0 l/ha) gave the greatest yield response at all seven sites, however, this response was not significantly greater than the next highest yielding treatment at any site. At the Yorkshire site the yield response to the strobilurin at T1 and T3 programme was similar to a three strobilurin based programme, (Tables 15a and 15b and Figure 3).

Hence stretching the interval between strobilurins (T1 and T3)and bridging the gap with a mixture of triazole and chlorothalonil consistently produced similar or greater yields at all sites compared with a three-spray programme including strobilurins at each application timing (Tables 15a and 15b).

Across all sites there was little difference in grain yield between a strobilurin based treatment applied at T1 and T2 compared with a strobilurin based treatment applied at T2 and T3 (Tables 15a and 15b).

At the Gloucestershire and Devon sites, where there was high disease pressure early in the season (Figure 1) and 23 and 45 days between T1 (GS 32) and T2 (GS 39) respectively the strobilurin based treatments at T2 and T3 produced significantly greater yields than programmes including a strobilurin at T1 and T2 (Tables 15a and 15b). This suggests that an appropriate dose of triazole with chlorothalonil at T1 can provide adequate disease control in situations where disease pressure is high prior to fungicide application.

At two sites strobilurin based treatments at T2 and T3 produced significantly greater yields than treatments with strobilurins applied at T1 (GS 31) and T2. These sites were at Devon where there was high disease pressure throughout the season and at the low disease pressure site in Berwickshire, which had an extended ripening period. Consequently both sites benefited from the improved disease control and greater green leaf area retention of the strobilurin based treatments later in the season regardless of the level of early disease and the 45 day time interval between T1 and T2 at the Devon site.

At Devon strobilurins at T1 and T3 provided the greatest yield when the programme was started at GS 32, however, when the programme was started earlier at GS 31 strobilurins applied at T2 and T3 gave the best performance. This implies that the benefit of strobilurins is not due to greater persistency but may have been due to improved efficacy compared with triazoles.

The data suggests a changing role for the strobilurins from *Septoria tritici* plus other leaf and ear diseases control and green leaf area retention to control of some leaf and ear diseases and green leaf area retention.

Figure 15a. The effect of treatment on grain yield (t/ha at 85%) at each site in 2002

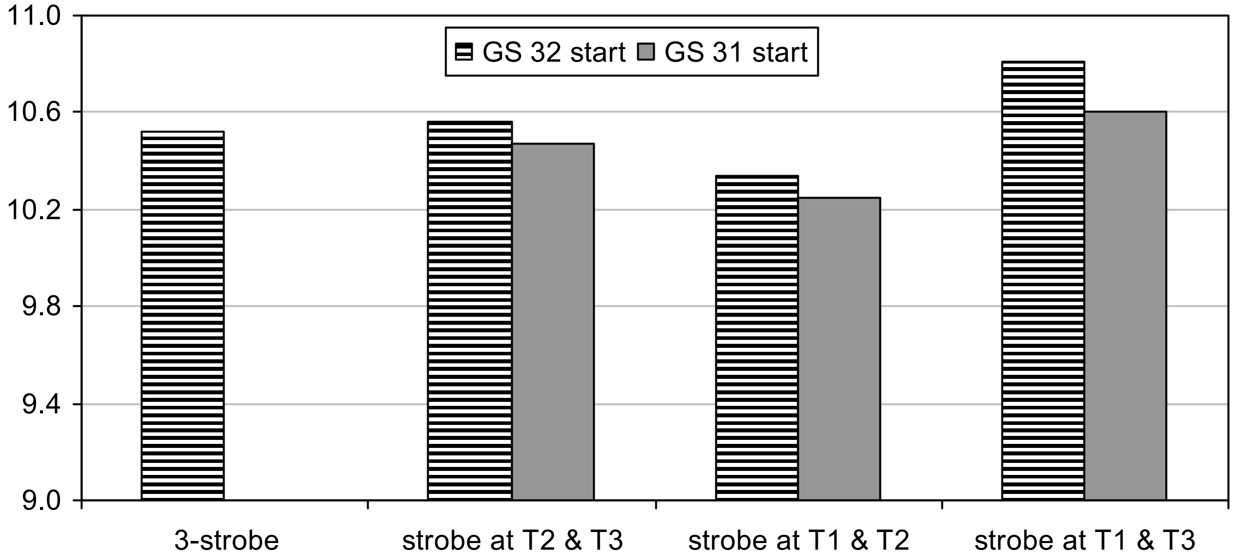
Trt. No.	Treatment*	Berwickshire	Yorkshire	Norfolk	Suffolk	Mean
1	Untreated	7.84	8.65	7.62	5.36	7.04
2	GS 32, 3-strobe	10.76	**12.67**	10.59	8.25	10.52
3	GS 31, T2 & T3	10.87	12.36	10.37	8.32	10.47
4	GS 31, T1 & T2	10.58	12.05	10.66	8.32	10.25
5	GS 32, T2 & T3	10.78	12.36	10.68	8.28	10.56
6	GS 32, T1 & T2	10.72	12.26	10.62	8.26	10.34
7	GS 32, T1 & T3	**11.14**	12.57	**10.90**	**8.52**	**10.81**
8	GS 31, T1 & T3	10.91	12.65	10.39	8.44	10.60
9	GS 32, two-spray strobe based	10.58	12.44	10.33	7.70	10.09
10	GS 32, two spray Opera based	10.48	12.02	10.30	7.86	10.20
LSD (P=0.05)		0.293	0.495	0.353	0.420	-
CV (%)		1.9	2.8	2.8	3.1	-

*Treatment describes the timing of strobilurin based treatments within a three spray programme. GS 31 or GS 32 denotes the timing of the first application. Figures in bold type denote the highest yielding treatment at each site; however, these were not necessarily significantly higher yielding than the other treatments.

Figure 15b. The effect of treatment on grain yield (t/ha at 85%) at each site in 2002

Trt. No.	Treatment*	Hampshire	Gloucs	Devon	Mean
1	Untreated	7.20	8.05	4.55	7.04
2	GS 32, 3-strobe	11.30	10.15	9.92	10.52
3	GS 31, T2 & T3	11.40	10.13	9.82	10.47
4	GS 31, T1 & T2	11.20	10.29	8.66	10.25
5	GS 32, T2 & T3	11.20	10.70	9.89	10.56
6	GS 32, T1 & T2	11.10	10.29	9.14	10.34
7	GS 32, T1 & T3	**11.50**	10.85	**10.22**	**10.81**
8	GS 31, T1 & T3	**11.50**	**11.11**	9.21	10.60
9	GS 32, two-spray strobe based	10.50	10.22	8.89	10.09
10	GS 32, two spray Opera based	10.60	10.54	9.59	10.20
LSD (P=0.05)		0.370	0.334	0.402	-
CV (%)		2.4	2.3	3.1	-

Figure 3. The effect of treatment on grain yield (t/ha at 85%) mean across all sites in 2002



<u>2003</u>

In this season yield data from individual sites shows few statistical differences between treatments. However, strobilurin (Twist 1.0 l + Opus 0.4 l) at T1 (GS 32) and strobilurin (Amistar 0.25 l + Folicur 0.25 l) at T3 (GS 65) with Opus 0.75 l+ Bravo 1.0 l at T2 (GS 39) gave the greatest yield (sometimes significant) response at the Berwickshire, Yorkshire, Norfolk, and Cambridgeshire sites. Trends suggest that a triazole based treatment at T1 followed by strobilurin based treatments at T2 and T3 also performed well at the Norfolk, Suffolk, Hampshire and Devon sites (Tables 16a and 16b and Figure 4).

Disease pressure was relatively low early in the season. This may explain why there was no obvious yield penalty when T1 was applied early at GS 31 compared with a later T1 application at the emergence of leaf 3 (GS 32).

At the Cambridge site, late in the season brown rust developed on the upper canopy leaves reaching 6.3, 7.0, and 5.5% on the flag, final leaf 2 and final leaf 3 respectively on 4th July. All treatments gave full control of this disease.

Table 16a. The effect of treatment on grain yield (t/ha at 85%) at each site in 2003

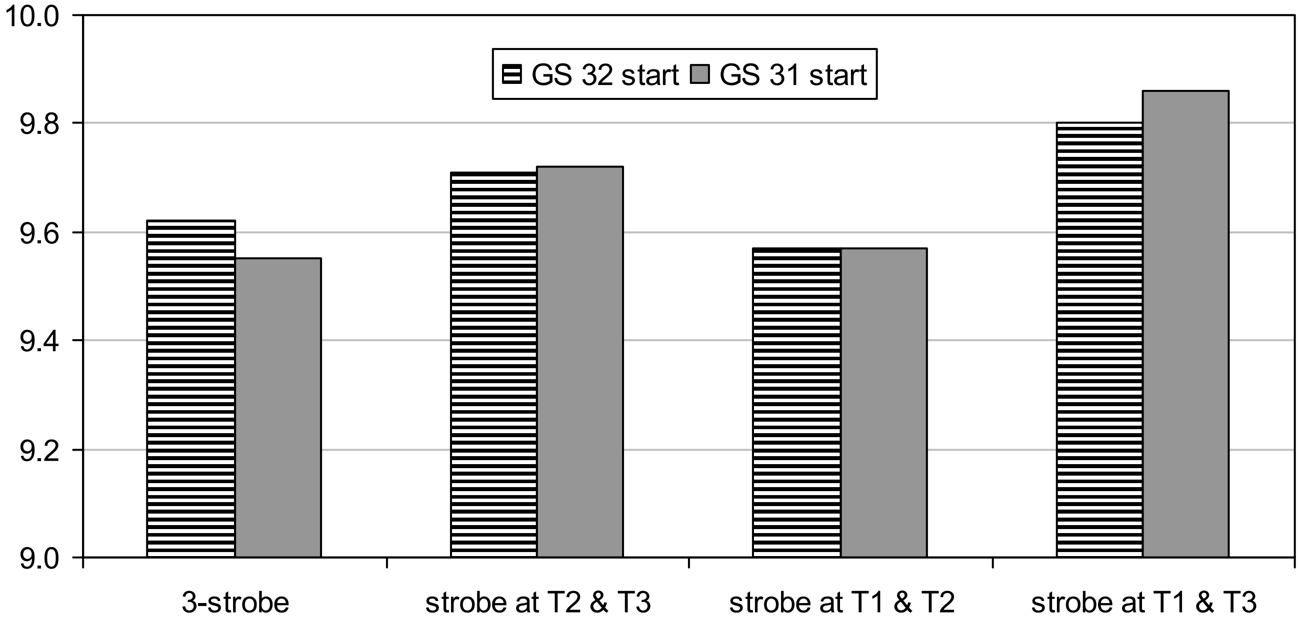
Trt. No.	Treatment*	Berwickshire	Yorkshire	Norfolk	Suffolk	Mean
1	Untreated	9.04	9.82	9.52	8.66	8.43
2	GS 31, 3-strobe	9.98	10.60	10.94	9.42	9.55
3	GS 32, 3-strobe	10.27	10.52	11.07	9.07	9.62
4	GS 31, T2 & T3	10.63	10.24	11.32	**9.54**	9.71
5	GS 32, T2 & T3	10.69	10.59	11.18	9.36	9.71
6	GS 31, T1 & T3	10.80	10.87	11.37	9.46	**9.85**
7	GS 32, T1 & T3	**10.84**	**11.02**	**11.41**	9.49	9.80
8	GS 31, T1 & T2	10.53	10.23	11.01	9.40	9.57
9	GS 32, T1 & T2	10.38	10.49	11.06	9.35	9.57
10	GS 32, two-spray strobe based	10.46	10.37	11.16	9.28	9.53
LSD (P=0.05)		0.778	0.454	0.200	NS	-
CV (%)		5.2	3.0	1.3	4.2	-

* Treatment describes the timing of strobilurin based treatments within a 3 spray programme. GS 31 or GS 32 denotes the timing of the first application. Figures in bold type denote the highest yielding treatment at each site; however, these were not necessarily significantly higher yielding than the other treatments.

Table 16b. The effect of treatment on grain yield (t/ha at 85%) at each site in 2003

Trt. No.	Treatment*	Cambs	Hampshire	Gloucs	Devon	Mean
1	Untreated	8.23	7.17	7.47	7.51	8.43
2	GS 31, 3-strobe	9.29	8.70	8.49	8.98	9.55
3	GS 32, 3-strobe	9.82	8.87	8.21	9.15	9.62
4	GS 31, T2 & T3	9.25	**8.89**	8.47	**9.37**	9.71
5	GS 32, T2 & T3	9.54	8.51	8.41	**9.37**	9.71
6	GS 31, T1 & T3	**9.98**	8.52	8.56	9.27	**9.85**
7	GS 32, T1 & T3	9.64	8.47	8.28	9.25	9.80
8	GS 31, T1 & T2	9.04	8.54	**8.63**	9.21	9.57
9	GS 32, T1 & T2	9.53	8.46	8.14	9.12	9.57
10	GS 32, two-spray strobe based	9.64	8.57	8.07	8.67	9.53
LSD (P=0.05)		0.817	0.507	0.543	0.544	-
CV (%)		5.9	4.1	4.5	4.2	-

Figure 4. The effect of treatment on grain yield (t/ha at 85%) at each site in 2003



2004

In 2004 disease and yield data reflects the impact of widespread *Septoria tritici* resistance to strobilurins (Tables 17a and 17b and 22a to 22b). In this year data at all sites suggests that strobilurins had little impact on the control of *Septoria tritici* (Tables 22a and b and Figure 5 (N.B. Treatment 2 triazole only)). At the Norfolk site the triazole only treatment (Treatment 2) and strobilurin + triazole + chlorothalonil at T1 followed by triazole + chlorothalonil at T2 followed by strobilurin + triazole at T3 (Treatment 11) gave the greatest control of *Septoria tritici* which was significantly better than the remaining treatments.

Programmes including a strobilurin at T3 preceded by strobilurin at T1 or T2 performed consistently well across all seasons and regions producing relatively good yields. There was no difference between programmes with strobilurin at T2 and T3 and T1 and T3. As in previous years strobilurin based treatments at T1 and T2 have given the poorest performance at each site and in 2004 these programmes in particular benefited from the addition of chlorothalonil. This trend is clearly demonstrated in Figures 5 & 6 showing data from the Norfolk site (Treatment 3, no chlorothalonil, Treatment 4 chlorothalonil at T1 only and Treatment 5 chlorothalonil at T1 and T2).

At the Cambridge site late in the season brown rust developed on the upper canopy leaves reaching 3.0, 9.3, and 5.8% on the flag, leaf 2 and leaf 3 respectively on 5th July. All treatments gave full control of this disease.

At each site comparison between the triazole + chlorothalonil programme (Treatment 2) and a programme with a similar amount of triazole and chlorothalonil at T1 and T2 with additional strobilurin at T2 and T3 (Treatment 8) suggests that yield responses to strobilurins were small (up to 0.4 t/ha), insignificant and unlikely to be cost effective at current strobilurin and grain prices. However, it should be noted that the equivalent dose of triazole in a co-formulation of kresoxim-methyl and epoxiconazole (Landmark) may have reduced efficacy compared with the same dose of straight triazole. A triazole only programme performed well at all sites.

Table 17a. The effect of treatment on grain yield (t/ha at 85%) at each site in 2004

Trt.	Treatment*	Berwickshire	Yorkshire	Norfolk	Suffolk	Mean
1	Untreated	7.21	5.69	7.27	6.06	6.96
2	Triazole based	9.96	7.55	9.71	8.31	8.80
3	T1 & T2	9.54	7.53	9.23	7.89	8.65
4	T1B & T2	9.99	7.49	9.39	7.66	8.62
5	T1B & T2B	10.17	7.54	**10.01**	7.83	8.77
6	T0 fb T2 & T3	**10.54**	7.73	9.69	**8.64**	**9.04**
7	T2 & T3	10.35	**7.82**	9.65	8.31	9.00
8	T2B fb T3	10.30	7.42	9.80	8.28	8.94
9	T2B fb T3 lower triazole T2	10.33	7.59	9.67	8.10	8.96
10	T0 fb T1B & T3	10.33	7.66	9.85	8.23	9.01
11	T1B & T3	10.06	7.65	9.75	7.77	8.81
12	Two-spray strobe based	10.03	7.35	9.44	7.89	8.66
LSD (P=0.05)		0.368	0.393	0.288	0.436	-
CV (%)		2.6	3.7	2.1	3.8	-

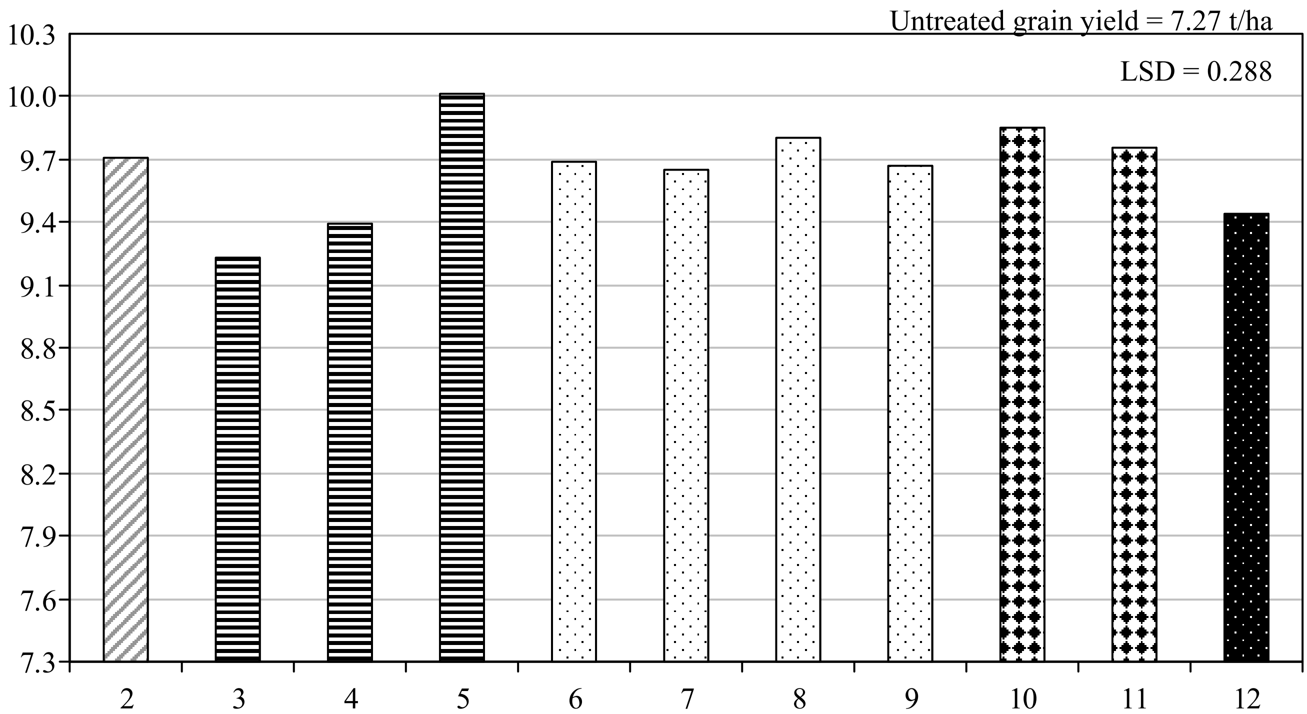
* Treatment describes the timing of strobilurin based treatments within a 3 spray programme. B at T1 and T2 denotes the addition of Bravo at 1.0 l/ha. Treatments began at GS 32 unless preceded by Bravo 1.0 l/ha at GS 30 as indicated. Figures in bold type denote the highest yielding treatment at each site; however, these were not necessarily significantly higher yielding than the other treatments.

Table 17b. The effect of treatment on grain yield (t/ha at 85%) at each site in 2004

Trt. No.	Treatment*	Cambs	Hampshire	Gloucs	Devon	Mean
1	Untreated	6.72	8.46	7.43	6.84	6.96
2	Triazole based	7.84	10.58	8.11	8.30	8.80
3	T1 & T2	7.99	10.41	8.24	8.34	8.65
4	T1B & T2	7.79	10.45	8.08	8.10	8.62
5	T1B & T2B	7.81	10.40	8.33	8.03	8.77
6	T0 fb T2 & T3	7.95	10.89	**8.65**	8.26	**9.04**
7	T2 & T3	7.83	11.00	8.37	**8.64**	9.00
8	T2B fb T3	7.96	10.85	8.42	8.52	8.94
9	T2B fb T3 lower triazole T2	**8.09**	11.00	8.35	8.53	8.96
10	T0 fb T1B & T3	8.00	**11.09**	8.50	8.39	9.01
11	T1B & T3	7.96	10.78	8.13	8.39	8.81
12	Two-spray strobe based	7.76	10.35	8.40	8.03	8.66
LSD (P=0.05)		0.312	0.651	0.390	0.500	-
CV (%)		2.8	4.3	3.3	4.2	-

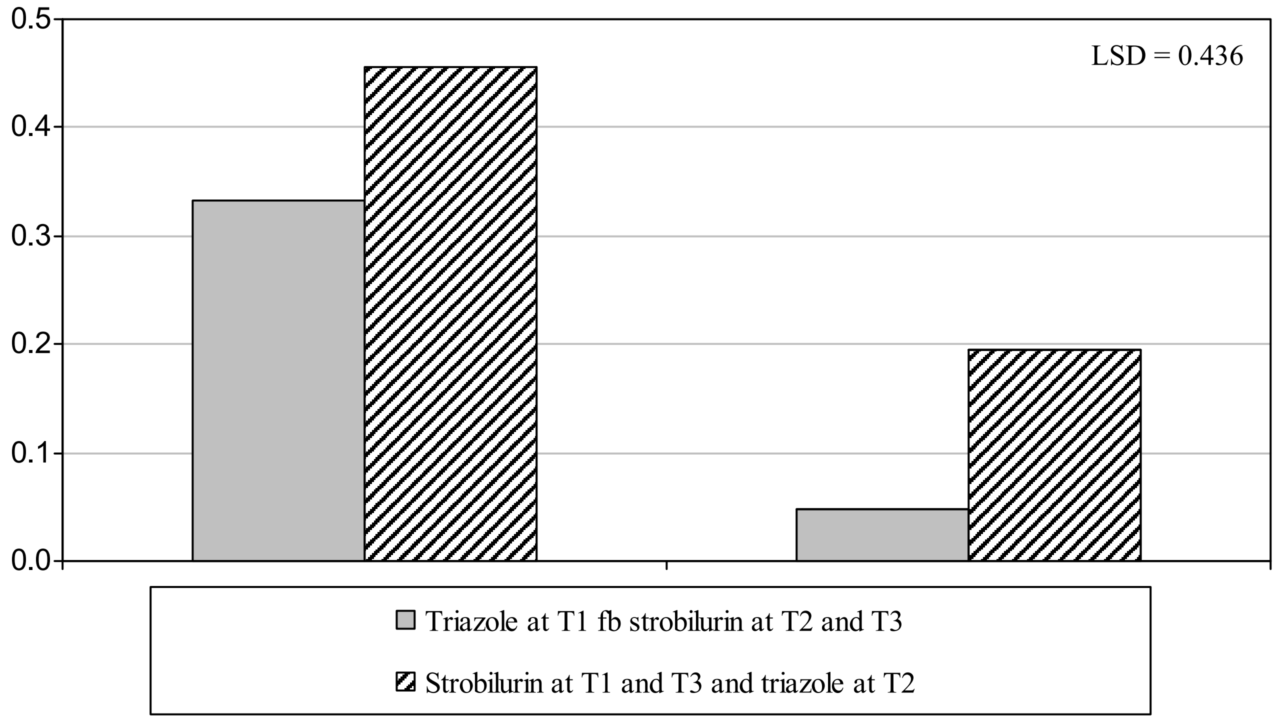
Figure 5. The effect of treatment on the *Septoria tritici* infection (% leaf cover) on final leaf 3, 6 July at GS 75-77 (mid to late milk), Morley, Norfolk in 2004

Figure 6. The effect of treatment on the grain yield (t/ha at 85% dm), Morley, Norfolk in 2004



A trend across all sites suggests a greater benefit from a T0 (GS 30, ear at 1cm) application of chlorothalonil when followed by mixtures including strobilurin at T1 (GS 32) and T3 (GS 65). This may also reflect the suggested compromised efficacy of the equivalent dose of triazole in the formulation of Landmark. The benefit of the T0 application was only significant at the Suffolk site when followed by strobilurins at T1 and T3. Although the T1 application at Suffolk was applied at GS 32 due to poor weather conditions the crop was nearing GS 33 and final leaf 3 was over 50% emerged, this coupled with relatively high, early disease pressure appears to have exaggerated the benefit of an earlier application (T0) in holding back disease development as demonstrated by Figures 7 & 8.

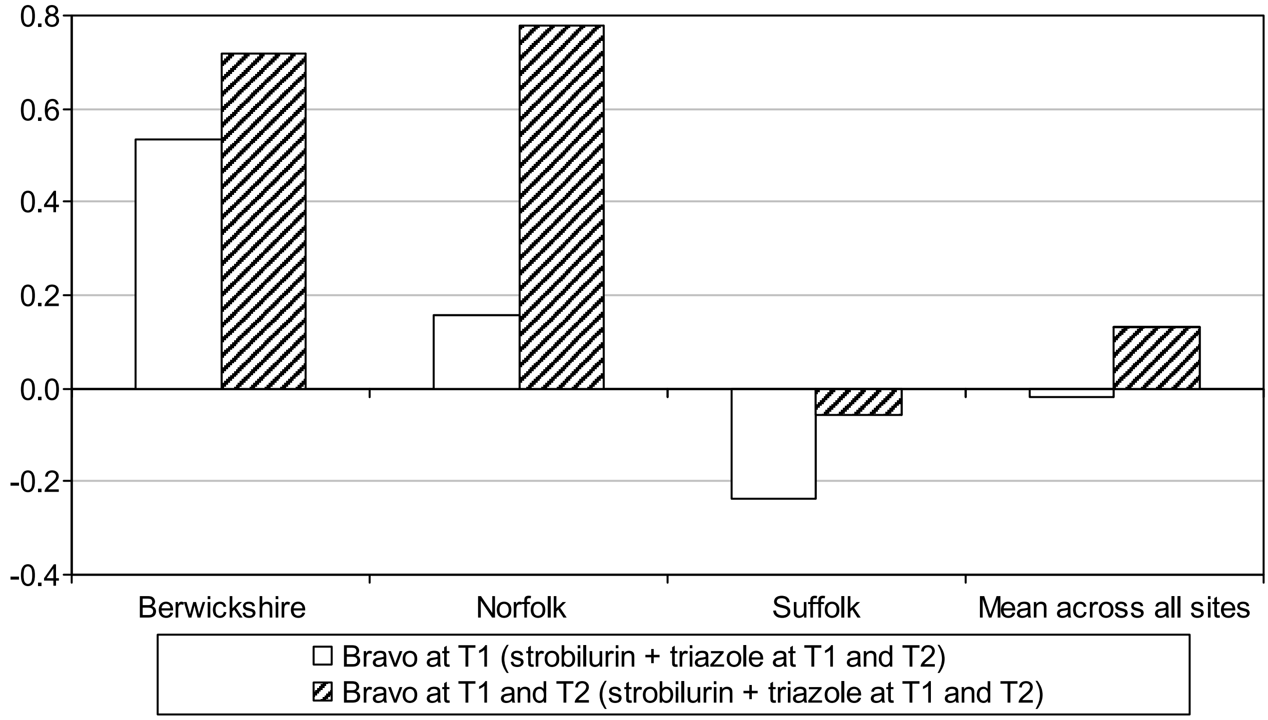
Figure 7. The yield response of T0 (GS 30) on grain yield (t/ha at 85% dm), Otley, Suffolk in 2004



fb = followed by

Perhaps chlorothalonil should now be considered as an integral part of the programme boosting control of *Septoria tritici* and grain yield. Inclusion of chlorothalonil in the programme is also believed to improve robustness with regards to the fungicide resistance strategy and may reduce the dose of triazole required. Data from the Berwickshire and Norfolk sites shows how the addition of chlorothalonil to a mixture of strobilurin and triazole at T1 (GS 32) and T2 (GS 39) can improve grain yield (Figure 6.). As chlorothalonil primarily offers protectant activity against *Septoria tritici* the potential benefit from the addition of chlorothalonil at each timing is strongly influenced by the timing of application in relationship to disease development. Prompt applications of chlorothalonil at T1 as final leaf 3 begins to emerge provide the greatest improvement to septoria control and grain yield as seen at the Berwickshire site (Figure 6). Conversely as seen at the Suffolk site there was no yield benefit from later T1 applications where disease pressure early in the season was high and consequently T1 applications were too late for chlorothalonil to provide adequate protectant activity, however, in this situation T0 application of chlorothalonil were of greater benefit (Figure 5). Data suggests a greater benefit from the addition of chlorothalonil at T1 and T2 when strobilurins are applied in mixture with triazole creating a more robust programme.

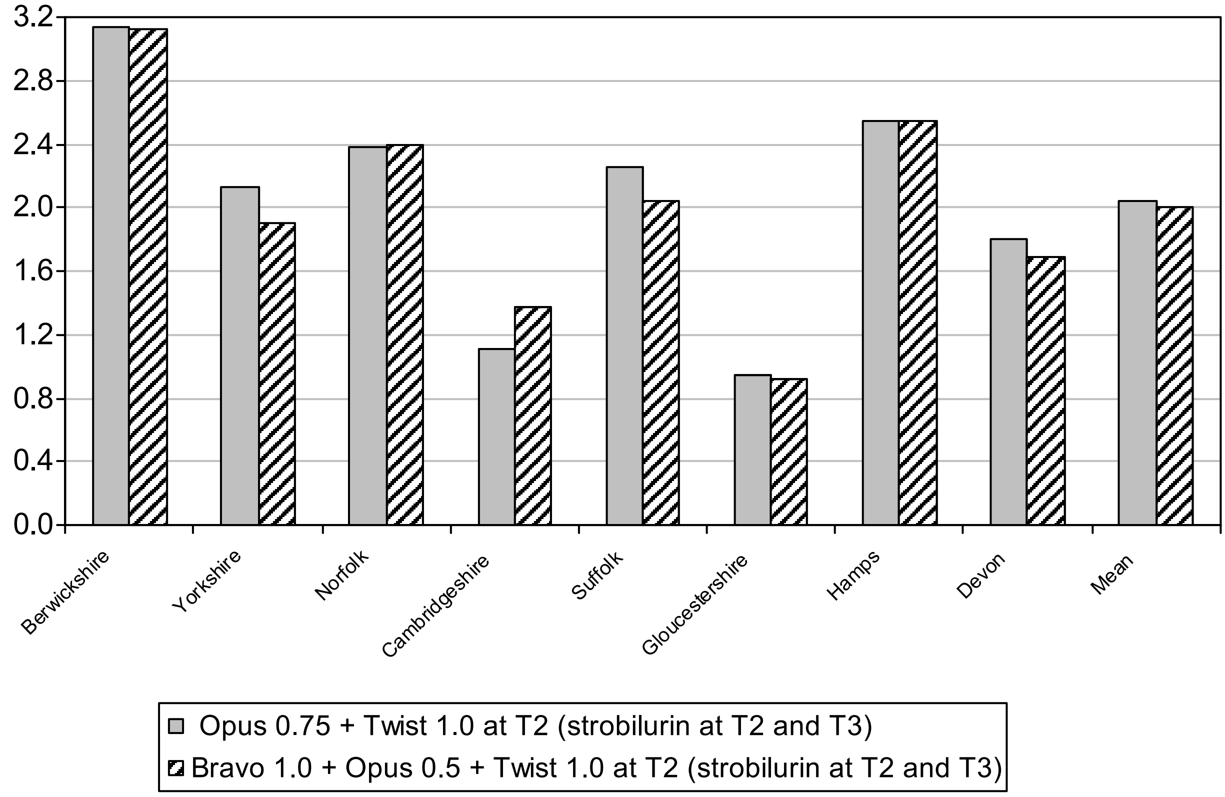
Figure 8. The effect (grain yield, t/ha) of adding chlorothalonil to a mixture of strobilurin and triazole T1 (GS 32) and T2 (GS 39)



Treatments were also designed to evaluate whether the addition of chlorothalonil to strobilurin and triazole mixtures at T2 allowed a lower dose of triazole to be applied. A comparison between

Treatment 8 (Twist 1.0 + Opus 0.75 + Bravo 1.0 l/ha at T2) and Treatment 9 (Twist 1.0 + Opus 0.75 + Bravo 1.0 l/ha at T2) at each site suggests that a lower dose of triazole at T2 (0.5 l/ha compared with 0.75 l/ha) can be utilised if tank mixed with chlorothalonil where protectant rather than eradicant activity is required (Figure 7).

Figure 9. Yield response (t/ha at 85% dm) to the addition of chlorothalonil to a strobilurin + triazole mixture at T2 compared with strobilurin + a more robust dose of triazole at T2



4. Discussion and Implications

In all three years disease pressure was diverse across the eight UK sites and disease development appeared to be largely driven by rainfall during April at the time when the upper canopy leaves were emerging. Despite the diversity of disease pressure between sites the most successful programmes at each site have been remarkably similar particularly with regard to the most appropriate timing of strobilurins within the programme.

In all years a strobilurin based treatment at T1 (GS 32) and T3 (GS 65) with a triazole based treatment at T2 (GS 39) was a consistently good treatment. In 2004 (when strobilurins had little impact on the control of *Septoria tritici*) programmes including a strobilurin at T3 either preceded by a strobilurin application at T1 or T2 performed consistently well across all sites. In 2004 the improved performance of programmes with strobilurins applied at T2 and T3 reflects the changing emphasis of the role of strobilurins from *Septoria tritici* control, ear disease control and green leaf area retention to primarily green leaf area retention and ear disease control. However, yield responses to strobilurins were small (up to 0.4 t/ha), and unlikely to be cost effective a current product costs and grain prices.

This project provides evidence that strobilurin based treatment at T1 (emergence of final leaf 3) and T2 (full flag leaf emergence) and the possible use of a triazole based treatment at T3 on the ear is not the most appropriate use of strobilurin chemistry as suggested at the HGCA Roadshows in the winter of 2001 and in previous years. The data suggests that with increasing resistance to strobilurins throughout the project the emphasis of their value appeared to change from *Septoria tritici* control and ear disease control plus some ‘physiological’ benefits to ear disease control and ‘physiological’ benefits. This suggests that if there is a role for strobilurins on future wheat crops they should be applied at the later timings within the fungicide strategy, particularly at T3.

In each year strobilurins at T1 and T2 have given the poorest performance at each site and in 2004 these programmes in particular benefited from the addition of chlorothalonil. In 2004, a triazole only programme performed well at all sites. There was no evidence from this data to suggest that strobilurins at T1 and T2 were beneficial when there was an extended time interval between these applications.

In each region disease progression will be influenced by seasonal weather patterns. Whilst fungicide dose within programmes must be flexible and tailored according to variety susceptibility and disease pressure these experiments suggest a similar strategy can be employed in all major arable regions in the UK.

5. Acknowledgements

The author would like to thank the collaborators (NIAB and SAC) and all the field teams involved in the conduct of these experiments.

Appendix

Disease control and green leaf area retention - 2002

Table 18a. The effect of treatment on *Septoria tritici,* leaf 2 during grain fill (GS 65-77), (% leaf cover) at each site in 2002

Trt. No.	Treatment*	Berwickshire 18 July	Yorkshire 20 June	Norfolk 21 June	Suffolk 5 July
1	Untreated	18.8	41.3	3.0	41.3
2	GS 32, 3-strobe	0.5	0.0	0.0	0.1
3	GS 31, T2 & T3	0.5	1.9	0.4	0.3
4	GS 31, T1 & T2	1.0	1.8	0.3	0.2
5	GS 32, T2 & T3	2.5	0.0	0.0	0.1
6	GS 32, T1 & T2	1.0	0.0	0.1	0.1
7	GS 32, T1 & T3	0.0	0.0	0.0	0.1
8	GS 31, T1 & T3	0.5	1.0	0.3	0.2
9	GS 32, two-spray strobe based	0.5	0.0	0.0	0.4
10	GS 32, two spray Opera based	0.5	0.0	0.0	0.2
LSD (P=0.05)		3.42	3.30	0.70	1.19
CV (%)		91.6	49.5	116.9	19.0

* Treatment describes the timing of strobilurin based treatments within a three spray programme. GS 31 or GS 32 denotes the timing of the first application.

Table 18b. The effect of treatment on *Septoria tritici,* leaf 2 during grain fill (GS 65-77), (% leaf cover) at each site in 2002

Trt. No.	Treatment*	Hampshire 28 June	Gloucestershire 20 June	Devon 11 July
1	Untreated	78.8	6.0	100.0
2	GS 32, 3-strobe	5.8	1.3	51.3
3	GS 31, T2 & T3	4.5	1.5	53.8
4	GS 31, T1 & T2	4.5	1.8	63.8
5	GS 32, T2 & T3	6.8	1.8	36.3
6	GS 32, T1 & T2	5.5	1.5	33.8
7	GS 32, T1 & T3	3.0	1.0	36.8
8	GS 31, T1 & T3	4.0	1.3	56.3
9	GS 32, two-spray strobe based	6.0	1.5	33.0
10	GS 32, two spray Opera based	5.0	1.5	33.3
LSD (P=0.05)		5.09	1.19	28.4
CV (%)		28.3	43.2	39.3

Table 19a. The effect of treatment on green leaf area retention, leaf 2 (% leaf cover) in early to mid July at each site in 2002

Trt. No.	Treatment*	Berwickshire 18 July	Yorkshire** 18 July	Norfolk** 16 July	Suffolk 12 July
1	Untreated	77.5	8.8	6.3	3.8
2	GS 32, 3-strobe	91.3	67.5	73.5	82.5
3	GS 31, T2 & T3	91.3	51.3	71.8	81.0
4	GS 31, T1 & T2	88.8	55.0	76.0	73.8
5	GS 32, T2 & T3	91.3	63.8	73.8	79.5
6	GS 32, T1 & T2	93.8	67.5	75.5	77.3
7	GS 32, T1 & T3	95.8	73.8	75.8	80.8
8	GS 31, T1 & T3	95.3	61.3	69.8	79.0
9	GS 32, two-spray strobe based	88.8	70.0	72.8	13.0
10	GS 32, two spray Opera based	91.3	68.8	70.8	5.7
LSD (P=0.05)		4.80	10.9	5.16	4.91
CV (%)		3.7	12.8	5.4	5.9

* Treatment describes the timing of strobilurin based treatments within a three spray programme. GS 31 or GS 32 denotes the timing of the first application.

** Data from Yorkshire, Norfolk and Suffolk reflects a combined assessment of leaf layers 1, 2 and 3.

Table 19b. The effect of treatment on green leaf area retention, leaf 2 (% leaf cover) in early to mid July at each site in 2002

Trt. No.	Treatment*	Hampshire 15 July	Gloucestershire 9 July	Devon 17 July
1	Untreated	0.0	6.3	0.0
2	GS 32, 3-strobe	52.5	63.8	24.5
3	GS 31, T2 & T3	60.0	75.0	14.3
4	GS 31, T1 & T2	62.5	71.3	11.3
5	GS 32, T2 & T3	62.5	77.5	18.8
6	GS 32, T1 & T2	48.8	70.0	20.0
7	GS 32, T1 & T3	77.5	80.0	32.5
8	GS 31, T1 & T3	75.0	81.3	12.0
9	GS 32, two-spray strobe based	50.0	63.8	20.0
10	GS 32, two spray Opera based	40.0	67.5	37.5
LSD (P=0.05)		15.63	10.32	15.1
CV (%)		20.4	10.8	54.5

Disease control and green leaf area retention - 2003

Table 20a. The effect of treatment on *Septoria tritici,* leaf 2 during grain fill (GS 65-77), (% leaf cover) at each site in 2003

Trt. No.	Treatment*	Berwickshire 17 July	Yorkshire 7 July	Norfolk 27 June	Suffolk 26 June
1	Untreated	35.1	17.5	7.5	3.5
2	GS 31, 3-strobe	2.3	16.3	0.4	0.3
3	GS 32, 3-strobe	2.3	13.8	0.9	0.3
4	GS 31, T2 & T3	2.5	10.0	0.2	0.3
5	GS 32, T2 & T3	2.8	20.0	0.3	0.2
6	GS 31, T1 & T3	2.3	4.5	0.2	0.2
7	GS 32, T1 & T3	0.0	3.3	0.1	0.2
8	GS 31, T1 & T2	2.3	13.8	0.4	0.3
9	GS 32, T1 & T2	3.0	11.3	0.8	0.3
10	GS 32, two-spray strobe based	6.0	21.3	0.7	0.4
LSD (P=0.05)		12.69	15.06	1.63	0.27
CV (%)		149.7	79.0	99.8	32.7

* Treatment describes the timing of strobilurin based treatments within a 3 spray programme. GS 31 or GS 32 denotes the timing of the first application.

Table 20b. The effect of treatment on *Septoria tritici,* leaf 2 during grain fill (GS 65-77), (% leaf cover) at each site in 2003

Trt. No.	Treatment*	Cambridgeshire 20 June	Hampshire 10 July	Gloucestershire 19 June	Devon 21 June
1	Untreated	5.0	61.3	7.8	10.0
2	GS 31, 3-strobe	0.1	3.8	0.0	0.4
3	GS 32, 3-strobe	0.2	3.3	0.0	0.1
4	GS 31, T2 & T3	0.2	3.0	0.0	0.0
5	GS 32, T2 & T3	0.1	2.8	0.0	0.0
6	GS 31, T1 & T3	0.1	1.8	0.0	0.0
7	GS 32, T1 & T3	0.2	2.5	0.0	0.0
8	GS 31, T1 & T2	0.2	4.5	0.0	0.4
9	GS 32, T1 & T2	0.3	3.8	0.0	0.0
10	GS 32, two-spray strobe based	0.1	4.3	1.3	3.6
LSD (P=0.05)		1.66	5.23	2.13	2.18
CV (%)		176.2	39.7	244.5	103.4

Table 21a. The effect of treatment on green leaf area retention, leaf 2, (% leaf cover) in early to mid July at each site in 2003

Trt. No.	Treatment*	Berwickshire 17 July	Yorkshire 16 July	Norfolk 9 July	Suffolk 10 July
1	Untreated	30.0	23.8	13.8	38.8
2	GS 31, 3-strobe	93.5	26.3	79.5	75.8
3	GS 32, 3-strobe	89.0	28.8	82.8	79.5
4	GS 31, T2 & T3	95.3	46.3	87.8	81.3
5	GS 32, T2 & T3	96.3	35.0	89.0	78.8
6	GS 31, T1 & T3	96.5	48.8	92.8	79.3
7	GS 32, T1 & T3	98.0	51.3	93.5	82.8
8	GS 31, T1 & T2	95.8	31.3	85.0	76.8
9	GS 32, T1 & T2	94.8	38.8	81.3	76.3
10	GS 32, two-spray strobe based	82.0	37.5	84.0	77.5
LSD (P=0.05)		5.64	15.03	6.07	6.05
CV (%)		4.5	28.2	5.3	5.6

* Treatment describes the timing of strobilurin based treatments within a 3 spray programme. GS 31 or GS 32 denotes the timing of the first application.

Table 21b. The effect of treatment on green leaf area retention, leaf 2, (% leaf cover) in early to mid July at each site in 2003

Trt. No.	Treatment*	Cambridgeshire 18 July	Hampshire	Gloucestershire	Devon 16 July
1	Untreated	0.0	-	-	0.0
2	GS 31, 3-strobe	0.8	-	-	47.5
3	GS 32, 3-strobe	1.8	-	-	38.8
4	GS 31, T2 & T3	1.3	-	-	35.0
5	GS 32, T2 & T3	2.0	-	-	43.8
6	GS 31, T1 & T3	1.1	-	-	46.3
7	GS 32, T1 & T3	2.3	-	-	48.8
8	GS 31, T1 & T2	1.6	-	-	38.8
9	GS 32, T1 & T2	2.0	-	-	47.5
10	GS 32, two-spray strobe based	1.3	-	-	28.8
LSD (P=0.05)		1.36	-	-	10.97
CV (%)		67.4	-	-	20.2

Disease control and green leaf area retention - 2004

Table 22a. The effect of treatment on *Septoria tritici,* leaf 2 during grain fill (GS 71-77), (% leaf cover) at each site in 2004

Trt. No.	Treatment*	Berwickshire 8 July	Yorkshire 19 July	Norfolk 6 July	Suffolk 7 July
1	Untreated	41.3	55.0	25.0	19.5
2	Triazole based	1.5	3.3	1.4	0.8
3	T1 & T2	10.0	3.0	5.0	3.4
4	T1B & T2	3.8	3.3	2.3	3.5
5	T1B & T2B	3.0	1.0	1.1	1.6
6	T0 fb T2 & T3	1.0	1.6	2.0	0.7
7	T2 & T3	1.5	2.5	2.6	1.7
8	T2B fb T3	5.5	1.4	1.5	0.6
9	T2B fb T3 lower triazole T2	3.0	3.1	1.1	0.7
10	T0 fb T1B & T3	2.5	0.3	0.9	0.8
11	T1B & T3	4.3	0.9	1.6	1.7
12	Two-spray strobe based	11.8	2.5	7.5	5.8
LSD (P=0.05)		7.56	4.03	1.82	1.55
CV (%)		70.6	43.1	29.1	33.0

* Treatment describes the timing of strobilurin based treatments within a 3 spray programme. B at T1 and T2 denotes the addition of Bravo at 1.0 l/ha. Treatments began at GS 32 unless preceded by Bravo 1.0 l/ha at GS 30 as indicated.

** Data from Gloucestershire reflects a combined assessment of leaf layers 1 and 2. Disease pressure was very low at this site throughout the season.

Table 22b. The effect of treatment on *Septoria tritici,* leaf 2 during grain fill (GS 71-77), (% leaf cover) at each site in 2004

Trt. No.	Treatment*	Cambridgeshire 5 July	Hampshire 28 June	Gloucestershire 7 July**	Devon 28 June
1	Untreated	10.0	15.0	9.7	25.0
2	Triazole based	0.1	2.3	0.4	12.5
3	T1 & T2	0.2	2.3	0.4	10.0
4	T1B & T2	0.6	4.5	0.8	12.5
5	T1B & T2B	0.1	1.3	0.3	9.3
6	T0 fb T2 & T3	0.1	1.8	0.4	10.0
7	T2 & T3	0.3	3.8	0.9	10.0
8	T2B fb T3	0.1	1.5	0.5	17.5
9	T2B fb T3 lower triazole T2	0.1	2.0	0.3	10.0
10	T0 fb T1B & T3	0.1	2.0	0.3	5.0
11	T1B & T3	0.1	3.5	0.3	7.5
12	Two-spray strobe based	1.0	7.3	0.7	15.0
LSD (P=0.05)		1.70	3.05	2.88	8.70
CV (%)		112.1	54.0	161.2	50.1

*Treatment describes the timing of strobilurin based treatments within a 3 spray programme. B at T1 and T2 denotes the addition of Bravo at 1.0 l/ha. Treatments began at GS 32 unless preceded by Bravo 1.0 l/ha at GS 30 as indicated.

Table 23a. The effect of treatment on green leaf area retention, leaf 2, (% leaf cover) in early to mid July at each site in 2004

Trt. No.	Treatment*	Berwickshire 21 July	Yorkshire 19 July	Norfolk 6 July	Suffolk 21 July
1	Untreated	7.5	37.5	13.8	0.0
2	Triazole based	88.8	63.8	75.0	57.3
3	T1 & T2	63.8	66.3	72.5	31.5
4	T1B & T2	83.8	62.5	75.0	25.3
5	T1B & T2B	89.5	65.0	76.3	46.5
6	T0 fb T2 & T3	86.3	61.3	76.3	60.0
7	T2 & T3	88.3	68.8	72.5	47.8
8	T2B fb T3	92.3	67.5	75.0	60.8
9	T2B fb T3 lower triazole T2	88.3	67.5	75.0	57.5
10	T0 fb T1B & T3	87.0	71.3	78.8	52.0
11	T1B & T3	80.8	57.5	77.5	45.0
12	Two-spray strobe based	65.0	65.0	55.0	31.2
LSD (P=0.05)		13.51	15.39	7.71	10.27
CV (%)		12.2	17.0	7.8	16.6

*Treatment describes the timing of strobilurin based treatments within a 3 spray programme. B at T1 and T2 denotes the addition of Bravo at 1.0 l/ha. Treatments began at GS 32 unless preceded by Bravo 1.0 l/ha at GS 30 as indicated.

Table 23b. The effect of treatment on green leaf area retention, leaf 2, (% leaf cover) during grain fill (GS 71-77), (% leaf cover) at each site in 2004

Trt. No.	Treatment*	Cambridgeshire 20 July	Hampshire 28 June	Gloucestershire	Devon 12 July
1	Untreated	0.5	86.3	-	41.3
2	Triazole based	42.5	93.8	-	77.5
3	T1 & T2	35.0	95.0	-	77.5
4	T1B & T2	47.5	91.3	-	61.3
5	T1B & T2B	42.5	95.3	-	85.0
6	T0 fb T2 & T3	50.0	95.0	-	76.3
7	T2 & T3	40.0	92.5	-	77.5
8	T2B fb T3	45.0	95.0	-	76.3
9	T2B fb T3 lower triazole T2	47.5	93.8	-	82.5
10	T0 fb T1B & T3	50.0	95.5	-	80.0
11	T1B & T3	42.5	95.3	-	66.3
12	Two-spray strobe based	30.0	88.8	-	46.3
LSD (P=0.05)		13.00	4.44	-	21.47
CV (%)		22.8	3.3	-	21.1

*Treatment describes the timing of strobilurin based treatments within a 3 spray programme. B at T1 and T2 denotes the addition of Bravo at 1.0 l/ha. Treatments began at GS 32 unless preceded by Bravo 1.0 l/ha at GS 30 as indicated.

Data not collected at the Gloucestershire site.