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Fungicide doses in sequences and mixtures for winter wheat

by

Stuart Knight[1], Jonathan Blake[2], Simon Oxley[3] and David Parsons[4]

[1]The Arable Group, The Old Rectory, Morley, Wymondham, Norfolk, NR18 9DB

[2]ADAS Rosemaund, Preston Wynne, Hereford, HR1 3PG

[3]SAC, West Mains Road, Edinburgh, EH9 3JG

[4]Cranfield University, Cranfield, Bedford, MK43 0AL

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Contents

Abstract

The performance of individual fungicides applied as single sprays to control foliar diseases in winter wheat has been evaluated in HGCA-funded research since 1994. A new project was commissioned to add information on the effects of using a sequence of two sprays or a mixture of two or more products, with the aim of establishing principles by which farmers could develop effective programmes from HGCA fungicide performance data. The project focused on control of *Septoria tritici* [(1)], and the impact of mixtures on the dose-response of the triazole fungicide Opus (epoxiconazole). Field experiments were conducted on three varieties representing a range of susceptibilities to septoria, and at four locations over a three year period, to give a range of disease pressures. The main treatments compared single sprays (at GS39) against 2-spray programmes (at GS32 and GS39), and Opus applied alone against mixtures with Bravo (chlorothalonil) or Bravo plus the strobilurin Vivid (pyraclostrobin).

In 2005 and 2006 septoria was the main disease present and the major influence on green leaf area and grain yield. Adding Bravo to a 2-spray Opus programme reduced the dose of triazole needed to obtain equal control of septoria, often by 50% or more, allowing optimum yields to be obtained at 15-30% lower doses of Opus and improving margins. Even when mixed with Bravo, optimum triazole (Opus) doses were 45-65% higher for the most compared to the least septoria-susceptible variety, and 40-60% higher under medium-high than under low septoria pressure. In 2007 yellow or brown rust were present as well as septoria at all locations, and in some cases these had an equal or greater influence on yield. The strobilurin Vivid was of more benefit than Bravo as a partner to control rusts. Adding Vivid, as well as Bravo, resulted in up to 70% lower optimum Opus doses whilst maintaining or improving margins.

Raising the grain price from £80 to £160/t increased the optimum dose of Opus by 25-30%. However, a range of doses would have given margins close to the optimum, and applying a dose slightly above the expected optimum would allow for application delays or higher than expected disease pressure. Early septoria progress, as indicated by within-season disease monitoring experiments, did not correlate well with end of season septoria levels or fungicide responsiveness. The Wheat Disease Manager computer programme, designed to predict yield response to fungicides from information available at the time of treatment, and a mixture calculator that was created to combine dose-response curves for disease for two individual fungicide active ingredients and produce a value for the mixture, both gave promising results.

[(1)] Most recent scientific name is *Mycosphaerella graminicola*

Summary

Introduction

The performance of individual fungicides in winter wheat, applied as single sprays, has been evaluated in HGCA-funded research since 1994. The experiments have allowed comparative dose-response curves to be produced for a range of fungicides, and for the control of the major foliar diseases. Using epoxiconazole (Opus) as an example, the research indicated a downward shift in the performance of triazole fungicides against *Septoria tritici* [(1)] between 1995 and 2005, and this has provided a compelling argument for the use of robust doses on farm to maintain disease control.

In practice the majority of wheat crops receive more than one fungicide spray, with each application consisting of a mixture of at least two products. A new project was commissioned to add information on the effects of using a sequence of two sprays, or a mixture of two or more products, on dose response curves for disease, green leaf area and yield, with the aim of establishing principles by which farmers could develop fungicide programmes in winter wheat from HGCA fungicide performance information. Due to its importance as the most widespread and damaging foliar disease of wheat in the UK, and the decline in performance of the major fungicide group (triazoles) used against it, control of septoria was the main focus of the project.

An additional limitation of the existing HGCA research was that fungicide performance was being evaluated on very susceptible varieties and in high disease risk locations. This ensures a stringent test, and enables potentially small differences in fungicide performance to be detected. In practice a range of varieties are present on farm, and not all of these are highly disease susceptible or grown in high risk areas. The ubiquitous nature of septoria and relative stability of varietal resistance mean that this disease most lends itself to adjusting fungicide dose (rather than fungicide choice). However there was a need for information to support decisions on the appropriate size of the adjustment in dose to account for varietal susceptibility and disease pressure.

The number of potential combinations is such that it would clearly not be possible to determine experimentally the dose response implications of all possible fungicide sequence and mixtures and for every disease. Therefore, the project also provided an opportunity to look at how closely the relative disease control and yield performance of mixtures and sequences could be predicted using computer programmes.

[(1)] Most recent scientific name is *Mycosphaerella graminicola*

Field Experimentation: Materials and Methods

Field experiments were conducted at three locations in England (in Herefordshire, Hampshire and Norfolk) and one in Scotland (Borders) in three successive seasons from 2004/05 to 2006/07. The experiments examined the impact of using sequences and mixtures of fungicides (compared to single sprays) on the dose response of Opus (125 g/l epoxiconazole, BASF) for foliar disease control, preservation of green leaf area, grain yield and margin. The treatment groups and Opus doses used are outlined in Table 1. The mixture partners used were Bravo 500 (500 g/l chlorothalonil, Syngenta Crop Protection), which has primarily protectant activity against septoria, and Vivid (250 g/l pyraclostrobin, BASF), which has good activity against rusts but like all strobilurins now has very limited septoria activity due to resistance. The mixture partners were included at fixed doses of 1.0 l/ha for Bravo and 0.5 l/ha for Vivid at both T1 and T2 (equivalent to a half dose at each timing). Treatments were applied in 200-220 l/ha water as a medium-fine spray, using conventional flat fan nozzles.

Table 1. Treatment groups, application timings and doses

Treatment Group	T1 Spray (GS32, leaf 3)	Opus doses (l/ha)	T2 Spray (GS39, flag lf)	Opus doses (l/ha)
untreated	none	-	none	-
single-spray Opus	none	-	Opus alone	0.25, 0.5, 1.0, 2.0
two-spray Opus	Opus alone	0.15, 0.3, 0.6, 1.2	Opus alone	0.25, 0.5, 1.0, 2.0
two-spray Opus + Bravo	Opus + Bravo 500	0.15, 0.3, 0.6, 1.2	Opus + Bravo 500	0.25, 0.5, 1.0, 2.0
two-spray Opus + Bravo + Vivid	Opus + Bravo 500 + Vivid	0.15, 0.3, 0.6, 1.2	Opus + Bravo 500 + Vivid	0.25, 0.5, 1.0, 2.0

At each location experiments were conducted on three varieties representing a range of susceptibilities to *S. tritici*, indicated by their resistance ratings to septoria on the HGCA Recommended List for Winter Wheat. These were Consort, most susceptible and rated 4, Einstein, intermediate and rated 5, and Robigus, least susceptible and rated 7. At all sites, treatments were evaluated using a randomised block design, in separate but adjacent trials for each variety. The main assessments and measurements were:

- foliar disease (% leaf area affected) and green leaf area by leaf layer on up to four occasions, with the main assessment at between GS69 and GS80.
- grain yield and specific weight

Results from individual experiments were analysed statistically by ANOVA, and used to fit exponential dose response curves. Margins, defined here as output value (yield x grain price) less the fungicide chemical costs (not including application costs), were calculated from the fitted yield curves using the following prices: grain £120/t (except where stated otherwise), Opus £26/litre, Bravo 500 £4.50/litre and Vivid £26/litre.

Field Experimentation: Results

In 2005 and 2006 the major pathogen present at all sites was *S. tritici*, and control of septoria was therefore the main foliar disease influence on green leaf area and grain yield. In 2007, yellow rust or brown rust were present at all locations, in addition to septoria. In a number of cases, control of rusts was an equal or greater influence on green leaf area and grain yield, and this was taken into account when selecting which yield and green leaf area results to combine when summarising performance.

Disease Control: *Septoria tritici*

Septoria levels varied between sites and seasons, from less than 10% to more than 75% on leaf 2 of the untreated for Consort, and from less than 5% to more than 25% on leaf 2 for Robigus. In some experiments a two-spray Opus programme resulted in better overall control of septoria on the top two or three final leaf layers than for the same total dose of Opus applied as a single spray. However in a number of cases there was no benefit to splitting the same dose between two sprays rather than one, especially where the total Opus dose applied was 0.5 l/ha or less. In seven out of eight experiments, adding Bravo substantially reduced the amount of Opus needed to get equal control of septoria on the final two or three leaf layers, compared to a two-spray Opus programme alone (Table 2).

Table 2. Reduction in the total dose of Opus needed to achieve the same level of septoria control, as a result of adding Bravo to a two-spray Opus programme. (Based on a comparison of the doses required to give an average 75% control compared to the untreated on the top 2-4 leaf layers at the final assessment timing).

Experiment(s)	% reduction in Opus dose required as a result of adding Bravo			
	Consort		Robigus	
	Mean	Range	Mean	Range
7 Site Mean excl. Herefordshire 2006	56%	12-70%	78%	69-90%
Herefordshire 2006	no reduction	-	no reduction	-

Adding Vivid as well as Bravo had little additional effect on septoria control. The exception was Herefordshire in 2006, where the addition of Bravo (only) to a two-spray Opus programme did not improve septoria control. There was however a small benefit where both Bravo and Vivid were added. The most likely explanation for this is wet weather that caused high infection pressure prior to application of the T2 sprays, resulting in high eradicant (triazole) requirement.

Disease Control: Brown Rust and Yellow Rust

In 2007, following a mild winter and unusually warm spring, brown rust was present in wheat crops across much of England, from an early stage. In these experiments, the disease was a particular problem on Consort and Robigus in Norfolk and on Einstein in Hampshire, but it did not appear until late in the season in Herefordshire. Conversely, yellow rust was the major problem on Robigus in the Borders. The addition of Bravo to a two-spray Opus sequence rarely improved brown rust control compared to the same dose of Opus applied alone. However, adding Vivid as well as Bravo to Opus generally resulted in an increase in brown rust control for the same dose of the triazole (Table 3).

Table 3. Reduction in the dose of Opus needed to achieve the same level of brown rust control, as a result of adding Bravo or Bravo + Vivid to a two-spray Opus programme. (Based on a comparison of the doses required to give 90% control compared to the untreated on the flag leaf and leaf 2 at the final assessment timing, mean of 4 trials).

% reduction in total dose of Opus required as a result of adding partner(s)			
Bravo		Bravo + Vivid	
Mean	Range	Mean	Range
2%	0-55	45%	0-87

In one trial, the addition of Bravo to a two-spray programme with Opus did not benefit the control of yellow rust compared to Opus alone. The addition of Vivid + Bravo did improve control compared to Opus + Bravo, but was no better than Opus alone.

Disease Control: Green Leaf Area

In 2005 and 2006, when septoria was the dominant disease, the amount of green leaf area remaining on the top three leaves at the final assessment timing mirrored the control of septoria achieved for each fungicide treatment. The addition of Bravo to a two-spray Opus programme therefore substantially increased the amount of green leaf compared to Opus alone, except Herefordshire in 2006 when the main improvement to leaf area was obtained where Bravo and Vivid, rather than Bravo only, were added. In 2007, in situations where brown rust and septoria were of equal significance, both Bravo and Vivid contributed to an increase in green leaf area compared to Opus alone. However, where brown rust or yellow rust were dominant, only where Vivid was added as well as Bravo was there an increase in green leaf area.

Grain Yield and Quality

The effects of Opus dose and fungicide treatment were mostly similar between sites and seasons in the first two years. At total Opus doses of 0.5-1.0 l/ha or less, there was often little yield difference between single and two-spray programmes that had received the same amount of triazole. In a two-spray programme, addition of Bravo substantially increased yield compared to the same total dose of Opus alone on all varieties. The yield difference decreased with increasing Opus dose. The addition of Vivid as well as Bravo gave a further small yield benefit, which often decreased only marginally at higher Opus doses. Herefordshire in 2006 was different, with a more obvious yield advantage from a two-spray Opus programme compared to a single spray, a smaller yield benefit from adding Bravo and a larger improvement from the addition of Vivid as well as Bravo, which decreased rapidly with increasing Opus dose.

The effects of fungicide treatment on the response of grain yield to Opus dose varied between experiments in 2007. There were some similarities between sites on Consort. When compared with the same total dose of Opus alone in two-spray programmes, the addition of Vivid as well as Bravo gave a larger yield benefit than just adding Bravo. In all cases the yield advantage over Opus alone decreased with increasing Opus dose, although in Hampshire, Herefordshire and Norfolk there was a yield benefit to the inclusion of Vivid (plus Bravo) up to the highest Opus dose evaluated.

Grain specific weight data were collected for most of the experiments. In a number of cases differences between treatments were fairly small and not statistically significant, especially for Einstein and Robigus. Where there were treatment effects, these showed very strong similarities to the effects of fungicide treatment on grain yield.

Margin

Optimum Opus doses for each of the two-spray fungicide treatments, and the margins achieved at those doses, are summarised below in Table 4 for Consort and Robigus in

2005 and 2006 (when septoria was the dominant disease). Only six of the eight experiment are included, as yield data for the Borders site were vary variable due to flooding in 2005 and responses to fungicide dose were erratic in 2006. The addition of Bravo to a two-spray Opus programme gave a higher margin and at a lower optimum dose of Opus. The addition of Vivid as well as Bravo further reduced the optimum Opus dose, but the highest margin achieved was similar to Opus + Bravo. On Consort the optimum Opus dose for the Opus-only two-spray treatment was above the maximum permitted total dose in two sprays (2.0 l/ha). The optimum Opus dose for the Opus + Bravo treatments was only just within this limit. On Robigus all treatments had an optimum Opus dose well within the maximum permitted in two sprays.

Of the six experiments, three had relatively low septoria pressure and three had medium-high disease pressure. For Consort, optimum Opus doses were about 40% higher in the medium-high than in the low disease pressure experiments, for each treatment group. For Robigus, optimum Opus doses were about 60% higher in the medium-high than in the low disease pressure experiments. As a consequence, optimum Opus doses (in mixtures) were about 65% higher on Consort than on Robigus in the low disease pressure experiments, but only about 45% higher on Consort than on Robigus in the medium-high disease pressure experiments.

Table 4. Effect of fungicide treatment, variety and disease pressure on optimum dose of Opus in two-spray programmes (mean of 6 experiments from 2005 and 2006: 3 with medium-high and 3 with relatively low septoria pressure).

Fungicide Treatment Group	Optimum Opus dose l/ha in two-spray programmes (and margin £/ha achieved at optimum dose)					
	Consort			Robigus		
	6 Site mean	3 Site (med-high)	3 Site (low)	6 Site mean	3 Site (med-high)	3 Site (low)
Opus two-spray	2.8 (1139)	3.2+	2.3	1.4 (1213)	1.8	1.1
Opus + Bravo	1.9 (1166)	2.2	1.6	1.2 (1237)	1.5	0.9
Opus + Bravo + Vivid	1.4 (1167)	1.6	1.1	0.9 (1240)	1.1	0.7

For the Opus + Bravo treatment, an analysis was done to identify the range of Opus doses that would have given a margin within £2/ha of that achieved at the optimum, for Consort and Robigus and under medium-high and low disease pressures (Table 5).

Table 5. Range of Opus doses in a two-spray programme including Bravo that would have given margins within £2/ha of that achieved at the optimum Opus dose (mean of 3 experiments with med-high and 3 with low disease pressure from 2005 and 2006).

Septoria Pressure	Optimum Opus dose, and highest and lowest doses (l/ha) that would have given a margin within £2/ha of the optimum					
	Consort			Robigus		
	Highest	Optimum	Lowest	Highest	Optimum	Lowest
Med-high	2.6	2.2	1.9	1.8	1.5	1.2
Low	1.9	1.6	1.3	1.2	0.9	0.7

Typically, Opus doses within 15-20% above or below the optimum would have resulted in a margin within £2/ha of that achieved at the optimum dose. For both Consort and Robigus, the highest dose that could have been applied to achieve a margin within £2/ha of the optimum in the low disease pressure experiments was approximately the same as the lowest dose that could have been applied to achieve a margin within £2/ha in the medium-high disease pressure experiments.

Over the duration of this project, the wheat grain price ranged from less than £80/t to more than £160/t. Further analysis showed that optimum Opus doses would have been 25-30% higher on Consort with wheat at £160/t than with wheat at £80/t. On Robigus, optimum doses would have been 30-50% higher with wheat at £160/t than at £80/t. The adjustments to Opus dose that would have been justified were smaller when Bravo and Vivid were included in mixture with Opus, then where Opus was applied alone. Fungicide prices were kept constant for this analysis, although in practice these may also change with changing wheat price.

Table 6. Effect of fungicide treatment and variety on optimum dose of Opus (and margin achieved) in two-spray programmes (4 site summary for 2007)

Variety	Fungicide Treatment	Optimum Opus dose l/ha in two-spray programmes (and margin £/ha achieved at optimum dose)			
		Borders	Hampshire	Herefordshire	Norfolk
Consort	Opus two-spray	2.0 (985)	3.2+ (921)	3.2+ (939)	3.2+ (910)
	Opus + Bravo + Vivid	1.20 (961)	1.68 (929)	1.6 (942)	1.52 (917)
Robigus	Opus two-spray	1.04 (1030)	1.76 (951)	1.76 (961)	2.64 (942)
	Opus + Bravo + Vivid	0.32 (1026)	0.24 (977)	0.4 (1079)	1.2 (1007)

The effects of fungicide treatment on optimum Opus dose (and margin) varied in 2007 (Table 6). At all sites optimum Opus doses on Consort were lower for Opus + Bravo + Vivid than for Opus alone in a two-spray programme (for which the optimum was above the highest dose evaluated at three sites). The addition of Bravo plus Vivid substantially reduced the optimum Opus dose on Robigus at all sites, while maintaining or increasing margins. On Consort the addition of just Bravo also resulted in consistently lower optimum Opus doses, but this was not true for Robigus.

Seasonal Disease Risk

'Live monitoring' experiments conducted on winter wheat as part of CropMonitor were a useful source of information on disease progress during the project. These involved detailed weekly assessments of foliar disease on each emerging leaf layer from GS31 through to GS75, on four wheat varieties that did not receive any fungicides. Three of the sites (Hampshire, Herefordshire and Norfolk) at which sequences and mixtures experiments were located also hosted live monitoring experiments that were sown at about the same time and in the same or nearby fields. In 2005 and 2006 two of the varieties in the live monitoring were the same as in sequences and mixtures (Consort and Robigus). In 2007 Ambrosia was substituted for Consort in live monitoring, but this has a similar rating (4) for resistance to septoria on the HGCA Recommended List. On the whole, early septoria progress as indicated by the live monitoring experiments was not a good guide to septoria levels at the end of the growing season (even on the final three leaf layers) or optimum Opus dose. The data suggest that the rate at which septoria levels increased towards the end of the growing season may have been more important. In 2007 the development of rusts would also have had a significant impact.

Predicting the Performance of Fungicide Mixtures

Data from the 2005 and 2006 field experiments were used to test the extent to which it was possible to predict yield responses to fungicide programmes. Predicted yield response values were obtained using the computer programme 'Wheat Disease Manager' (WDM), which accounted for local weather (from the Met office network), varietal disease resistance (from the HGCA Recommended List for Winter Wheat) and observations of disease severity prior to spray decisions, entered into the observations dialog of WDM. Details of the products, doses and spray timings for each fungicide treatment were entered, and the yield responses predicted for each spray programme were noted. The yields obtained in the double dose treatments in the experiments were taken as representing the 'potential yield' for each variety at each site and were entered into WDM. This allowed the predicted yield responses for each programme to be plotted as predicted yield against the actual yields obtained from the experiments.

Of the 15 site x season x variety combinations tested, significant relationships between predicted and actual yields were recorded in 13 cases. Predicted yield responses to fungicide treatments as a proportion of untreated yield loss were generally in agreement with actual responses, although predictions tended to underestimate losses where the crop was untreated. The model could be recalibrated to resolve this underestimation, and more accurately predict potential yields.

The ability to predict the disease control performance of a fungicide mixture was examined by developing a 'mixture calculator' capable of taking dose-response curves for two individual active ingredients, combining them to produce response curves for the mixture, and displaying the result graphically. The calculator uses two methods of combining response curves, the additive dose method (ADM) when the mode of action is the same and the multiplicative survival method (MSM) when it is different. The resulting % disease is presented against the individual dose response curves for the two components of the mixture either as a single (straight line) value representing the chosen dose of each component, or as a curve where the full dose represents the chosen dose of each. Predicted performances against *S. tritici* and *S. nodorum* for a mix of two triazole fungicides, two non-triazoles and a triazole with a non-triazole, were compared against formulated mixtures of the two active ingredients using HGCA fungicide performance data from 2005. Taking into account the variability found in the experiments, the fungicide mixture calculator gave acceptable results.

Conclusions and Implications for Levy Payers

In situations where the dominant foliar disease on winter wheat was *S. tritici*, the addition of Bravo to Opus in a two-spray (T1 + T2) fungicide programme has:

- reduced the dose of triazole (Opus) required to obtain equal disease control, often by 50% or more,
- allowed optimum yields to be obtained at 15-30% lower doses of triazole (Opus), whilst improving margins.

Even when mixed with Bravo, optimum triazole (Opus) doses were an average of:

- 45-65% higher for the most septoria susceptible variety compared to the least.
- 40-60% higher under medium-high than under low septoria pressure.

Where brown or yellow rust were an equal or greater threat on one or more varieties:

- Vivid was of more benefit than Bravo as a mix partner for Opus to control rusts.
- Adding Vivid as well as Bravo resulted in up to 70% lower optimum triazole (Opus) doses whilst in most cases maintaining or increasing margins.

However it is important to note that choice of triazole at T1 and T2 (to reflect the target diseases) is important as well as triazole dose, and choice of mixture partner(s)

All other things being equal, increasing the grain price from £80/t to £160/t increased the optimum dose of the triazole (Opus) typically by 25-30%. Changing triazole dose is though only one way of responding to grain price. Other ways include applying an additional spray (for example at T0 or T3), or applying an appropriate mixture partner where this was otherwise not planned. Results obtained here suggest that adding a suitable mixture partner will often be more cost-effective than increasing the triazole dose. A range of triazole doses can deliver margins that are close to that achieved at the optimum. Applying a dose that is slightly above the expected optimum, especially where relatively low doses are being considered, will provide insurance in the event of higher than expected disease pressure or unexpected delays in application. However, robust disease control is best achieved through using appropriate fungicide mixtures rather than routinely applying higher than necessary doses of triazole. This may also help to avoid a potential escalation in selection for less sensitive disease isolates.

Figure 1 can be used as a guide to the relative dose of triazole that is likely to be required to achieve optimum yield, based on the septoria resistance rating of the variety, seasonal/regional septoria pressure, the threat (or not) from rusts and choice of mixture partner(s). The figure is based on the relative optimum doses obtained in the experiments, and therefore assumes programmes with well-timed applications at T1 and T2, the use of a triazole with good activity against septoria and rusts, and (where applicable) the addition of chlorothalonil or a rust-active strobilurin at robust doses at both timings. The longer the horizontal bar, the higher the dose of triazole required. Where the bar extends beyond the vertical dotted line, this indicates that it is unlikely that optimum yield will be achieved with this particular treatment for this combination of varietal resistance and disease pressure, so an appropriate partner (or further partner) should be used. Where the bar is very close to, or touching, the dotted line, using an appropriate partner (or further partner) is preferable to avoid over-reliance on the triazole component.

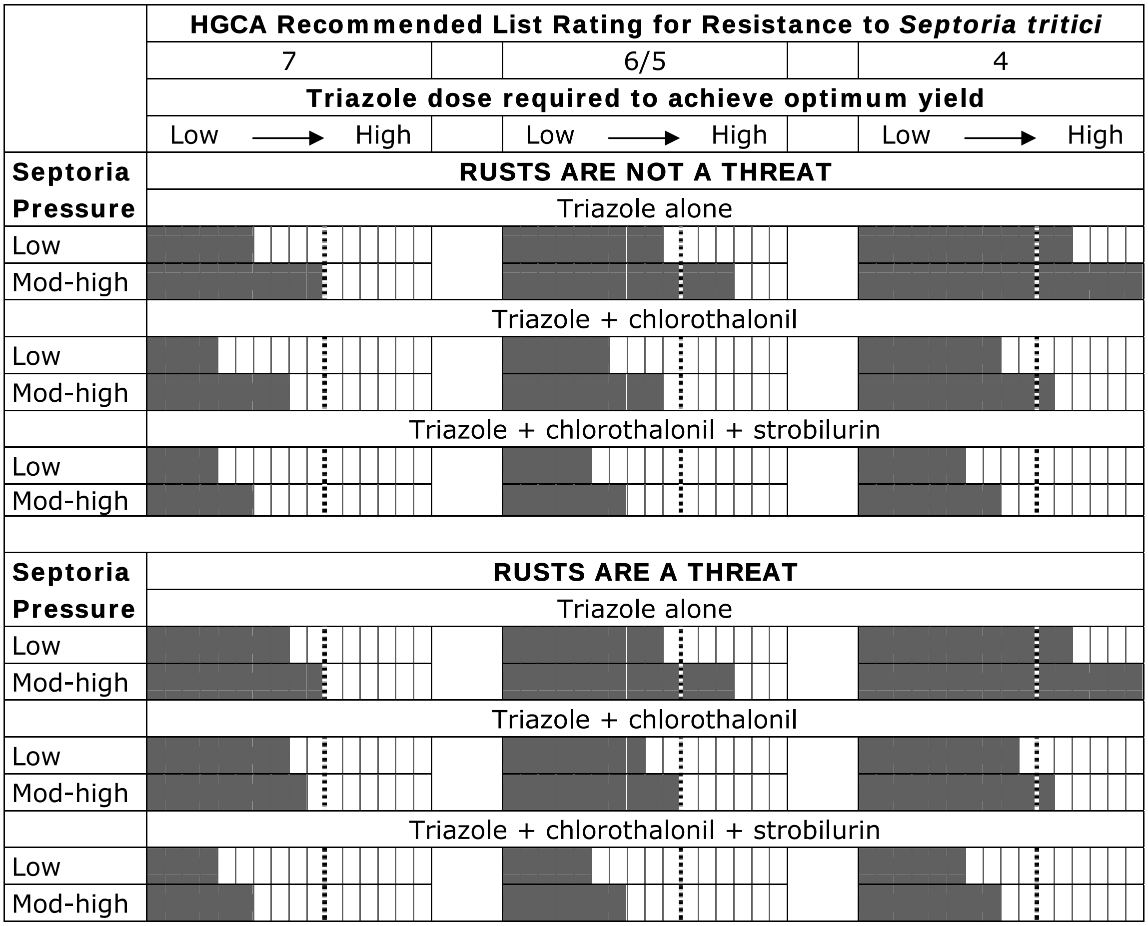


Figure 1. A guide to relative optimum triazole doses for different disease scenarios

Comparisons of the results obtained in the field experimentation within this project against indicators of disease pressure from within-season monitoring have highlighted the difficulties that exist in forecasting fungicide response based on septoria progress. Such information may have a role in monitoring rust development, which can affect the most appropriate mixture partner(s) for the triazole, and potentially the extent to which triazole doses can be reduced on varieties that are less susceptible to septoria.

Prediction of yield response (and economic return) from fungicides is a prerequisite for objective treatment decisions. To be of value the prediction needs to be made with information available at the time of the treatment decision. The degree of predictive value demonstrated here suggests that WDM could help support treatment decisions if the system could be delivered to users in an appropriate form. Although only limited testing was possible with the available data, a fungicide mixture calculator that was designed to take dose-response curves for individual fungicide active ingredients and combine them to produce dose-response curves for mixtures gave promising results.

Technical Detail

1.0 Introduction

1.1 Background

The performance of individual fungicide active ingredients in winter wheat, when applied as single sprays, has been evaluated in ongoing HGCA-funded research since 1994. The experiments have allowed comparative dose-response curves to be produced for a range of fungicides, for the control of the major foliar diseases when applied to highly-susceptible varieties at high disease pressure sites. These have been reported in a series of HGCA final project reports, 'Wheat Disease Management Guides' (most recent version published in 2008) and as an interactive 'Fungicide Performance' tool, all of which can be found on the HGCA web site (www.hgca.com).

This research, along with other studies, had indicated a downward shift in the performance of triazoles (for example epoxiconazole) against *Septoria tritici* [(1)] over the 10-year period from 1995 to 2005. This has been attributed to steadily declining sensitivity of the disease to azole fungicides, the impact of which has been a 'straightening' of dose response curves, compared to the mid 1990s when relatively low doses could often achieve a high proportion of the control obtained at full dose. This has provided a compelling argument for the use of robust doses of triazole fungicides on farm to maintain control of septoria.

In practice however the majority of wheat crops receive more than one fungicide spray and each application usually consists of a mixture of at least two products. A new project was therefore commissioned, to complement the existing research, which would add important information on the effects of using a sequence of two sprays, or a mixture of two or more products, on the shape of the dose response curves for disease, green leaf area and yield. Due to its importance as the most widespread (92% of crops affected in the 2007 CropMonitor[(2)] national annual survey of winter wheat diseases) and damaging (estimated annual losses of £30 million even with fungicides) foliar disease in wheat in the UK, and the significance of declining sensitivity to the major fungicide group (triazoles) used against it, control of septoria was the main focus of the project.

An additional limitation of the existing HGCA research was that fungicide performance was being evaluated only on very susceptible varieties and at high risk locations. This ensures a stern test for the fungicides, and enables potentially small differences in performance between them to be detected. In practice though a wide range of varieties are present on farm, and not all of these are highly susceptible to disease or grown in high disease pressure situations. Surveys of commercial crops (such as the CropMonitor survey of winter wheat diseases) show that disease risk is often poorly evaluated when deciding treatments, with fungicides overused on relatively disease resistant varieties and underused on the most susceptible ones, and input levels not always reflecting seasonal risk.

The ubiquitous nature of septoria and the relative stability of varietal resistance mean that this disease most lends itself to adjusting fungicide dose (rather than simply fungicide choice) to account for the threat posed by it. There is however a need for information to support decisions on the appropriate size of the adjustment in dose to account for varietal susceptibility and disease pressure.

The number of potential combinations is such that it would clearly not be possible to determine experimentally the dose response implications of all possible fungicide sequences and mixtures and for every disease. Therefore, the project also provided an opportunity to look at how closely the relative disease control and yield performance of mixtures could be predicted from data on the performance of the individual fungicide active ingredients applied as single sprays, generated by ongoing HGCA studies.

(1) Most recent scientific name is *Mycosphaerella graminicola*

(2) For more information on CropMonitor go to www.cropmonitor.co.uk

1.2 Project Overall Aim

To establish the principles by which farmers could develop fungicide programmes and mixtures in winter wheat from HGCA fungicide performance information.

Specific objectives:

1. To determine how mixtures and sequences affect dose response (including effects on disease and yield).
2. To determine how to get from a *Septoria tritici* resistance rating on the HGCA Recommended Lists to a fungicide dose decision and give better guidance on varietal risk in relation to economics.
3. To improve the interpretation of appropriate fungicide dose information in the context of seasonal disease risk (from CropMonitor).
4. To develop an approach to calculate the efficacy of a mixture and sequences given the dose response curves for each component.

2.0 Materials and Methods (Field Experimentation)

2.1 Overview

Field experiments were conducted at three locations in England and one in Scotland in three successive seasons from 2004/05 to 2006/07. The experiments examined the impact of using sequences and mixtures of fungicides (compared to single sprays) on the dose response of a triazole (epoxiconazole, as Opus) for foliar disease control, preservation of green leaf area, grain yield and margin (output value less fungicide cost). At each location the experiments were conducted on three varieties that represented a range of susceptibilities to *Septoria tritici*, indicated by their resistance ratings to septoria leaf blotch on the HGCA Recommended List for Winter Wheat. Disease, green leaf area, grain yield and specific weight were recorded, and used to fit dose response curves.

2.2 Sites

Field experiments were established at four locations and over three seasons (2004/05, 2005/06 and 2006/07) in order to provide a range of disease pressures (Table 2.1). As the main disease target was *S. tritici*, two sites (Sutton Scotney and Rosemaund) were selected that were representative of moderate-high septoria risk locations (based on rainfall and long term severity), and two sites (Whitsome and Morley) that were representative of lower risk locations. However, the actual disease levels that occurred each year at each site did not necessarily follow this pattern. Further site details can be found in appendix D, and rainfall records in appendix E.

Table 2.1 Locations of the field experiments

Site	**County**	**Soil Type**	**Long term average septoria severity**
SAC Whitsome	Borders	clay loam	low-moderate
TAG Sutton Scotney	Hampshire	silty clay loam over chalk	moderate
ADAS Rosemaund	Herefordshire	deep silty clay loam	moderate-high
TAG Morley	Norfolk	sandy loam over clay	low

2.3 Varieties

The field experiments were conducted on three varieties (Consort, Einstein and Robigus) at every location to provide a range of susceptibilities to *S. tritici*, and to enable data to be generated to address objective 2. The same varieties were used in all years, with the exception of the Herefordshire site in 2004/05 where Einstein was inadvertently replaced by Equinox. For each variety, resistance ratings to the main foliar diseases are shown in Table 2.2. These are based on the 2008/09 HGCA Recommended List for Winter Wheat, and therefore average ratings over the three project years. Where different, their ratings when the project started in 2004/05 are shown in brackets (Equinox was removed from the Recommended List after 2004/05).

Table 2.2 Varieties used in the field experiments

	2008/09 Recommended List Disease Resistance Ratings[2]			
Variety	*Septoria tritici*	Yellow Rust	Brown Rust	Mildew
Consort	4	7 (5)	3 (4)	6
Einstein	5	6 (5)	5 (6)	6 (7)
Equinox	(4)	(4)	(9)	(5)
Robigus	7	3	6 (9)	6 (9)

[2] HGCA Recommended Lists for Winter Wheat 2008/09 & 2004/05 (www.hgca.com)

2.4 Fungicide Treatments

In all, 18 treatments were compared on each of the varieties. These consisted of:
- four 1-spray Opus treatments applied at T2 (GS39, flag leaf emerged) at quarter, half, full and double the recommended dose
- four 2-spray Opus treatments with applications at T2 as above but preceded by applications at T1 (GS32, leaf 3 emerged) at 60% of the dose to be applied at T2
- four 2-spray Opus + Bravo treatments as for the 2-spray Opus treatments above but with the addition of a fixed dose of Bravo 500 (equal to half the recommended dose) at T1 and T2
- four 2-spray Opus + Bravo + Vivid treatments as for the 2-spray Opus + Bravo treatments above but with the addition of a fixed dose of Vivid (equal to half the recommended dose) at T1 and T2
- two fully untreateds

The treatment structure is summarised in table 2.3, the full treatment list is shown in table 2.4 and the fungicide products used in table 2.5.

Table 2.3 Treatment groups, application timings and number of doses

Fungicide Treatment Group	T1 (GS32, final leaf 3 emerging)	Number of Opus doses (l/ha)	T2 (GS39, flag leaf emerged)	Number of Opus doses (l/ha)
untreated	none	-	none	-
1-spray Opus	none	-	Opus alone	4 (0.25, 0.5, 1.0 and 2.0)
2-spray Opus	Opus alone	4 (0.15, 0.3, 0.6 and 1.2)	Opus alone	4 (0.25, 0.5, 1.0 and 2.0)
2-spray Opus + Bravo	Opus + Bravo 500	4 (0.15, 0.3, 0.6 and 1.2)	Opus + Bravo 500	4 (0.25, 0.5, 1.0 and 2.0)
2-spray Opus + Bravo + Vivid	Opus + Bravo 500 + Vivid	4 (0.15, 0.3, 0.6 and 1.2)	Opus + Bravo 500 + Vivid	4 (0.25, 0.5, 1.0 and 2.0)

Table 2.4 Full treatment list

Treat	Opus Dose (l/ha)			Bravo Dose (l/ha)			Vivid Dose (l/ha)		
No.	T1	T2	Total	T1	T2	Total	T1	T2	Total
1 untr.	0	0	0	0	0	0	0	0	0
2	0	0.25	0.25	0	0	0	0	0	0
3	0	0.5	0.5	0	0	0	0	0	0
4	0	1.0	1.0	0	0	0	0	0	0
5	0	2.0	2.0	0	0	0	0	0	0
6	0.15	0.25	0.4	0	0	0	0	0	0
7	0.3	0.5	0.8	0	0	0	0	0	0
8	0.6	1.0	1.6	0	0	0	0	0	0
9	1.2	2.0	3.2	0	0	0	0	0	0
10	0.15	0.25	0.4	1.0	1.0	2.0	0	0	0
11	0.3	0.5	0.8	1.0	1.0	2.0	0	0	0
12	0.6	1.0	1.6	1.0	1.0	2.0	0	0	0
13	1.2	2.0	3.2	1.0	1.0	2.0	0	0	0
14	0.15	0.25	0.4	1.0	1.0	2.0	0.5	0.5	1.0
15	0.3	0.5	0.8	1.0	1.0	2.0	0.5	0.5	1.0
16	0.6	1.0	1.6	1.0	1.0	2.0	0.5	0.5	1.0
17	1.2	2.0	3.2	1.0	1.0	2.0	0.5	0.5	1.0
18 untr.	0	0	0	0	0	0	0	0	0

It should be noted that the maximum individual dose of Opus than can be applied to winter wheat is 1.0 l/ha. The maximum total dose that can be applied is 2.0 l/ha. The highest doses used at T1 and T2 in each treatment group were included to allow dose response curves to be fitted, and are not in any way intended to represent actual recommendations for use.

Table 2.5 Fungicide products used

Product	Recommended Full Dose (l/ha)	Active Ingredient	Concentration (g ai / litre)	Formulation	Manufacturer
Opus	1.0	epoxiconazole	125	SC	BASF
Bravo 500	2.0	chlorothalonil	500	SC	Syngenta CP
Vivid	1.0	pyraclostrobin	250	SC	BASF

Opus has both eradicant and protectant activity against septoria (and rusts). Bravo has primarily protectant activity against septoria. Vivid has activity against rusts, but like all strobilurin fungicides now has very limited septoria activity due to resistance.

2.5 Application of Fungicide Treatments

All fungicide treatments were applied in 200-220 l/ha water as a medium-fine spray, using plot spraying equipment fitted with conventional flat fan nozzles.

2.6 Assessments

The assessments and monitoring conducted during the three seasons consisted of:

- Date, growth stage and emerging leaf at each fungicide application timing (see appendix C)
- Foliar disease (% leaf area affected by leaf layer) prior to the T1 application timing (global untreated, see appendix B)
- Full assessment of foliar diseases (% leaf area affected) and green leaf area by leaf layer at around the T2 application timing, and again at around GS71-77 (for the Borders site two assessments were often done, one at around GS69-71 and one at around GS77-80, due to later maturity)
- Grain yield and specific weight (using plot combines fitted with weighing and sampling systems)
- Weekly rainfall

2.7 Experiment design, statistical analysis and curve fitting

At all sites, treatments were evaluated using a randomised block design, in separate but adjacent trials for each variety. In 2005 and 2006, disease and green leaf area results for individual leaf layers were logit transformed, and then back transformed to produce treatment means for presentation. Data were discarded if there were:

- No significant treatment effects. Assessments were included when treatment and at least one of treatment group or treatment dose were significant.
- Excessive missing values
- Oddities such as 0% disease and 0% green leaf area *i.e.* the leaf was dead

Disease, green leaf area and yield data were analysed by ANOVA with the following general structure:

Source of variation	d.f.	
block stratum	2	
block.*units* stratum		
treatment	1	untreated vs treated
treatment group	3	between groups of treatments (Opus 1-spray, Opus 2-spray, Opus+Bravo 2-spray, Opus+Bravo+Vivid)
treatment dose	3	between doses of treatment groups
treatment.group.dose	9	interaction between doses and treatment groups
Residual	35	
Total	53	

Where appropriate, in 2005 and 2006 the ANOVA included a covariate on plot position within the block, if found to be significant. This allowed for a linear trend across the block.

Data from the experiments were used to fit exponential dose response curves (where dose is the proportion of the recommended dose for the fungicide that was applied at the T2 timing) describing the effect of fungicides on disease, green leaf area, yield and grain quality. Sets of data for which no exponential curves could be fitted, or with negative adjusted R^2 or unrealistic fits, had just the observed means plotted. Curves were fitted to the means for each dose, such that the R^2 values shown only represent uncertainty associated with lack of fit to the model, not variability in the observations. In 2007, curves were also fitted based on the replicates for each dose which takes into account variability in the observations. This tends to result in lower R^2 values, but does not affect the estimates for the curve parameters. Therefore, only the fits to the means for each dose are shown in this report.

In 2005 and 2006, over-assessment means and dose response curves were calculated from two or more assessments on two or more leaf layers. In the case of disease control the means represented both eradicant and protectant activity. As most of the treatments involved two-spray programmes it was not practical to separate these out.

2.8 Margin Calculations

Margins, defined for the purposes of this report as output value (yield x grain price) less the fungicide chemical costs (not including application costs), were calculated using the following prices (unless stated otherwise):

Grain value £120/t (same price assumed for all varieties with no premium).

Opus £26/litre

Bravo 500 £4.50/litre

Vivid £26/litre

3.0 Results (Field Experimentation)

Results from the field experimentation are reported in the following sections:

3.1 Disease control (*Septoria tritici*)

3.2 Disease control (Brown rust and Yellow rust)

3.3 Green Leaf Area

3.4 Grain Yield

3.5 Grain Specific Weight

3.6 Margins

In sections 3.1-3.5, response curves are presented for key individual experiments from the three years of the project. Both fitted curves and the original data points are shown on the graphs. The original fitted curves were plotted against the dose of Opus applied at T2 (parameters and statistics for which can be found in appendix F). However, in this section of the report the curves are shown plotted against the total (T1 + T2) dose of Opus applied, to allow easier visual comparison of the 1-spray and 2-spray Opus treatment groups. The highest dose evaluated for the 1-spray Opus treatment group was 2.0 l/ha, compared to 3.2 (1.2 + 2.0) l/ha for all of the 2-spray treatment groups. The 1-spray Opus treatment group curves are therefore shorter, but consist of the same number of points. Note that these highest doses exceed the maximum approved individual and total doses of Opus respectively.

The response curves for disease and green leaf area in 2005 and 2006 are based on over-assessment means for two or three of the top three final leaf layers. The curves for 2007 however are based on a single assessment on one of the top two final leaf layers.

In 2005 and 2006 the dominant pathogen present at all sites was *S. tritici*, and control of septoria was therefore the main disease influence on green leaf area and grain yield. In 2007, yellow rust or brown rust were present at all locations, together with septoria. In a number of cases, control of rusts was an equal or greater influence on green leaf area and grain yield. This has been taken into account when selecting which yield and green leaf area results from over the three years it is appropriate to combine when averaging or summarising performance.

3.1 Disease Control (*Septoria tritici*)

Septoria pressure varied substantially between sites and seasons, as indicated by levels on leaf 2 of the untreated by the final assessment timing at GS69-77 in late June or early July (Table 3.1.1). Assessments in 2007 were in some cases confounded by the presence of rusts, which resulted in rapid senescence of the untreated plots.

Table 3.1.1 Levels of *S. tritici* on leaf 2 of the untreated at final assessment timing

		% *S. tritici* on leaf 2 of untreated		
Year	Site	Consort	Einstein	Robigus
2005	Borders	58.6	26.0	23.7
	Hampshire	8.7	8.1	2.7
	Herefordshire	11.0	-	3.0
	Norfolk	25.0	24.5	13.1
2006	Borders	14.7	9.4	1.6
	Hampshire	64.3	35.2	28.6
	Herefordshire	75.8	14.8	10.7
	Norfolk	10.5	1.8	3.4
2007	Borders*	39.2	32.0	25.8
	Hampshire	-	-	-
	Herefordshire	19.0	17.2	20.0
	Norfolk	26.7	14.7	26.3

* Flag leaf levels shown, as values for leaf 2 untreated were unreliable

Results for septoria control in Norfolk in 2005 are shown in figures 3.1.1-3.1.3.

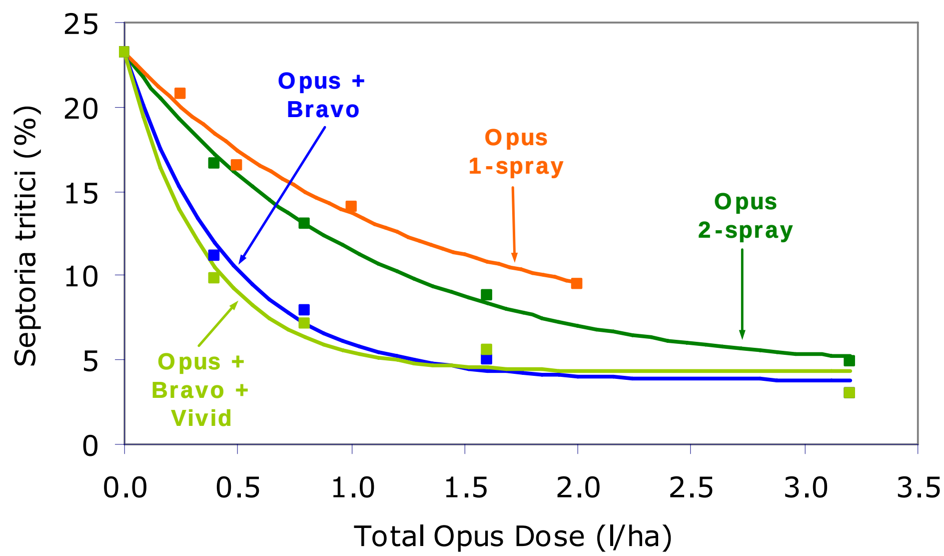


Fig. 3.1.1 Effect of fungicide treatment and total Opus dose on the mean % area of the flag leaf, leaf 2 and leaf 3 showing *S. tritici* symptoms on Consort in Norfolk at GS69-75 in 2005

Untreated septoria levels were highest on Consort and lowest on Robigus. All three varieties showed similar treatment effects. 2-spray Opus treatments gave slightly better septoria control than the same total dose applied as a single spray. For the same dose of Opus, the addition of Bravo substantially increased septoria control compared to 2-spray Opus-only treatments, especially at total doses of 0.4-0.8 l/ha. However, adding Vivid as well as Bravo had little further effect on septoria control.

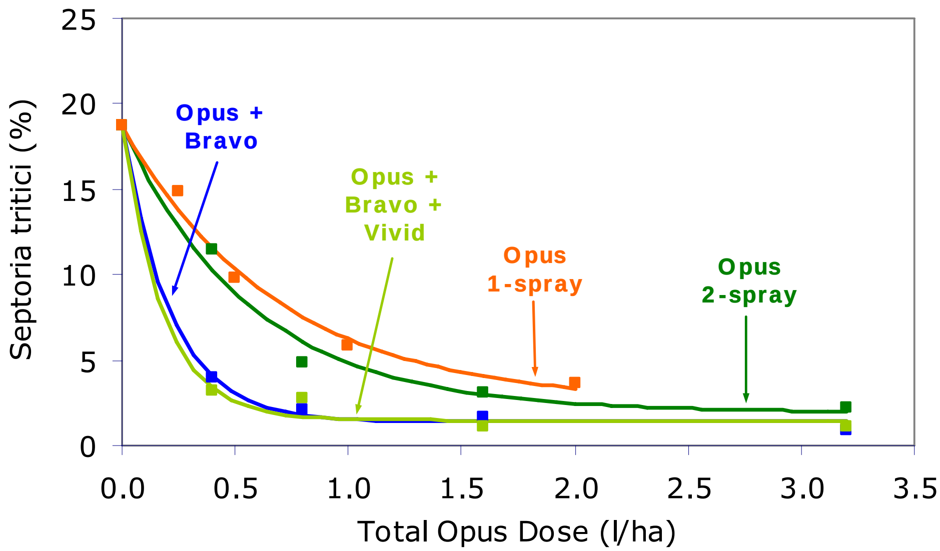


Fig. 3.1.2 Effect of fungicide treatment and total Opus dose on the mean % area of the flag leaf, leaf 2 and leaf 3 showing *S. tritici* symptoms on Einstein in Norfolk at GS69-75 in 2005

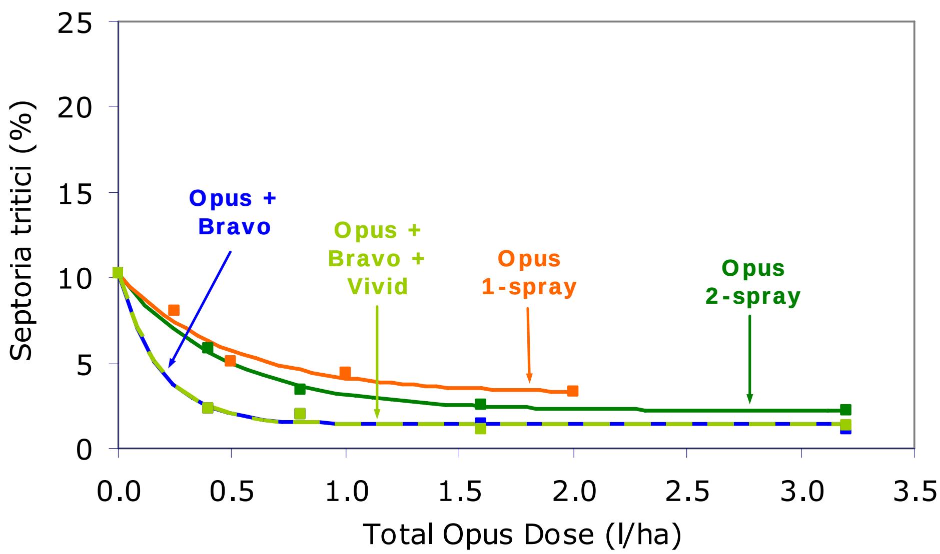


Fig. 3.1.3 Effect of fungicide treatment and total Opus dose on the mean % area of the flag leaf, leaf 2 and leaf 3 showing *S. tritici* symptoms on Robigus in Norfolk at GS69-75 in 2005

Results similar to those in Norfolk were also obtained at other sites in 2005, for example on Einstein in Hampshire (figure 3.1.4)

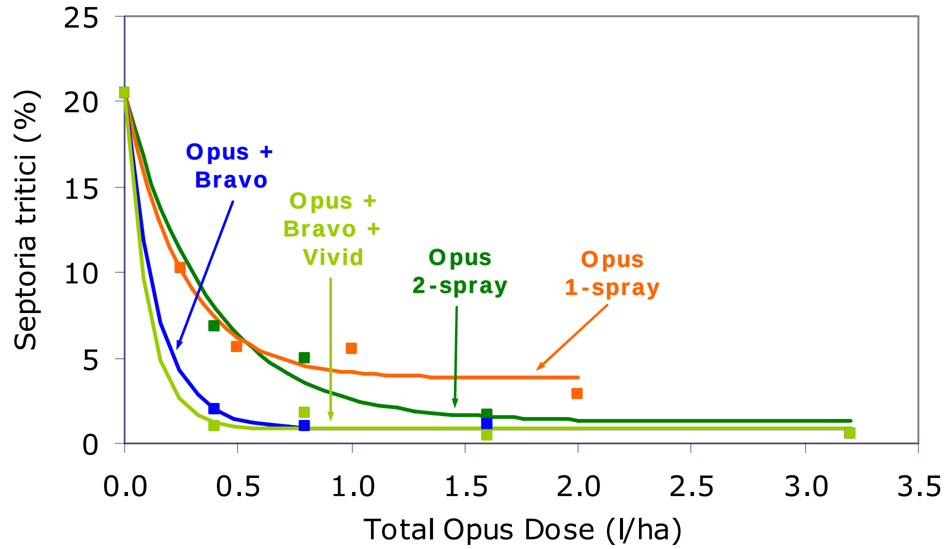


Fig. 3.1.4 Effect of fungicide treatment and total Opus dose on the mean % leaf area of leaf 2 and leaf 3 showing *S. tritici* symptoms on Einstein in Hampshire at GS69 in 2005

At three out of four sites in 2006 similar trends were observed to those seen in 2005, with the addition of Bravo resulting in the greatest reduction in septoria levels compared to 2-spray Opus-only treatments. In Hampshire there was no improvement in septoria control on the two final leaf layers as a result of applying the same total dose of Opus as a 2-spray programme rather than as a single spray (figure 3.1.5).

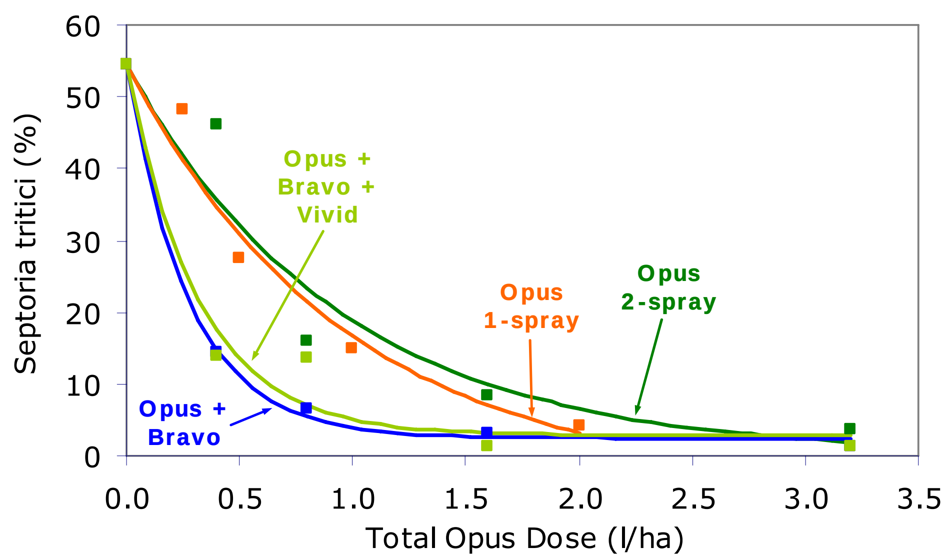


Fig. 3.1.5 Effect of fungicide treatment and total Opus dose on the mean % leaf area of the flag leaf and leaf 2 showing *S. tritici* symptoms on Consort in Hampshire at GS71-75 in 2006

However in contrast to 2005 and other locations in 2006, the addition of Bravo alone did not improve septoria control compared to 2-spray Opus-only treatments receiving the same dose of Opus, on either Robigus or Consort in Herefordshire (figure 3.1.6). There was a small benefit where Vivid as well as Bravo was added.

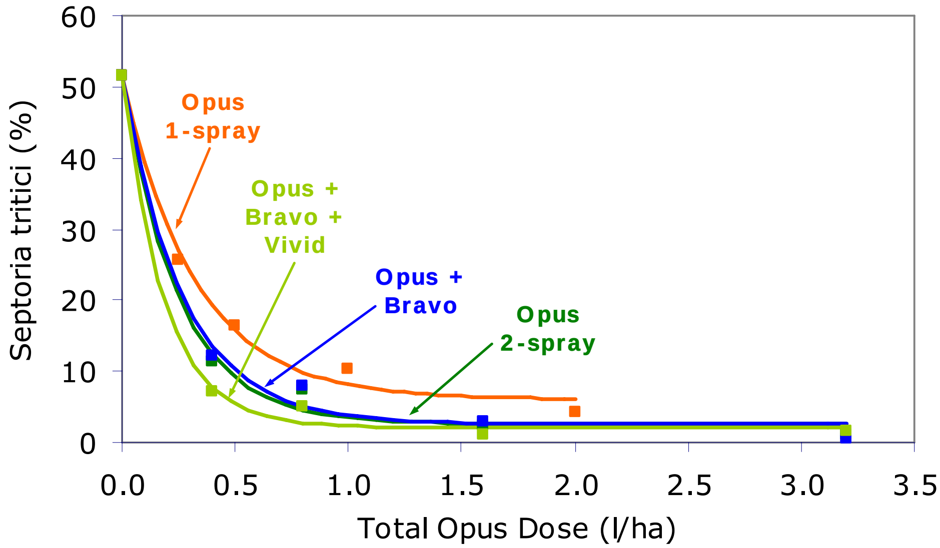


Fig. 3.1.6 Effect of fungicide treatment and total Opus dose on the mean % area of the flag leaf and leaf 2 showing *S. tritici* symptoms on Consort in Herefordshire at GS71-73 in 2006

In 2007 the addition of Bravo increased the control of septoria compared to 2-spray Opus-only treatments for example on Robigus in both Hampshire (figure 3.1.7) and Herefordshire (figure 3.1.8). There was little difference in septoria levels between single and 2-spray programmes that had received the same total doses of Opus.

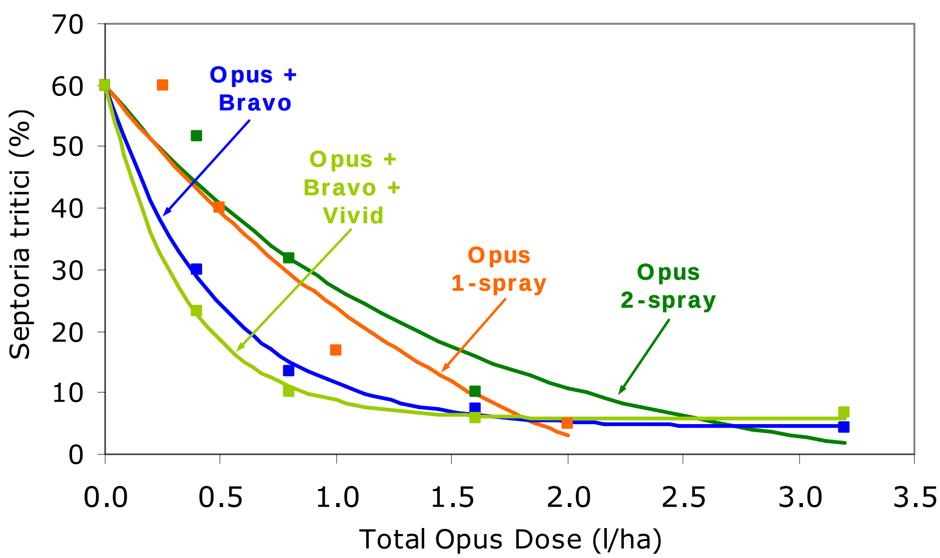


Fig. 3.1.7 Effect of fungicide treatment and total Opus dose on the % leaf area of the flag leaf showing *S. tritici* symptoms on Robigus in Hampshire at GS75-80 in 2007

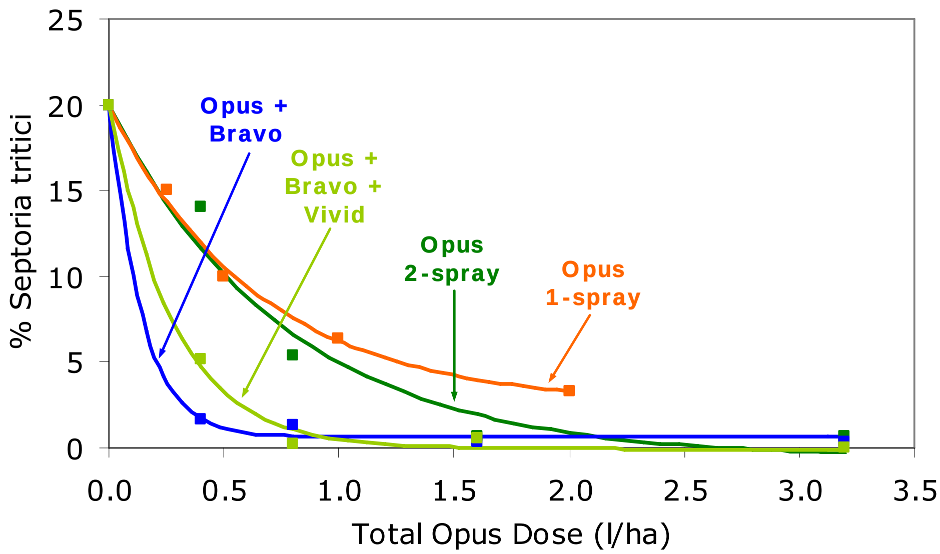


Fig. 3.1.8 Effect of fungicide treatment and total Opus dose on the % leaf area of leaf 2 showing *S. tritici* symptoms on Robigus in Herefordshire at GS69-71 in 2007

Summary of *Septoria tritici* Control

In seven out of eight experiments from 2005 and 2006, where septoria was the only disease present at significant levels, the addition of Bravo reduced the total dose of Opus needed to achieve equal disease control on the final two or three leaf layers, typically by half or more compared to 2-spray Opus-only treatments (Table 3.1.2). This was true for Consort, Robigus and Einstein (not shown). The exception was Herefordshire in 2006, where the addition of Bravo alone did not reduce the dose of Opus required. The addition of Vivid as well as Bravo did not reduce further the total Opus dose needed in the seven experiments, but did result in a reduction in the Opus dose required in Herefordshire in 2006.

Table 3.1.2 % Reduction in the dose of Opus needed as a result of adding Bravo or Bravo + Vivid to a 2-spray Opus programme. (Based on a comparison of the doses required to achieve an average 75% reduction in septoria levels compared to the untreated at GS69-75, on the top 2-4 leaf layers at the final assessment timing).

Experiment(s)	% reduction in total dose of Opus required as a result of adding Bravo			
	Consort		Robigus	
	Mean	Range	Mean	Range
7 Site Mean excl. Herefordshire 2006	56%	12-70%	78%	69-90%
Herefordshire 2006	no reduction	-	no reduction	-

Experiment(s)	% reduction in total dose of Opus required as a result of adding Bravo + Vivid			
	Consort		Robigus	
	Mean	Range	Mean	Range
7 Site Mean excl. Herefordshire 2006	58%	12-75%	77%	65-89%
Herefordshire 2006	26%	-	28%	-

A cross-site analysis was done to compare the effects of treatment group and Opus dose on levels of septoria on leaf 2 at GS69-77 on each variety for 2005 and 2006 (Table 3.1.3a and b). A similar analysis was performed for their effects on overall septoria levels on leaves 3, 2 and the flag leaf (see appendix G). Treatment group effects followed similar trends on all three varieties. Disease levels on Einstein appeared to be more responsive to fungicide treatment than those on Robigus or Einstein, although it should be noted that the means for Einstein included one less site (in 2005). There was a suggestion too on Consort of a slightly smaller benefit from the addition of Bravo and a slightly greater benefit from 2-sprays of Opus compared to 1-spray, and from the addition of Vivid, compared to the other two varieties. Septoria levels on leaf 2 of Robigus were less responsive to Opus dose, when compared to Einstein in particular.

Table 3.1.3 Cross-site analysis of % leaf area of leaf 2 showing *S. tritici* symptoms at GS69-77 (mean of 4 sites from 2005 and 2006, except Einstein 3 sites only in 2005) (a) Effect of treatment group (mean of four Opus doses) and (b) Effect of Opus dose (mean of four treatment groups)

(a)

Variety	% *S. tritici* on leaf 2 per treatment group				
	Untreated	Opus 1-spray	Opus 2-spray	Opus + Bravo	Opus + Bravo + Vivid
Consort	18.1	11.4	6.9	4.8	3.9
Einstein	10.7	4.2	3.4	1.5	1.5
Robigus	8.5	4.9	3.5	1.8	1.6
	F prob. <0.001, SEM 0.899 (max), 3.815 (min) d.f. 1201				

(b)

Variety	% *S. tritici* on leaf 2 per T2 (or total) Opus dose				
	0 (untreated)	0.25 (0.4)	0.5 (0.8)	1.0 (1.6)	2.0 (3.2)
Consort	18.1	10.9	7.6	5.3	3.2
Einstein	10.7	4.4	3.2	2.1	0.9
Robigus	8.5	3.9	3.6	2.5	1.8
	F prob. <0.001, SEM 0.899 (max), 3.815 (min) d.f. 1201				

3.2 Disease Control (Brown Rust and Yellow Rust)

In the first two seasons, *S. tritici* was the dominant disease at all sites, with little or no rust recorded in any of the trials. In 2007 disease pressure was mixed. Brown rust was present in wheat crops across much of England from an early stage. This followed a mild winter with few frosts, and an exceptionally warm spring with average air temperatures ranging from 1.5 to 3.5^{O}C above normal from January through to April. As a result, brown rust was recorded in one or more varieties in Norfolk, Hampshire and (late in the season) Herefordshire. Highest levels rust were recorded on Einstein in Hampshire, and on Consort and Robigus in Norfolk (figures 3.2.1-3.2.3).

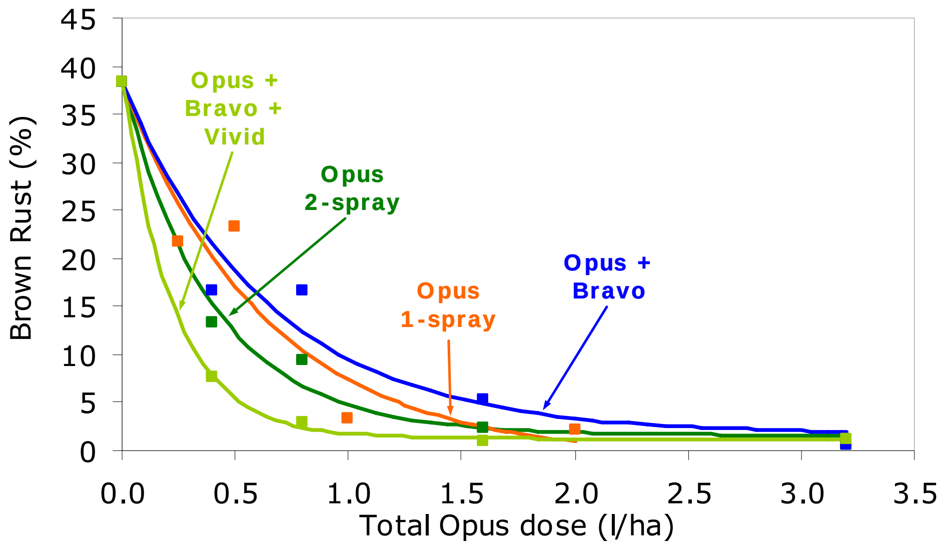


Fig. 3.2.1 Effect of fungicide treatment and total Opus dose on the % leaf area of leaf 2 showing brown rust symptoms on Einstein in Hampshire at GS75-80 in 2007

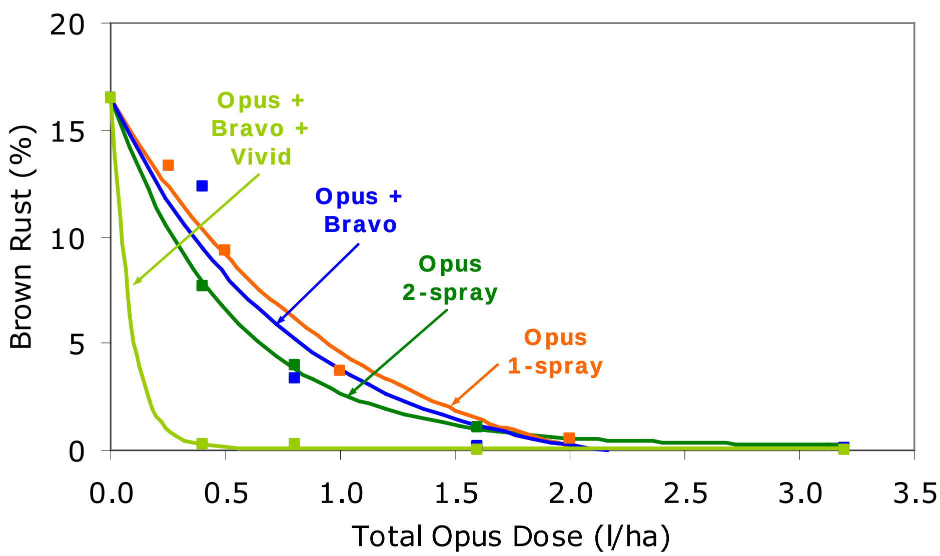


Fig. 3.2.2 Effect of fungicide treatment and total Opus dose on the % leaf area of the flag leaf showing brown rust symptoms on Robigus in Norfolk at GS71-73 in 2007

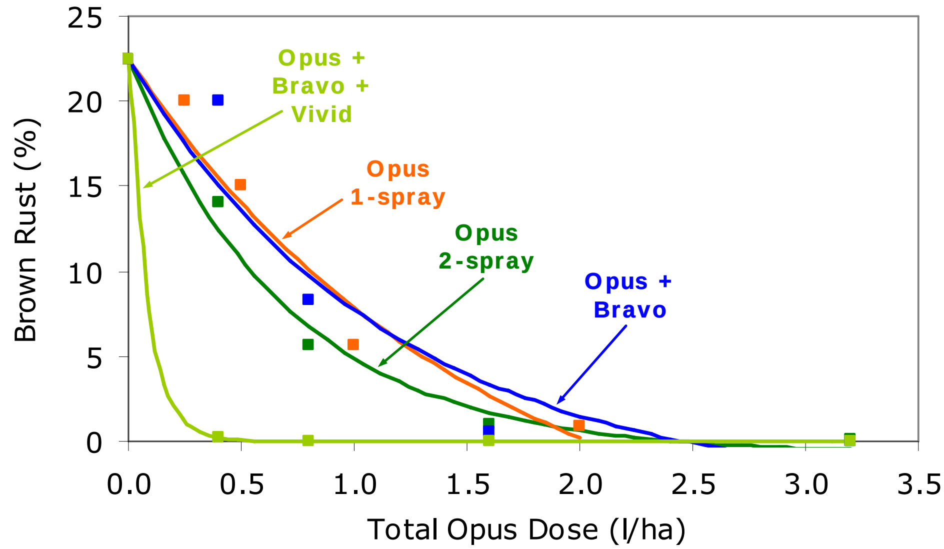


Fig. 3.2.3 Effect of fungicide treatment and total Opus dose on the % leaf area of leaf 2 showing brown rust symptoms on Robigus in Norfolk at GS71-73 in 2007

The addition of Vivid (plus Bravo) substantially reduced levels of brown rust compared to 2-spray treatments based on Opus or Opus + Bravo only. In a number of trials there was a tendency for the Opus + Bravo treatments to have slightly higher brown rust levels than 2-spray Opus-only treatments that had received the same Opus dose. Splitting the same dose of Opus between two sprays rather than just one generally resulted in lower levels of brown rust.

When averaged over four site/variety combinations (Consort and Robigus in Norfolk, Einstein in Hampshire and Robigus in Herefordshire), there was little reduction in the total dose of Opus needed to achieve equal control of brown rust as a result of adding Bravo to a 2-spray Opus programme. Adding Vivid as well as Bravo however reduced the dose of Opus required by nearly half (Table 3.2.1).

Table 3.2.1 Reduction in the total dose of Opus needed to achieve the same level of brown rust control, as a result of adding Bravo or Bravo + Vivid to a 2-spray Opus-only programme. (Based on a comparison of the doses required to achieve an average 90% reduction in brown rust levels compared to the untreated on the flag leaf and leaf 2 at the final assessment timing, mean of 4 trials).

% reduction in total dose of Opus required as a result of adding partner(s)			
Bravo		Bravo + Vivid	
Mean	Range	Mean	Range
2%	<0-55	45%	0-87

A cross-site analysis was done to compare the effects of treatment group and Opus dose on levels of brown rust on leaf 2 and the flag leaf at GS69-77 on each variety for 2007 (Table 3.2.2a and b). Note that the means for Consort are based on fewer values than for Einstein and Robigus. Effects of treatment group and Opus dose showed similar trends on all three varieties.

Table 3.2.2 Cross-site analysis of % area of leaf 2 and the flag leaf with brown rust symptoms at GS71-80 (based on 3 sites from 2007). (a) Effect of treatment group (mean of four Opus doses) and (b) Effect of Opus dose (mean of four treatment groups)

(a)

Variety	% brown Rust on leaf 2 and the flag leaf per treatment group				
	Untreated	Opus 1-spray	Opus 2-spray	Opus + Bravo	Opus + Bravo + Vivid
Consort	13.9	3.9	2.3	1.6	0.2
Einstein	11.6	4.0	2.2	2.4	0.9
Robigus	12.4	4.2	2.8	2.5	0.3
	F prob. <0.001, SEM 0.308 (max), 0.755 (min) d.f. 668				

(b)

Variety	% brown Rust on leaf 2 and the flag leaf per T2 (or total) Opus dose				
	0 (untreated)	0.25 (0.4)	0.5 (0.8)	1.0 (1.6)	2.0 (3.2)
Consort	13.9	5.4	1.7	0.7	0.3
Einstein	11.6	4.5	3.6	1.0	0.4
Robigus	12.4	5.9	3.0	0.8	0.1
	F prob. <0.001, SEM 0.308 (max), 0.755 (min) d.f. 668				

In 2007, yellow rust was recorded on Robigus in the Borders and (early in the season) Norfolk. In the Borders experiment, the addition of Bravo did not improve the control of yellow rust compared to 2-spray Opus-only treatments. The addition of Vivid (plus Bravo) did improve control compared to 2-spray Opus + Bravo treatments, but overall was no better than the 2-spray Opus-only treatments (figure 3.2.4).

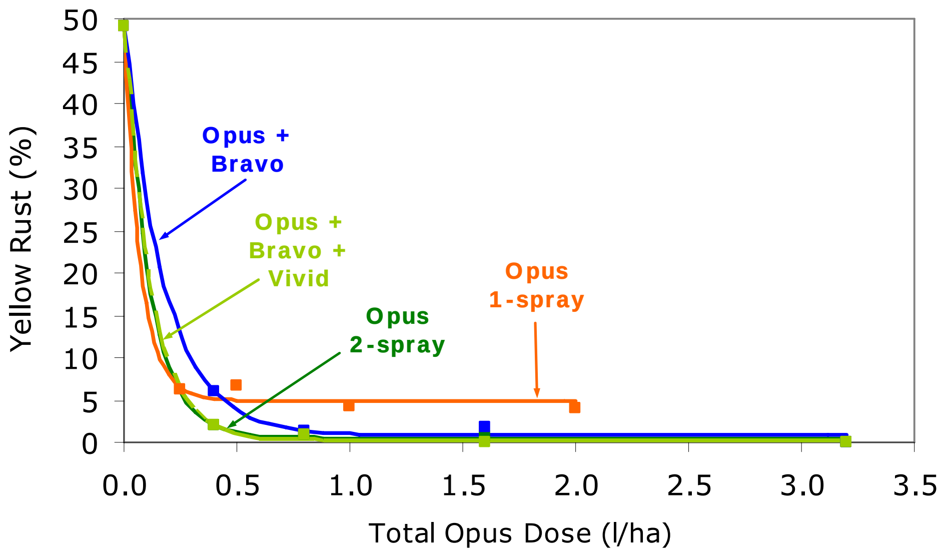


Fig. 3.2.4 Effect of fungicide treatment and total Opus dose on the % leaf area of leaf 2 showing yellow rust symptoms on Robigus in the Borders at GS65-73 in 2007

3.3 Disease Control (Green Leaf Area)

For all three varieties in Norfolk in 2005 the amount of green leaf area remaining on the top three leaves at the final assessment timing mirrored the control of septoria achieved for each treatment group. The addition of Bravo therefore substantially increased the amount of green leaf area remaining compared to 2-spray Opus-only treatments, especially at total Opus doses of 0.4-0.8 l/ha (figures 3.3.1-3.3.3).

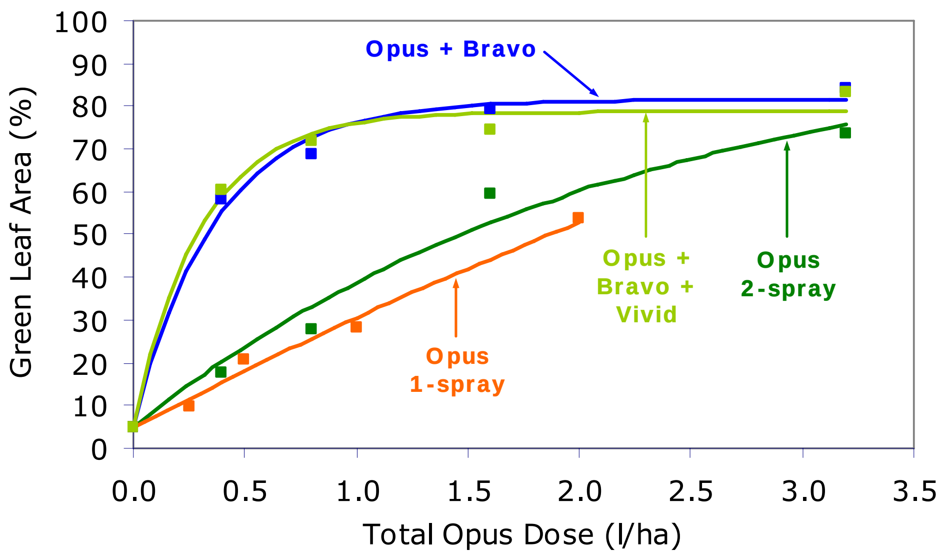


Fig. 3.3.1 Effect of fungicide treatment and total Opus dose on the % green leaf area of the flag leaf, leaf 2 and leaf 3 on Consort in Norfolk at GS69-75 in 2005

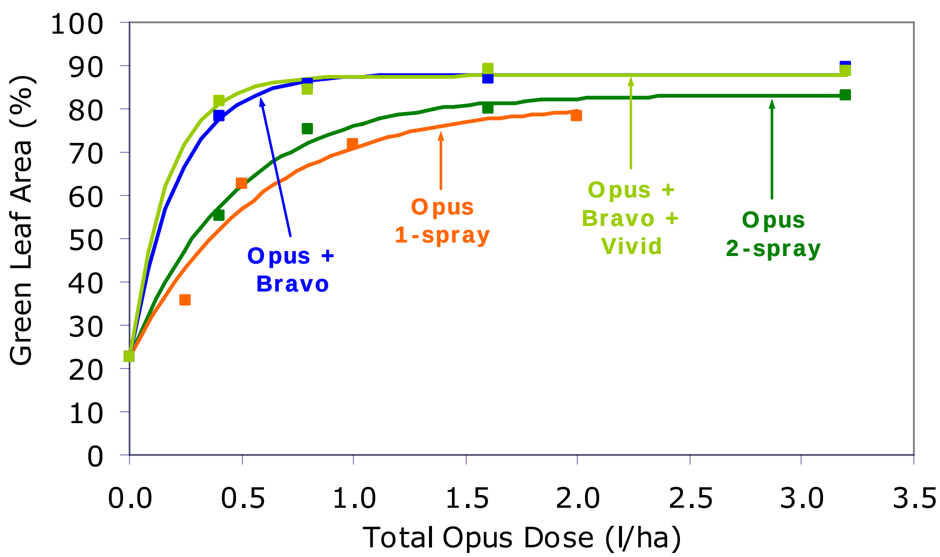


Fig. 3.3.2 Effect of fungicide treatment and total Opus dose on the % green leaf area of the flag leaf, leaf 2 and leaf 3 on Einstein in Norfolk at GS69-75 in 2005

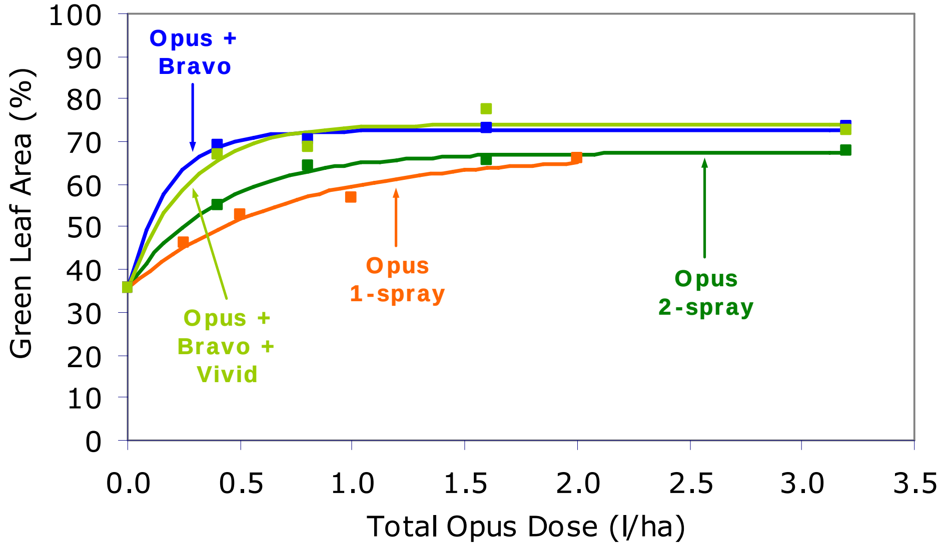


Fig. 3.3.3 Effect of fungicide treatment and total Opus dose on the % green leaf area of the flag leaf, leaf 2 and leaf 3 on Robigus in Norfolk at GS69-75 in 2005

Similar treatment effects were seen in 2006, for example on Consort in Hampshire (figure 3.3.4). However, on the same variety in Herefordshire (figure 3.3.5) the main improvement to green leaf area was obtained where Bravo + Vivid, rather than Bravo only, were added to 2-spray Opus-only treatments, again reflecting septoria control.

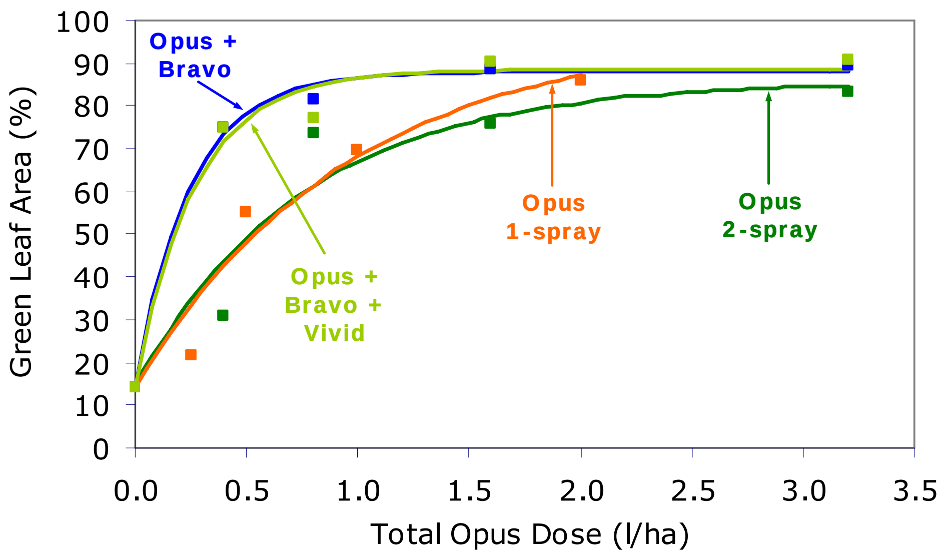


Fig. 3.3.4 Effect of fungicide treatment and total Opus dose on the % green leaf area of the flag leaf and leaf 2 on Consort in Hampshire at GS71-75 in 2006

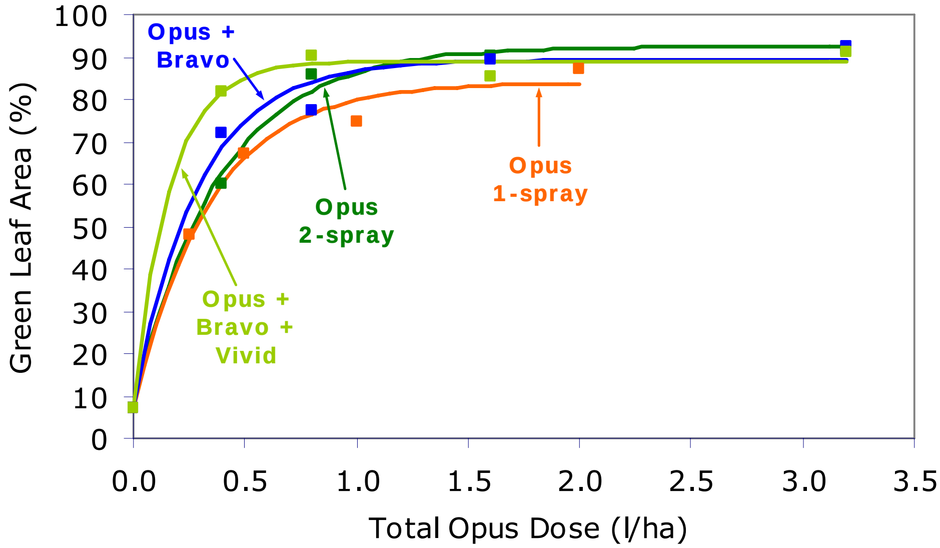


Fig. 3.3.5 Effect of fungicide treatment and total Opus dose on the % green leaf area of the flag leaf and leaf 2 on Consort in Herefordshire at GS71-73 in 2006

In 2007, in situations where (brown) rust and septoria were of equal significance, for example on Einstein in Hampshire (figure 3.3.6) and Consort in Norfolk (figure 3.3.7) both Bravo and Vivid contributed to an increase in green leaf area compared to Opus-only 2-spray treatments.

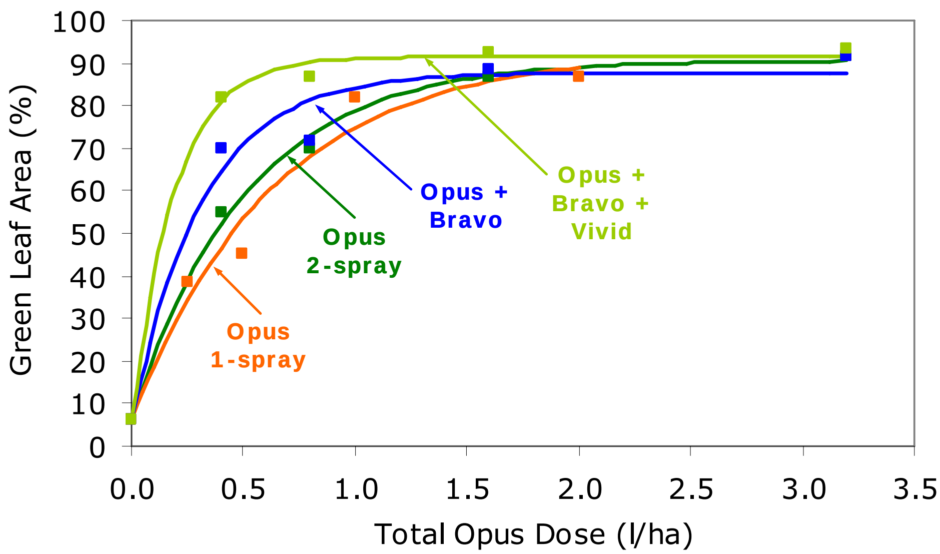


Fig. 3.3.6 Effect of fungicide treatment and total Opus dose on the % green leaf area of leaf 2 on Einstein in Hampshire at GS75-80 in 2007

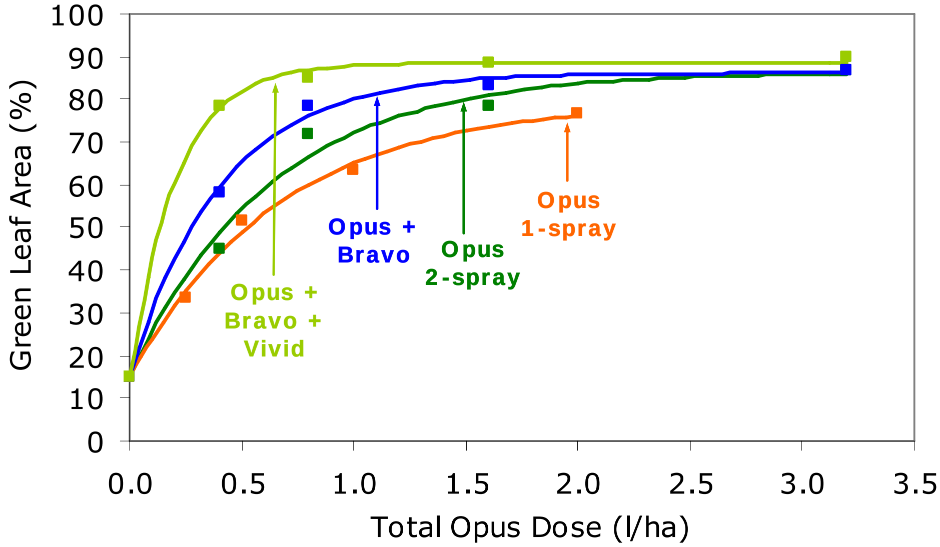


Fig. 3.3.7 Effect of fungicide treatment and total Opus dose on the % green leaf area of leaf 2 on Consort in Norfolk at GS71-73 in 2007

However, where brown rust or yellow rust were dominant, for example on Robigus in Norfolk (figure 3.3.8) or the Borders (figure 3.3.9) respectively, only where Vivid was added as well as Bravo was there an increase in green leaf area compared to 2-spray Opus-only treatments that had received the same dose of Opus.

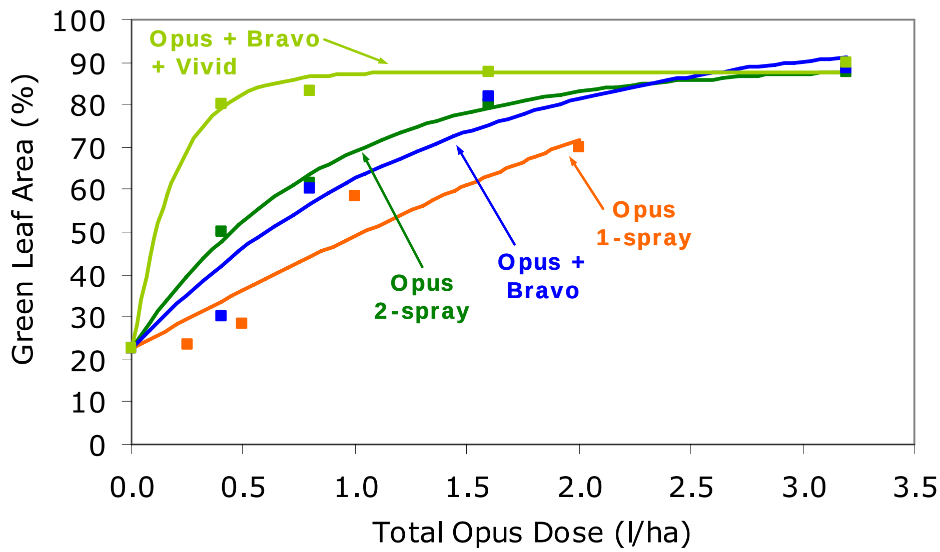


Fig. 3.3.8 Effect of fungicide treatment and total Opus dose on the % green leaf area of leaf 2 on Robigus in Norfolk at GS71-73 in 2007

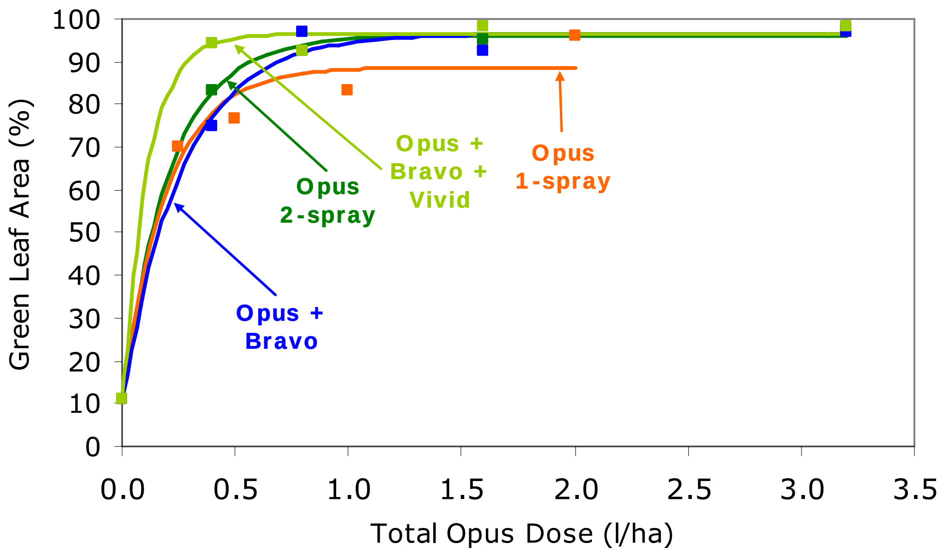


Fig. 3.3.9 Effect of fungicide treatment and total Opus dose on the % green leaf area of the flag leaf on Robigus in the Borders at GS73 in 2007

A cross-site analysis was done to compare the effects of treatment group and Opus dose on green leaf area remaining on leaf 2 at GS69-77 on each variety for 2005 and 2006 (Table 3.3.1a and b). A separate analysis was conducted for 2007 (Table 3.3.2a and b), due to the impact of rusts. Similar analyses were performed for overall green leaf area on leaves 3, 2 and the flag leaf (see appendix G). In 2005/2006 treatment group effects were similar on all varieties, but differences between varieties were much greater when untreated than when treated with Opus + Bravo (+ Vivid).

Table 3.3.1 Cross-site analysis showing % green leaf area remaining on leaf 2 at GS69-77 (mean of 4 sites from 2005 and 2006, except Einstein 3 sites only in 2005) (a) Effect of treatment group (mean of four Opus doses) and (b) Effect of Opus dose (mean of four treatment groups)

(a)

Variety	% green leaf area remaining on leaf 2 per treatment group				
	Untreated	Opus 1-spray	Opus 2-spray	Opus + Bravo	Opus + Bravo + Vivid
Consort	69.1	81.9	85.7	90.1	91.3
Einstein	73.2	83.5	86.9	89.1	90.4
Robigus	79.9	89.8	91.7	93.4	95.1
	F prob. <0.001, SEM 1.123 (max), 4.201 (min) d.f. 2278				

(b)

Variety	% green leaf area remaining on leaf 2 per T2 (or total) Opus dose				
	0 (untreated)	0.25 (0.4)	0.5 (0.8)	1.0 (1.6)	2.0 (3.2)
Consort	69.1	81.9	85.5	89.3	92.4
Einstein	73.2	83.5	87.4	88.5	90.5
Robigus	79.9	90.3	92.1	93.8	93.9
	F prob. <0.001, SEM 1.123 (max), 4.201 (min) d.f. 2278				

In 2007, % green leaf areas were generally lower than in 2005/2006, whether treated (except Einstein) or untreated. Green leaf area also benefited more from the addition of Vivid, especially on Consort and Robigus. The response to Opus dose was much greater on both of these varieties in 2007 than in 2005/2006.

Table 3.3.2 Cross-site analysis showing % green leaf area remaining on leaf 2 at GS71-80 (mean of 4 sites from 2007). (a) Effect of treatment group (mean of four Opus doses) and (b) Effect of Opus dose (mean of four treatment groups)

(a)

Variety	% green leaf area remaining on leaf 2 per treatment group				
	Untreated	Opus 1-spray	Opus 2-spray	Opus + Bravo	Opus + Bravo + Vivid
Consort	56.5	65.1	72.8	76.8	83.2
Einstein	62.7	80.7	88.6	91.2	93.3
Robigus	57.6	71.7	79.9	85.4	90.3
	F prob. <0.001, SEM 2.202 (max), 3.114 (min) d.f. 868				

(b)

Variety	% green leaf area remaining on leaf 2 per T2 (or total) Opus dose				
	0 (untreated)	0.25 (0.4)	0.5 (0.8)	1.0 (1.6)	2.0 (3.2)
Consort	56.5	63.8	70.5	77.6	86.1
Einstein	62.7	84.1	85.8	91.0	93.0
Robigus	57.6	71.3	76.8	87.5	91.9
	F prob. <0.001, SEM 2.202 (max), 3.114 (min) d.f. 868				

3.4 Grain Yield

Grain yields from Norfolk in 2005 are shown in figures 3.4.1-3.4.3. At total Opus doses of 0.5-1.0 l/ha or less, there was little difference in yield between 1-spray and 2-spray treatments that had received the same amount of triazole. In 2-spray treatments, the addition of Bravo substantially increased yield compared to the same dose of Opus alone on all varieties. The yield difference decreased with increasing Opus dose above about 0.75 l/ha on Einstein and Robigus, but only above 1.25 l/ha on Consort. The addition of Vivid as well as Bravo gave a further small yield benefit, which on Einstein and Robigus decreased only marginally at higher Opus doses.

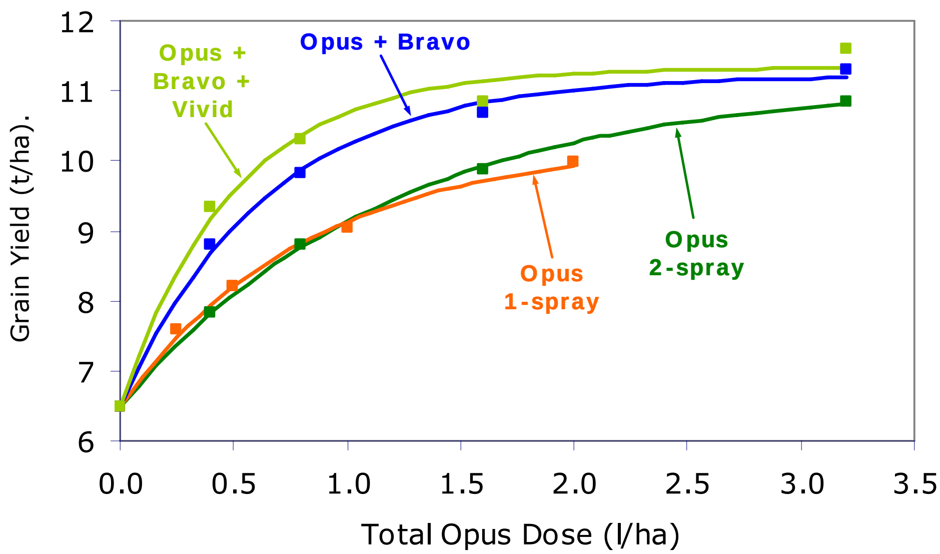


Fig. 3.4.1 Effect of fungicide treatment and total Opus dose on the grain yield of Consort in Norfolk in 2005

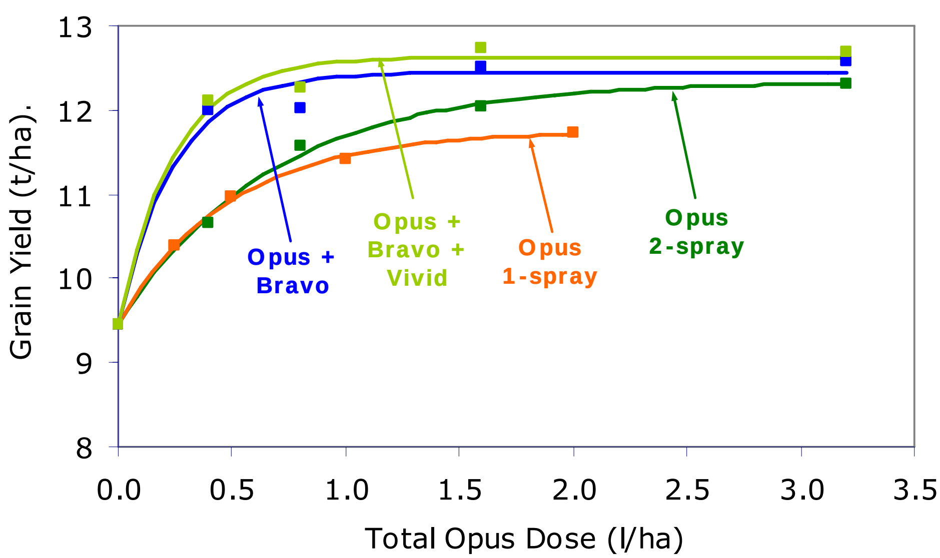


Fig. 3.4.2 Effect of fungicide treatment and total Opus dose on the grain yield of Einstein in Norfolk in 2005

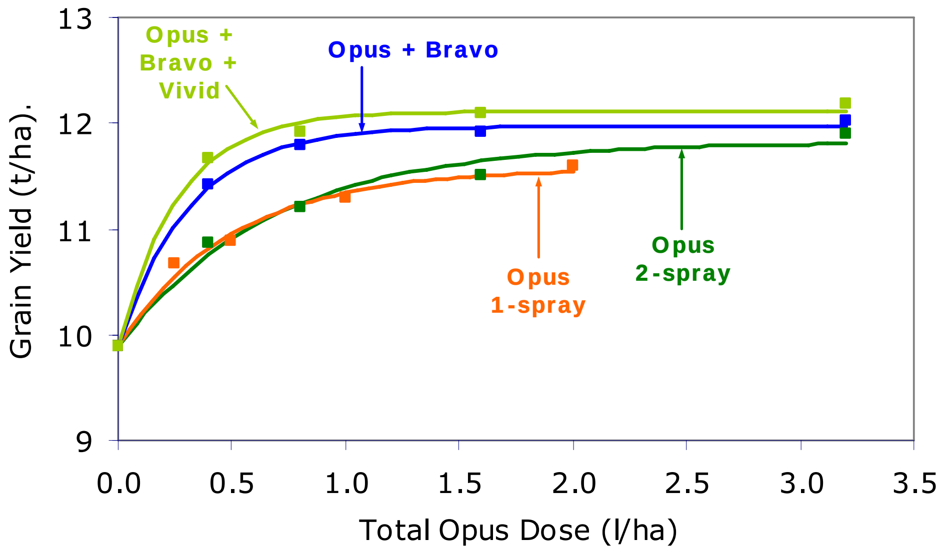


Fig. 3.4.3 Effect of fungicide treatment and total Opus dose on the grain yield of Robigus in Norfolk in 2005

There were similar trends in grain yields in 2006 on for example Consort in Hampshire (Fig. 3.4.4). However, on the same variety in Herefordshire there was a clearer yield benefit to applying the same total dose of Opus as a 2-spray treatment rather than as a single spray (Fig. 3.4.5). In contrast to other experiments, the yield advantage from adding Bravo to 2-spray Opus-only treatments was smaller and decreased only gradually with increasing Opus dose. The addition of Vivid as well as Bravo resulted in a larger yield increase compared to the same dose of Opus alone, but this decreased rapidly with increasing Opus dose and was non-existent above about 1.75 l/ha.

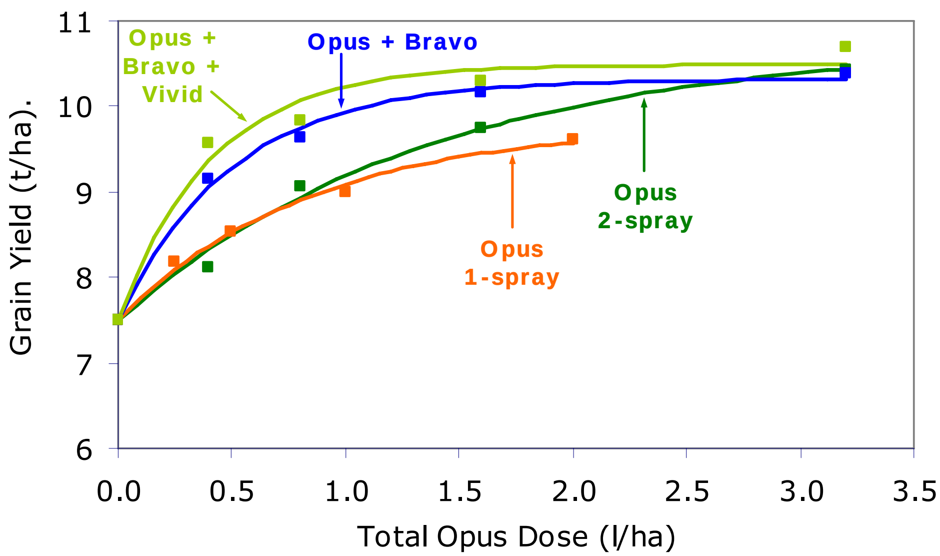


Fig. 3.4.4 Effect of fungicide treatment and total Opus dose on the grain yield of Consort in Hampshire in 2006

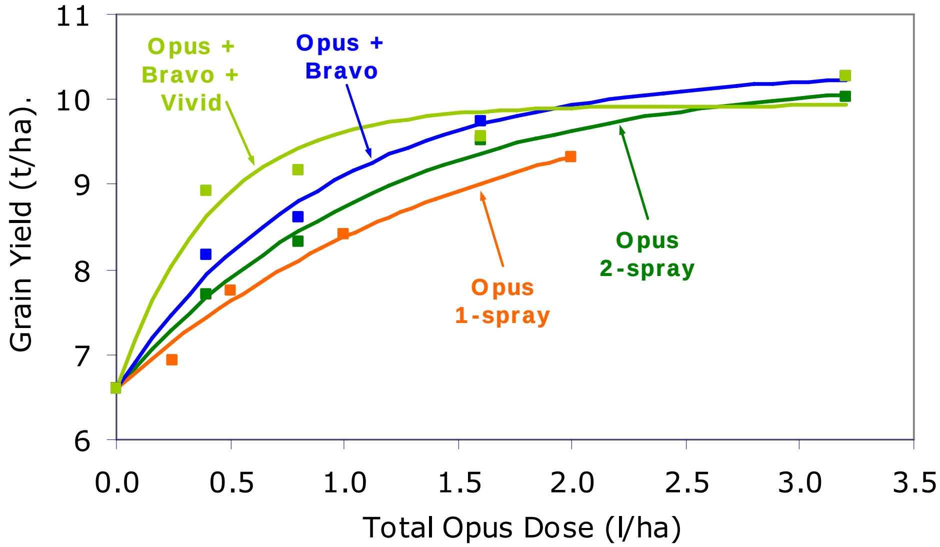


Fig. 3.4.5 Effect of fungicide treatment and total Opus dose on the grain yield of Consort in Herefordshire in 2006

The effects of fungicide treatment on the response of grain yield to Opus dose varied between experiments in 2007. There were some similarities between sites though, for example on Consort (Figures 3.4.6 – 3.4.9). The addition of Vivid as well as Bravo gave a larger yield benefit than the addition of just Bravo, when both were compared with Opus-only 2-spray treatments receiving the same total dose of Opus. In all cases the yield advantage over Opus alone decreased with increasing Opus dose, although in Hampshire, Herefordshire and Norfolk there was a yield benefit to the addition of Vivid (plus Bravo) right up to the highest total Opus dose evaluated.

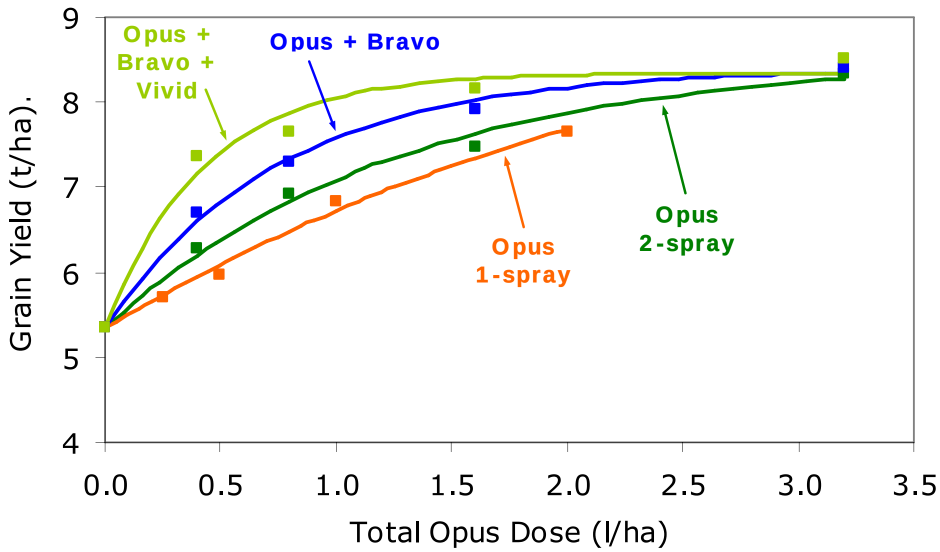


Fig. 3.4.6 Effect of fungicide treatment and total Opus dose on the grain yield of Consort in Norfolk in 2007

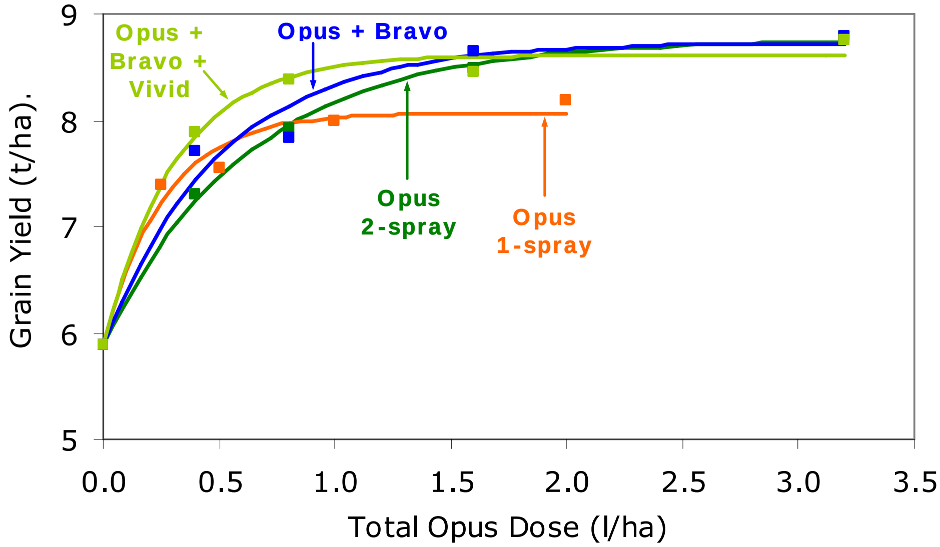


Fig. 3.4.7 Effect of fungicide treatment and total Opus dose on the grain yield of Consort in the Borders in 2007

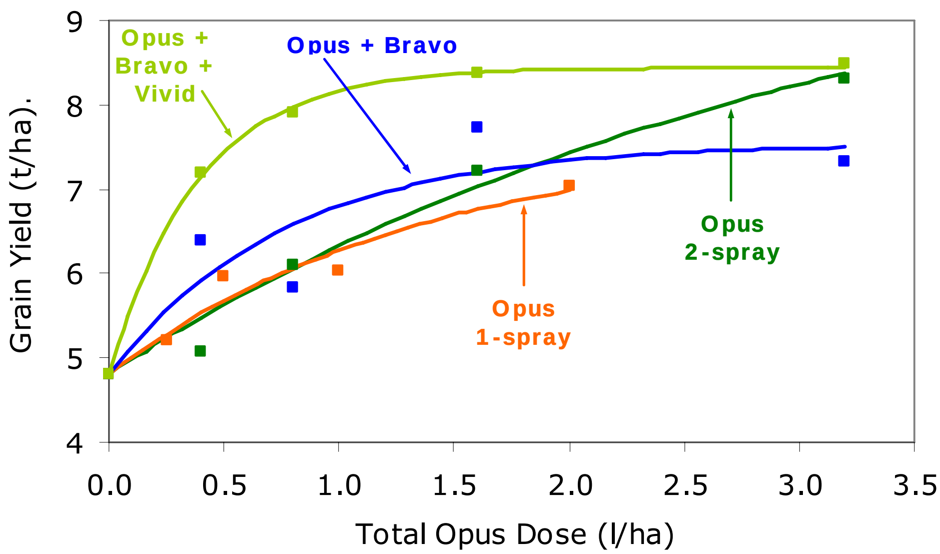


Fig. 3.4.8 Effect of fungicide treatment and total Opus dose on the grain yield of Consort in Hampshire in 2007

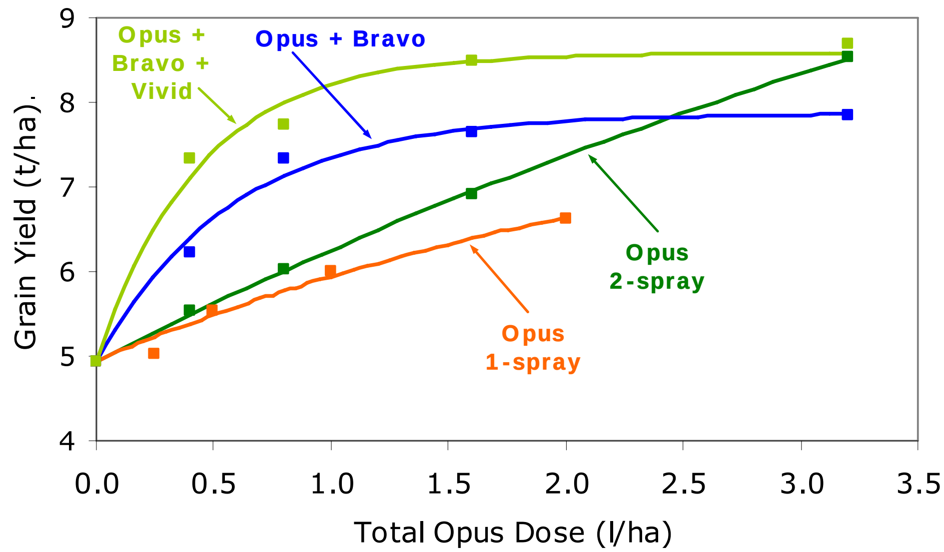


Fig. 3.4.9 Effect of fungicide treatment and total Opus dose on the grain yield of Consort in Herefordshire in 2007

A cross-site analysis was done to compare the effects of treatment group and Opus dose on grain yield for each variety for 2005 and 2006 (Table 3.4.1a and b). A separate analysis was done for 2007 (Table 3.4.2a and b), due to the impact of rusts. In 2005/2006 the effects of treatment group were similar on the three varieties, although responses to fungicide treatment were larger on Consort than on Einstein or Robigus. The effects of Opus dose also showed similar trends between varieties, but the yield increases with dose were larger for Consort than for Einstein or Robigus.

Table 3.4.1 Cross-site analysis for grain yield (mean of 3 sites from 2005 and 2006, except Einstein 2 sites only in 2005). (a) Effect of treatment group (mean of four Opus doses) and (b) Effect of Opus dose (mean of four treatment groups)

(a)

Variety	grain yield (t/ha) per treatment group				
	Untreated	Opus 1-spray	Opus 2-spray	Opus + Bravo	Opus + Bravo + Vivid
Consort	7.43	8.81	9.22	9.74	10.03
Einstein	9.31	10.12	10.40	10.73	11.00
Robigus	9.17	10.06	10.33	10.54	10.74
	F prob. <0.001, SEM 0.088 (max), 0.305 (min) d.f. 920				

(b)

Variety	grain yield (t/ha) per T2 (or total) Opus dose				
	0 (untreated)	0.25 (0.4)	0.5 (0.8)	1.0 (1.6)	2.0 (3.2)
Consort	7.43	8.69	9.21	9.71	10.19
Einstein	9.31	10.18	10.49	10.67	10.91
Robigus	9.17	10.14	10.34	10.51	10.68
	F prob. <0.001, SEM 0.088 (max), 0.305 (min) d.f. 920				

In 2007, the yield of Robigus was much more responsive to fungicide treatment than in 2005/2006, and indeed it was more similar to Consort. The addition of Vivid gave a larger increase in yield for Consort and Robigus than previously, but this was less evident for Einstein. Robigus was however still less responsive to Opus dose than Consort even in 2007, and Einstein was surprisingly unresponsive, especially above a 0.5 T2 (0.8 total) dose.

Table 3.4.2 Cross-site analysis for grain yield (mean of 4 sites from 2007). (a) Effect of treatment group (mean of four Opus doses) and (b) Effect of Opus dose (mean of four treatment groups)

(a)

Variety	grain yield (t/ha) per treatment group				
	Untreated	Opus 1-spray	Opus 2-spray	Opus + Bravo	Opus + Bravo + Vivid
Consort	5.24	6.55	7.18	7.48	8.09
Einstein	7.10	7.86	8.18	8.36	8.60
Robigus	5.87	7.60	8.10	8.36	8.86
	F prob. <0.001, SEM 0.129 (max), 0.183 (min) d.f. 619				

(b)

Variety	grain yield (t/ha) per T2 (or total) Opus dose				
	0 (untreated)	0.25 (0.4)	0.5 (0.8)	1.0 (1.6)	2.0 (3.2)
Consort	5.24	6.52	6.98	7.65	8.14
Einstein	7.10	8.00	8.22	8.35	8.43
Robigus	5.87	7.69	8.02	8.48	8.72
	F prob. <0.001, SEM 0.129 (max), 0.183 (min) d.f. 619				

3.5 Grain Specific Weight

Grain specific weight data were collected for all of the experiments. In a number of cases differences between treatments were fairly small and not statistically significant, especially for Einstein and Robigus. However there were clear treatment effects for example in Norfolk in 2005 for all three varieties (figures 3.5.1 – 3.5.3), and these showed very strong similarities to the effects of fungicide treatment on grain yield.

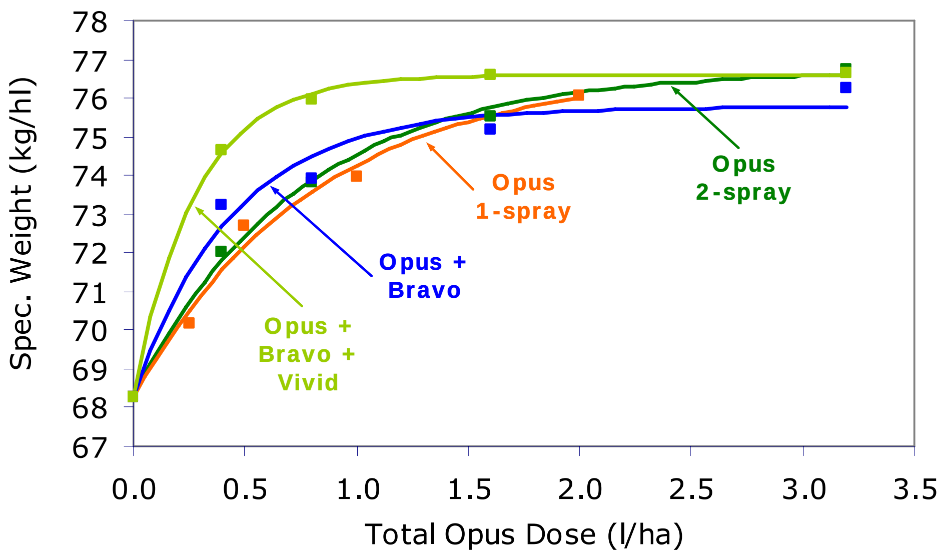


Fig. 3.5.1 Effect of fungicide treatment and total Opus dose on the grain specific weight of Consort in Norfolk in 2005

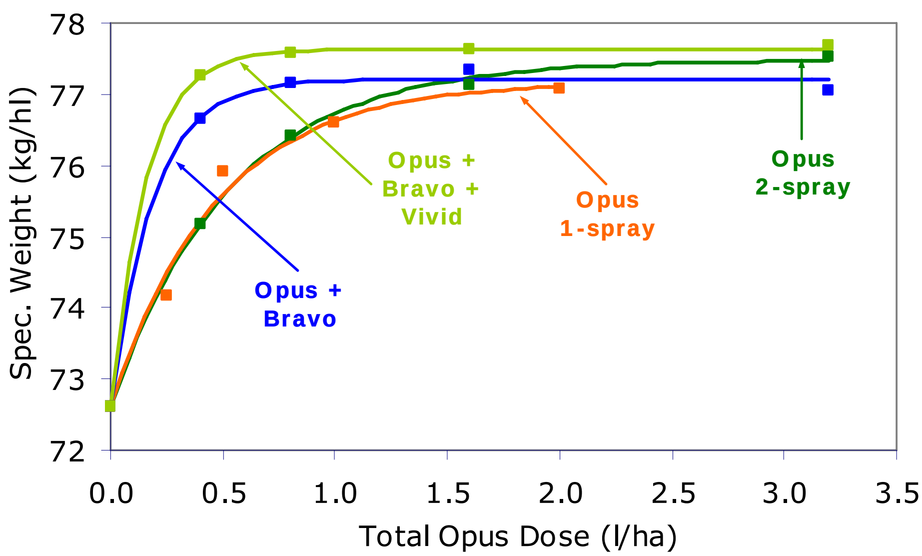


Fig. 3.5.2 Effect of fungicide treatment and total Opus dose on the grain specific weight of Einstein in Norfolk in 2005

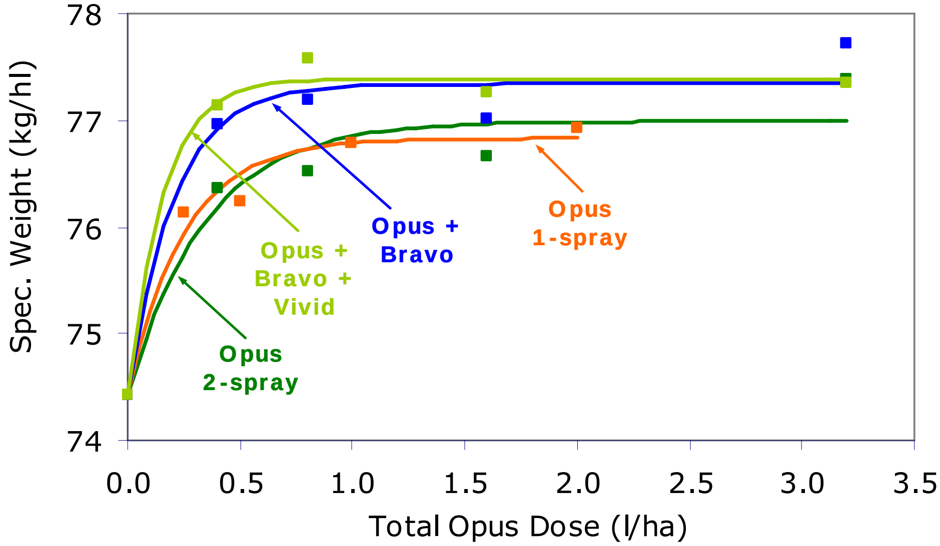


Fig. 3.5.3 Effect of fungicide treatment and total Opus dose on the grain specific weight of Robigus in Norfolk in 2005

3.6 Margin

For each experiment, margins were calculated as output value (grain yield x grain price) less the chemical cost of the fungicide treatment. Unless otherwise indicated, the grain price used was £120 per tonne. Margins were calculated for all four fungicide treatments using the grain yield values that were used to produce the fitted dose response curves. Only the margins for the three 2-spray treatment groups are shown.

2005 and 2006 (*Septoria tritici*)

The effects of Opus dose on margin in Norfolk in 2005 are presented in figures 3.6.1-3.6.3. Also shown are mean septoria levels taken from figures 3.1.1-3.1.3, so that the relationship between septoria levels and margin can be examined. The addition of Bravo consistently resulted in higher margins and lower optimum Opus doses than for 2-spray Opus-only treatments. The addition of Vivid as well as Bravo resulted in highest margins that were similar to Opus + Bravo, but at slightly lower optimum Opus doses particularly on Consort. The margin for the Opus-only 2-spray treatment increased up to the highest dose evaluated on Consort. On the other two varieties optimum Opus doses were lower, but on Einstein still only just within the maximum dose that can be applied in two sprays for the Opus-only 2-spray treatment. For the

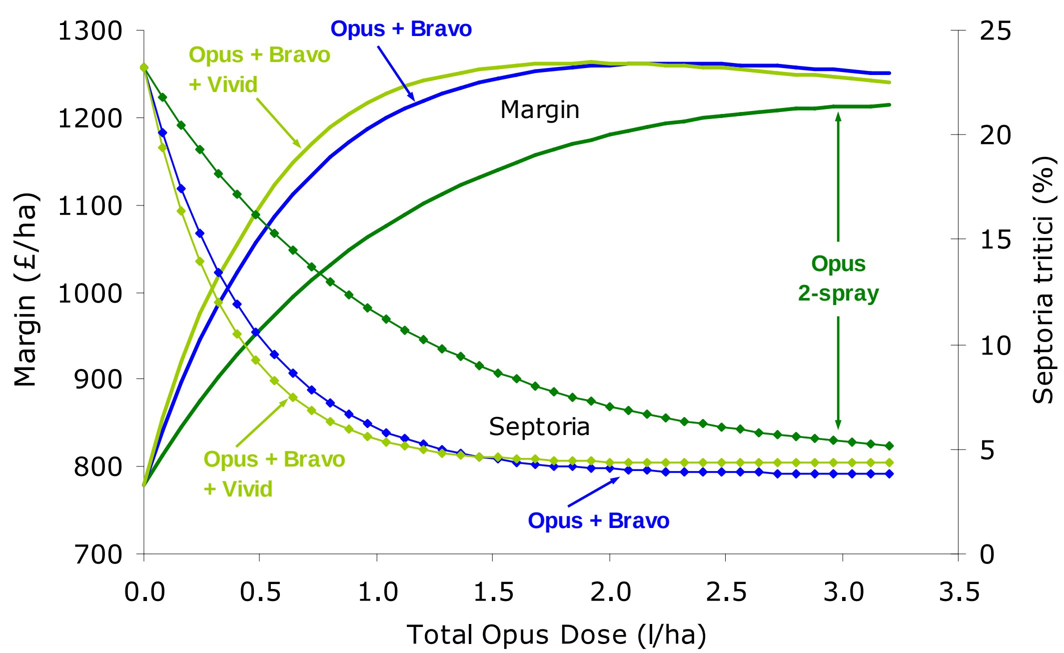


Fig. 3.6.1 Effect of fungicide treatment and total Opus dose on margin (output value less fungicide cost) and mean % leaf area with *S. tritici* symptoms on Consort in Norfolk in 2005

Opus + Bravo treatments, the level of septoria remaining at the optimum Opus dose on Consort was about 4%, compared to less than 2% on either Einstein or Robigus.

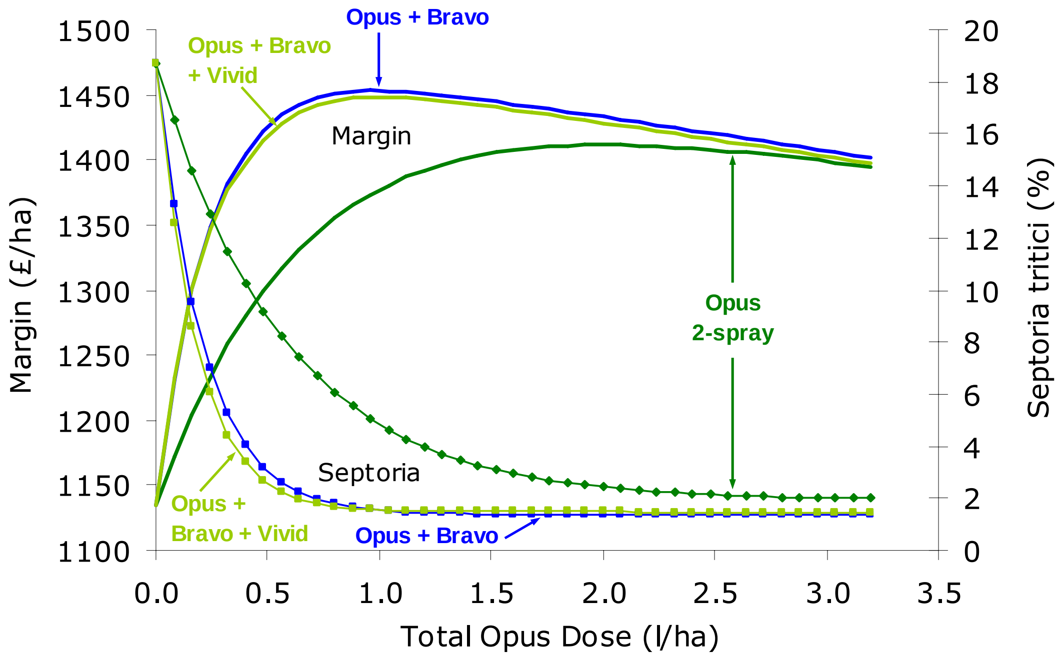


Fig. 3.6.2 Effect of fungicide treatment and total Opus dose on margin (output value less fungicide cost) and mean % leaf area with *S. tritici* symptoms on Einstein in Norfolk in 2005

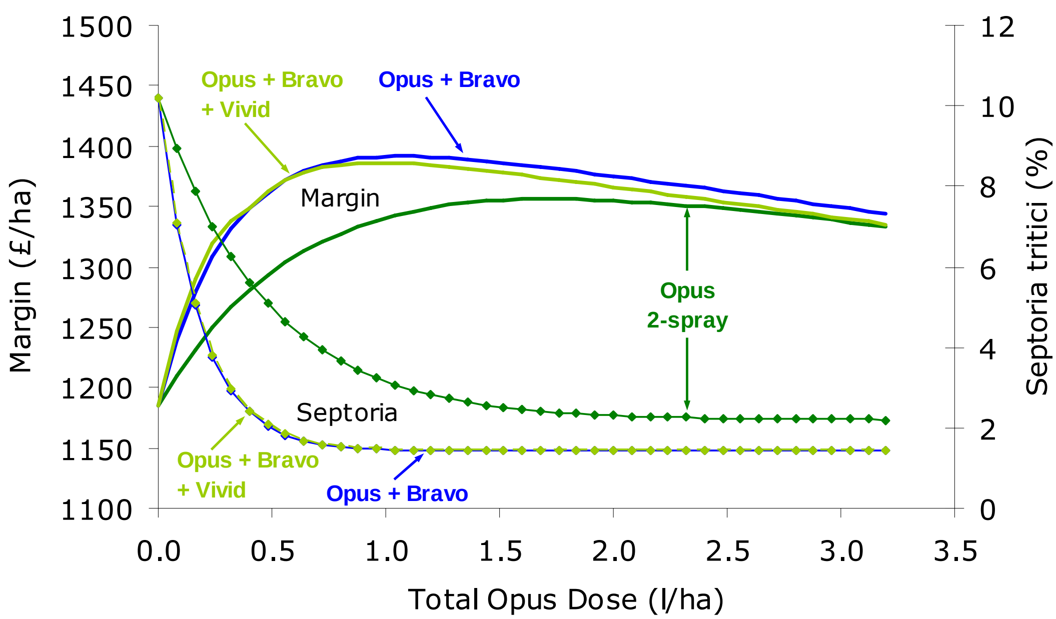


Fig. 3.6.3 Effect of fungicide treatment and total Opus dose on margin (output value less fungicide cost) and mean % leaf area with *S. tritici* symptoms on Robigus in Norfolk in 2005

The effects of total Opus dose on margin for each of the 2-spray fungicide treatment groups are summarised below for 2005 and 2006 (when septoria was the dominant disease). Only six of the eight experiments are included in the mean, as yield data for the Borders site were vary variable due to flooding in 2005 and responses to fungicide dose were erratic in 2006. Only the two variety extremes (Consort and Robigus) are presented here.

On Consort, the addition of Bravo to a 2-spray-only Opus treatment gave a higher margin at a lower optimum dose of Opus (figure 3.6.4). The addition of Vivid as well as Bravo further reduced the optimum Opus dose, but gave a similar highest margin to Opus + Bravo. The optimum Opus dose for the Opus-only 2-spray treatment was well above the maximum permitted total dose in two sprays (2.0 l/ha). The optimum Opus dose for the Opus + Bravo treatments was only just within this limit.

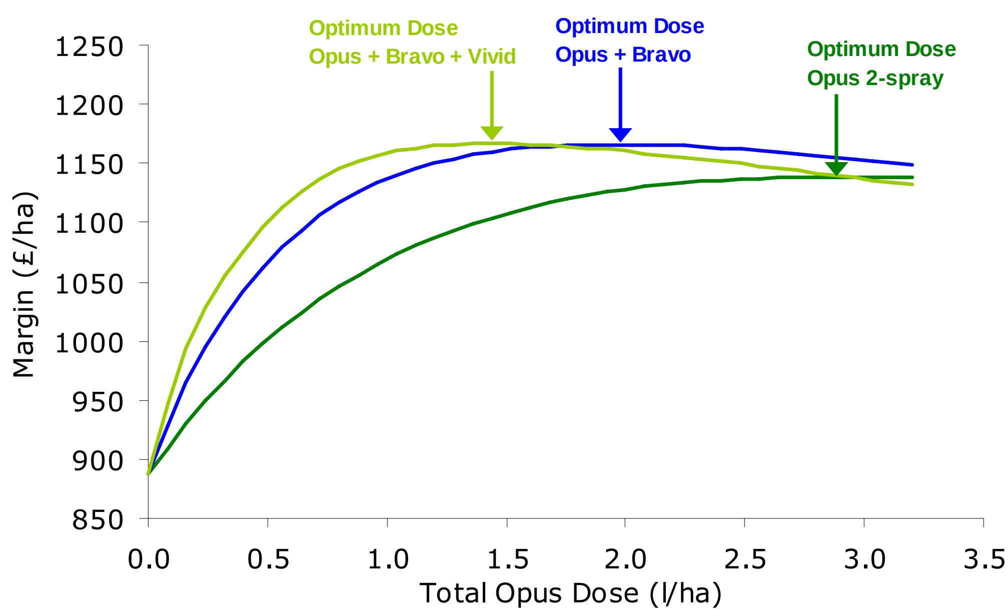


Fig. 3.6.4 Effect of fungicide treatment and total Opus dose on margin (output value less fungicide cost) for Consort: mean of six septoria experiments from 2005 and 2006

On Robigus (figure 3.6.5), the relative effects of fungicide treatment group on margin and optimum Opus dose were very similar to those on Consort. However, optimum doses were lower for Robigus than for the same treatment group on Consort, and the differences between treatment groups were smaller, with all having an optimum well within the maximum permitted Opus dose in two sprays.

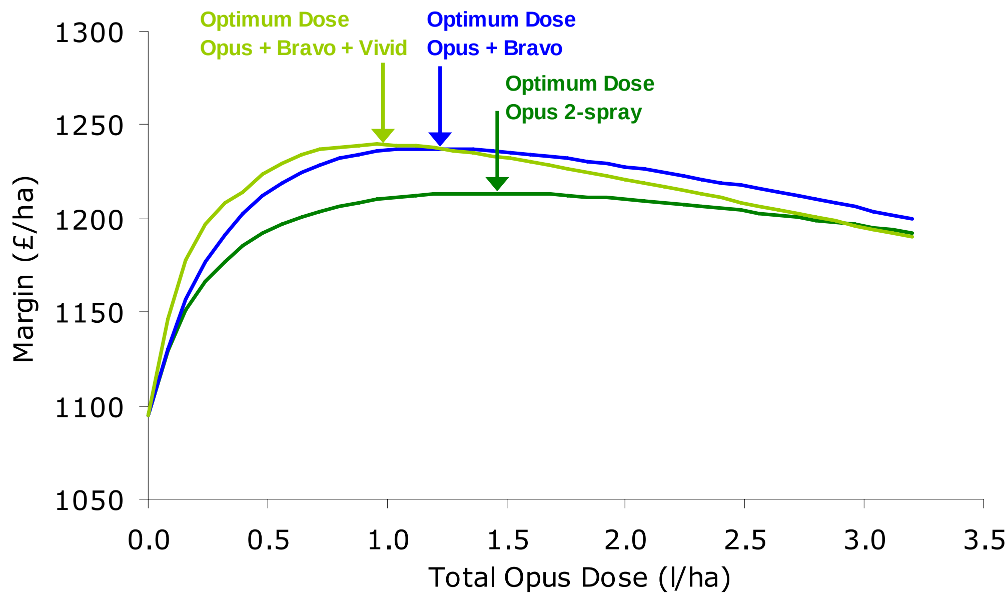


Fig. 3.6.5 Effect of fungicide treatment and total Opus dose on margin (output value less fungicide cost) for Robigus: mean of six septoria experiments from 2005 and 2006

Of the six experiments that were included in figures 3.6.4 and 3.6.5, three had relatively low septoria pressure, and three had medium-high pressure (Table 3.6.1).

Table 3.6.1 Effect of fungicide treatment, variety and disease pressure on optimum Opus doses in two-spray programmes. (Mean of 6 experiments from 2005 and 2006: 3 med-high disease with ≥25% septoria (Consort) or ≥10% septoria (Robigus) on leaf 2 of untreated at the final assessment timing = Norfolk 2005, Herefordshire & Hampshire 2006; and 3 low disease with ≤12% septoria (Consort) or ≤5% septoria (Robigus) on leaf 2 of untreated = Herefordshire & Hampshire 2005, Norfolk 2006).

Fungicide Treatment Group	Optimum Opus dose l/ha in 2-spray programmes (and margin £/ha achieved at optimum dose)					
	Consort			Robigus		
	6 Site mean	3 Site (med-high)	3 Site (low)	6 Site mean	3 Site (med-high)	3 Site (low)
Opus 2-spray	2.8 (1139)	3.2+	2.3	1.4 (1213)	1.8	1.1
Opus + Bravo	1.9 (1166)	2.2	1.6	1.2 (1237)	1.5	0.9
Opus + Bravo + Vivid	1.4 (1167)	1.6	1.1	0.9 (1240)	1.1	0.7

For Consort, optimum Opus doses were about 40% higher in the medium-high disease than in the low disease pressure experiments, for each treatment group. For Robigus, optimum Opus doses were about 60% higher in the medium-high than in the low disease pressure experiments. As a consequence, optimum Opus doses (in mixtures) were about 65% higher on Consort than on Robigus in the low disease pressure experiments, but only about 45% higher on Consort than on Robigus in the medium-high disease pressure experiments.

For the Opus + Bravo fungicide treatment, an analysis was undertaken to identify the range of Opus doses that would have given a margin within £2/ha of that achieved at the optimum Opus dose, for Consort and Robigus and under medium-high and low disease pressures (Table 3.6.2). Typically, Opus doses within 15-20% above or below the optimum would have resulted in a margin within £2/ha of that achieved at the optimum dose. Interestingly, for both Consort and Robigus, the highest dose that could have been applied to achieve a margin within £2/ha of the optimum under low disease pressure was approximately the same as the lowest dose that could have been applied to achieve a margin within £2/ha under medium-high disease pressure.

Table 3.6.2 Range of Opus doses in a two-spray programme including Bravo that would have given margins within £2/ha of that achieved at the optimum Opus dose (mean of 3 experiments with medium-high disease and 3 experiments with low disease pressure from 2005 and 2006).

	Optimum Opus dose, and highest and lowest doses (l/ha) that would have given a margin within £2/ha of the optimum					
	Consort			Robigus		
	Highest	Optimum	Lowest	Highest	Optimum	Lowest
Med-high	2.6	2.2	1.9	1.8	1.5	1.2
Low	1.9	1.6	1.3	1.2	0.9	0.7

Over the three year duration of this project, the ex-farm 'feed' wheat grain price ranged from less than £80/t to more than £160/t. Table 3.6.3 shows the effect that different grain prices have on the optimum Opus dose for each fungicide treatment. Fungicide prices have been kept constant for this analysis, although in practice these may also change with changing wheat price.

Table 3.6.3 Effect of grain price on optimum dose of Opus in two-spray programmes (mean of 6 experiments from 2005 and 2006, fungicide prices kept constant).

Fungicide Treatment Group	Optimum Opus dose l/ha in 2-spray programmes (and margin £/ha achieved at optimum dose)					
	Consort			Robigus		
	Wheat £120/t	Wheat £80/t	Wheat £160/t	Wheat £120/t	Wheat £80/t	Wheat £160/t
Opus 2-spray	2.8 (1139)	2.4 (737)	3.2+ (1545)	1.4 (1213)	1.1 (798)	1.7 (1632)
Opus + Bravo	1.9 (1166)	1.7 (759)	2.2 (1576)	1.2 (1237)	1.0 (813)	1.4 (1664)
Opus + Bravo + Vivid	1.4 (1167)	1.3 (755)	1.6 (1580)	0.9 (1240)	0.8 (807)	1.1 (1673)

Optimum Opus doses would have been 25-30% higher on Consort with wheat at £160/t than with wheat at £80/t. On Robigus, optimum doses would have been 30-50% higher with wheat at £160/t than with wheat at £80/t. The adjustments to Opus dose that would have been justified were smaller when Bravo and Vivid were included in mixture with Opus, then where Opus was applied alone.

2007 (Rusts and Septoria)

The effects of total Opus dose on margins in Norfolk in 2007 are shown for Consort and Robigus relative to levels of septoria and brown rust respectively. On Consort (figure 3.6.6), the addition of Bravo to a 2-spray Opus-only treatment resulted in a higher margin and at a lower optimum Opus dose as in 2005, although the difference was less pronounced than in 2005. The addition of Vivid as well as Bravo reduced the optimum Opus dose further, but did not result in a higher margin than Opus + Bravo. Levels of septoria remaining were very similar at the optimum Opus doses for all three treatment groups.

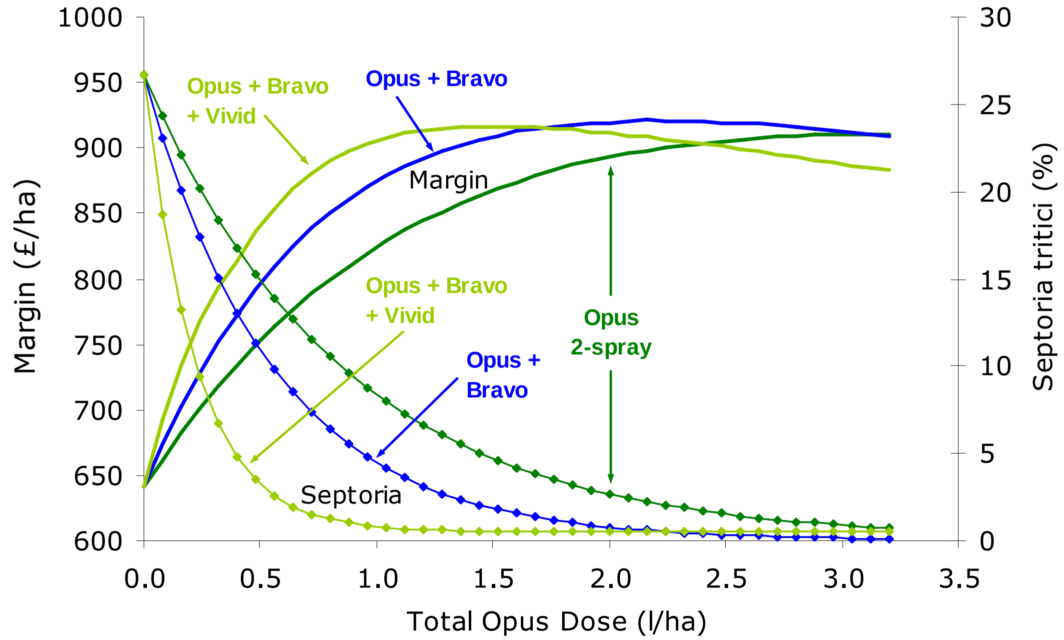


Fig. 3.6.6 Effect of fungicide treatment and total Opus dose on margin (output value less fungicide cost) and % area of leaf 2 with *S. tritici* symptoms on Consort in Norfolk in 2007

On Robigus (figure 3.6.7), the addition of Bravo to a 2-spray Opus-only treatment also resulted in a higher margin, but did not result in a lower optimum Opus dose. As on Consort, the addition of Vivid as well as Bravo gave a similar margin to Opus + Bravo, but this was achieved at a much lower optimum Opus dose. Levels of brown rust remaining were again very similar at the optimum Opus doses for all treatments.

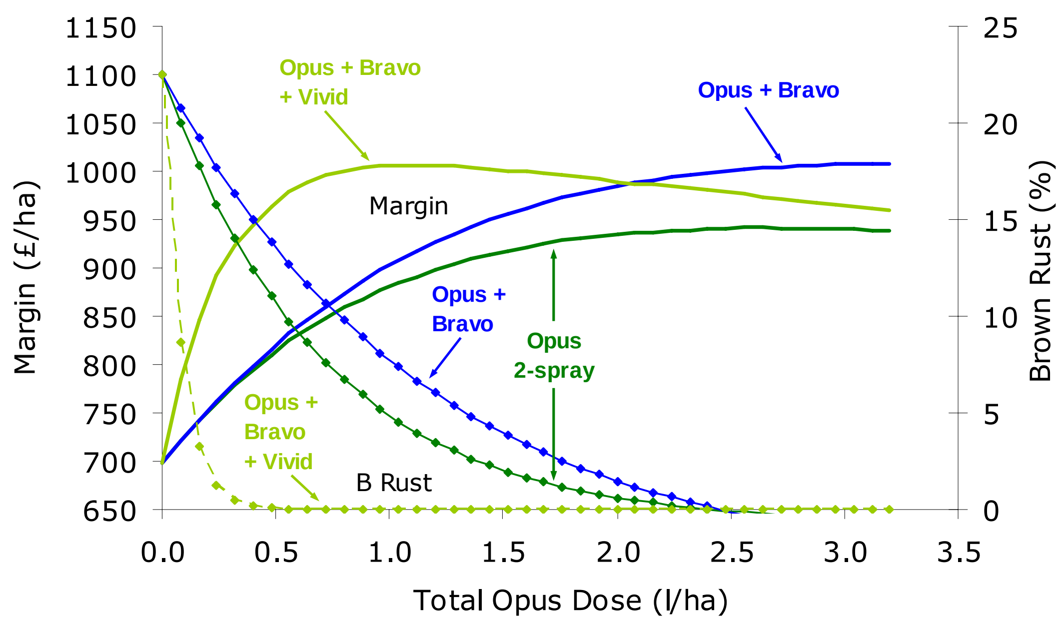


Fig. 3.6.7 Effect of fungicide treatment and total Opus dose on margin (output value less fungicide cost) and % area of leaf 2 with brown rust symptoms on Robigus in Norfolk in 2007

Overall, the effects of fungicide treatment on optimum Opus dose (and margin achieved at that dose) varied between sites and varieties in 2007 (Table 3.6.4). On Consort, optimum Opus doses were highest for the Opus-only 2-spray treatment group, and lowest for the Opus + Bravo + Vivid 2-spray treatment, at all 4 sites. At three out of four sites, the optimum was not reached within the range of Opus doses evaluated for the Opus-only 2-spray treatment. Although the addition of Bravo or Bravo and Vivid as partners consistently resulted in lower optimum Opus doses, they did not always result in improvements to margins. On Robigus, the addition of Bravo resulted in higher optimum Opus doses than for the 2-spray Opus-only treatment, at three out of four sites. At two of these though, the Opus + Bravo treatment did give a higher margin. In contrast, the addition of Vivid as well as Bravo substantially reduced the optimum Opus dose at all four sites, whilst maintaining or increasing margins.

Table 3.6.4 Effect of fungicide treatment and variety on optimum dose of Opus (and margin achieved) in two-spray programmes (4 site summary for 2007)

Variety	Fungicide Treatment	Optimum Opus dose l/ha in 2-spray programmes (and margin £/ha achieved at optimum dose)			
		Borders	Hampshire	Herefordshire	Norfolk
Consort	Opus 2-spray	2.0 (985)	3.2+ (921)	3.2+ (939)	3.2+ (910)
	Opus + Bravo	1.76 (982)	2.16 (820)	1.84 (873)	2.16 (921)
	Opus + Bravo + Vivid	1.20 (961)	1.68 (929)	1.6 (942)	1.52 (917)
Robigus	Opus 2-spray	1.04 (1030)	1.76 (951)	1.76 (961)	2.64 (942)
	Opus + Bravo	1.04 (1008)	2.0 (935)	1.92 (1071)	3.2+ (1008)
	Opus + Bravo + Vivid	0.32 (1026)	0.24 (977)	0.4 (1079)	1.2 (1007)

4.0 Discussion (Field Experimentation)

The field experimentation was intended to provide data on the relative impacts of sequences and mixtures, varietal susceptibility and disease pressure on triazole dose response for septoria control and yield. In 2005 and 2006, green leaf area and yields were a good reflection of septoria control as this was the main disease present. In 2007, the occurrence of significant levels of brown or yellow rust meant that green lead area and yields no longer reflected just septoria control. However, this did provide much-needed data on optimum triazole doses and the effects of mixture partners for brown rust in particular, as well as a useful 'reality check' when considering how much weighting should be given to resistance ratings for septoria when making fungicide dose decisions.

Application timing relative to crop growth stage, leaf emergence and time of disease infection can be critical in determining the effectiveness of a given dose of fungicide, and also in determining the relative contribution of components in a mixture that have eradicant or mainly protectant activity. Results from a single field experiment in Norfolk in 2005 on the variety Einstein (Knight, 2006) showed that half, three-quarter and full doses of Opus, with or without Bravo as a partner, gave similar control of septoria when applied promptly at T1, but just a five day delay in application of a half dose of Opus led to significantly higher septoria levels. Even raising the Opus to full dose did not compensate for this delay. However, raising the Opus dose was typically of more benefit to septoria control than adding Bravo when applications were delayed.

The intention in this work was to ensure that applications at T1 and T2 were well timed, such that the protectant activity of the partner products was not compromised and the eradicant ability of the triazole (Opus) was not stretched to the limit. This was largely achieved in all experiments, so when considering the effectiveness of the doses and partners indicated, it would be wrong to assume similar effectiveness if the same treatments were less well-timed. Despite prompt application, one experiment in 2006 (Herefordshire) failed to show the same benefit to septoria control from the addition of Bravo. This may be because the weather during May of that year was consistently wet in the run up to the T2 spray timing, which would have meant that an adequate triazole dose to achieve maximum eradication was the most important factor in determining effective septoria control.

With the exception of this one experiment, adding Bravo to Opus had a clear effect on the shape of the dose response for septoria, increasing the steepness of the curve at lower doses of the triazole and re-introducing the 'elbow' that has tended to disappear from triazole-only dose response curves since the mid 1990s. The further addition of the strobilurin Vivid tended not to alter the shape of the dose response compared to Opus + Bravo only. Some protectant activity against septoria was seen from Vivid applied alone in HGCA fungicide performance experiments during the three years of this project, but this would have been small compared to the contributions of the Opus and Bravo.

The effects of the two partner fungicides in the rust-affected experiments in 2007 could not have been more different. In some cases, the dose response curve for Opus + Bravo lay above that for Opus alone, implying a slight reduction in rust control for the same dose of triazole. Although this didn't happen in all experiments, it was apparent in all of those where rust was the major disease present. There are at least two possible explanations for this. One is that the presence of Bravo in some way reduced the effectiveness (possibly the speed of uptake) of the triazole against the rusts. This effect was reported in a number of other experiments where rust pressure was high in 2007, and with a range of triazoles, not just Opus. Another is that the application of Bravo increased the susceptibility of the crop to rust. In several experiments in 2007, treatments that had received Bravo only were found to have higher levels of rust than the untreated. This was explained by Bravo achieving good control of septoria on leaves compared to the untreated, which resulted in more green leaf area remaining upon which rusts could thrive. Whatever the explanation, provided the dose of triazole (Opus) was adequate, there was no penalty to the inclusion of Bravo, and often green leaf area was increased through improved control of septoria.

In contrast, addition of the strobilurin Vivid substantially altered the dose response curve for brown rust, and very high levels of control were achieved at low doses of triazole. It is worth noting that even at the lowest total dose of Opus evaluated in the two spray treatments (0.4 l/ha), the Opus + Bravo + Vivid treatment received the equivalent of a full dose (1.0 l/ha) of Vivid (as two half doses), and HGCA fungicide performance trials have shown that even when applied alone a half dose or more of Vivid would be expected to give a high level of brown rust control. In practice on farm, strobilurins are often applied at slightly less than half dose (typically 30-40% doses at a single timing, or perhaps 60-70% total doses over a programme); therefore the steepness of the curve (*i.e.* the extent to which they substitute for the dose of triazole required) may be slightly less in practice than in these experiments.

Grain yields generally reflected disease control and green leaf area in all three years. However, it is clear that the inclusion of the strobilurin (Vivid) was typically adding slightly more to yield than would have been anticipated from septoria control and green leaf area even in situations where septoria was dominant. Whilst the addition of the strobilurin did not always increase yield or margin above that achievable with Opus + Bravo alone, it did allow similar margins to be achieved at lower triazole doses. Even in the septoria dominated experiments, in some cases it would not have been possible to achieve the optimum margin within the total dose of Opus (with Bravo) permitted in two sprays without the addition of the strobilurin. In addition, allowing margins to be maximised without having to rely on high doses of any one single component in the mixture is preferable in order to minimise selection pressure.

The economic analysis revealed that a range of factors have an influence on optimum triazole doses. Of these, the biggest influences are disease pressure and varietal susceptibility. The smallest is grain price, and although this does have an effect it is important to keep this in perspective. Therefore optimum fungicide doses are likely to be higher in a high disease / low grain price year than in a low disease / high grain price year. Where relatively resistant varieties are routinely receiving robust fungicide programmes, there may be little need to adjust fungicide inputs in response to higher grain prices. With a relatively wide range of doses capable of delivering margins that are close to those achievable at the optimum, for both the more septoria susceptible and more resistant varieties, and for both low and medium-high disease pressure situations, and given that it might not always be possible to predict rust outbreaks, a prudent strategy is likely to be to always use the triazoles in a mixture with one or both partners (depending on the disease risk) and to use triazole doses that are just slightly above the expected optimum for the particular situation.

5.0 Seasonal Disease Risk

5.1 Introduction

A specific objective of this project was to interpret the information generated on optimum doses, and the impact of variety and fungicide treatment, in the context of seasonal disease pressure. Key sources of information on disease progress during the growing season have been the 'Live Disease Monitoring' experiments that have been conducted on winter wheat as part of the CropMonitor project. These experiments involve detailed weekly assessments (10 plants per plot, with three replicates per treatment) of foliar disease on each leaf layer as it emerges, from GS31 in early April through to GS73-75 in late June or early July, on four wheat varieties. The three sites in England (in Hampshire, Herefordshire and Norfolk) at which the sequences and mixtures experiments were located also hosted live monitoring experiments in all three seasons, which were generally sown at about the same time and often in the same or nearby fields. Two of the varieties in the live monitoring experiments in 2005 and 2006, Consort and Robigus, were the same as those included in the sequences and mixtures experiments. In 2007 Ambrosia was substituted for Consort in the live monitoring experiments, but this has a similar rating (of 4) for resistance to septoria on the HGCA Recommended List for Winter Wheat. The live monitoring experiments received no fungicide sprays whatsoever.

The following charts show the (untreated) levels of *S. tritici* recorded on final leaf 3, leaf 2 and (for 2005 and 2006 only) the flag leaf, from the end of April or beginning of May through to late June or early July, on each of the two varieties. Also shown are the dates that the T2 sprays were applied in the sequences and mixtures experiments, relative to disease progress on each of the top three leaf layers in the untreated live monitoring experiments.

5.2 Progress of *S. tritici* in 2005

In the 2005 live monitoring experiments, septoria development on the final three leaf layers was more advanced in Hampshire than in Herefordshire or Norfolk (figures 5.2.1-5.5.6). However at the time that the T2 fungicide sprays were applied to the sequences and mixtures experiments (shown on the charts) visible disease levels on leaf 3 of Consort for example were similar for Hampshire and Herefordshire. By the end of the growing season untreated septoria levels were highest in Hampshire and lowest in Norfolk in the live monitoring experiments, but this was not really reflected in the disease levels recorded in the untreated plots in the sequences and mixtures experiments. However, it should be noted that the final assessment in the sequences and mixtures experiment in Hampshire was carried out in mid June, and the live monitoring data indicate that septoria levels increased beyond this date. Nevertheless septoria progress in the live monitoring experiments does not in this case help to explain why optimum Opus doses in 2005 were higher in the Norfolk sequences and mixtures experiments than in the Hampshire or Herefordshire experiments.

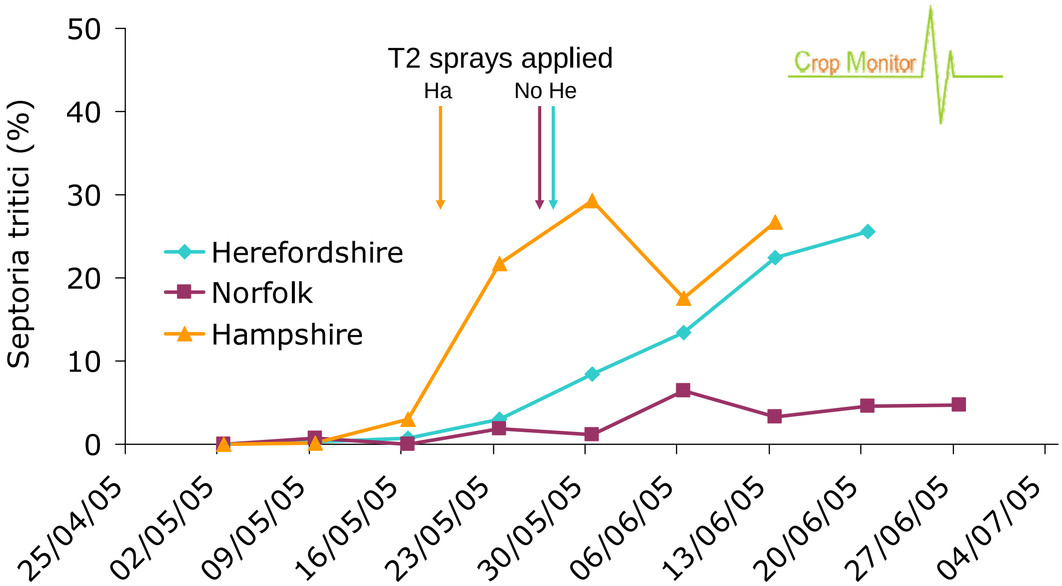


Fig. 5.2.1 Progress of *S. tritici* on final leaf 3 of Consort at three sites in 2005

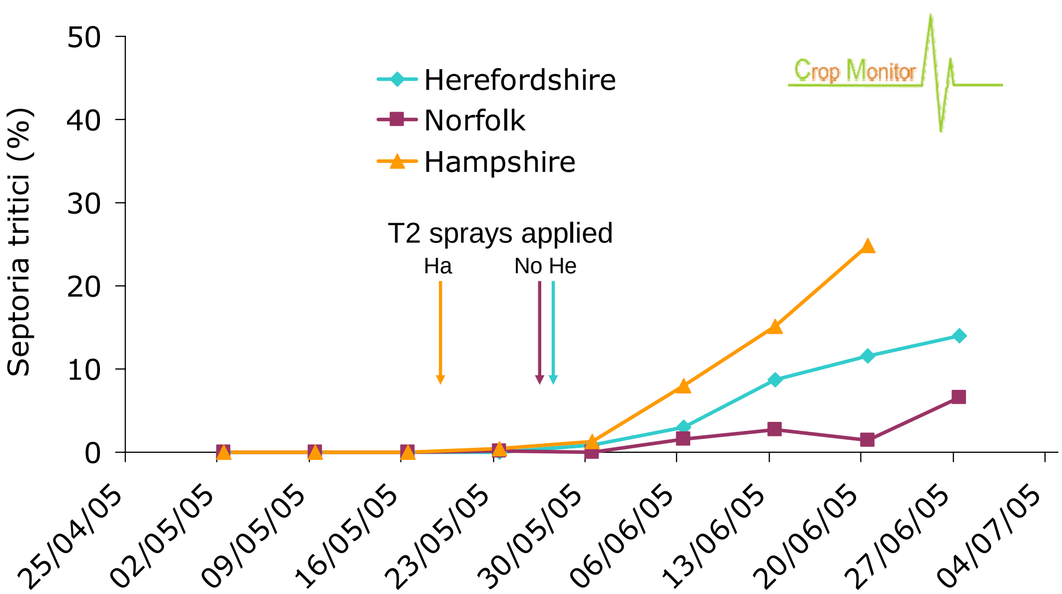


Fig. 5.2.2 Progress of *S. tritici* on final leaf 3 of Robigus at three sites in 2005

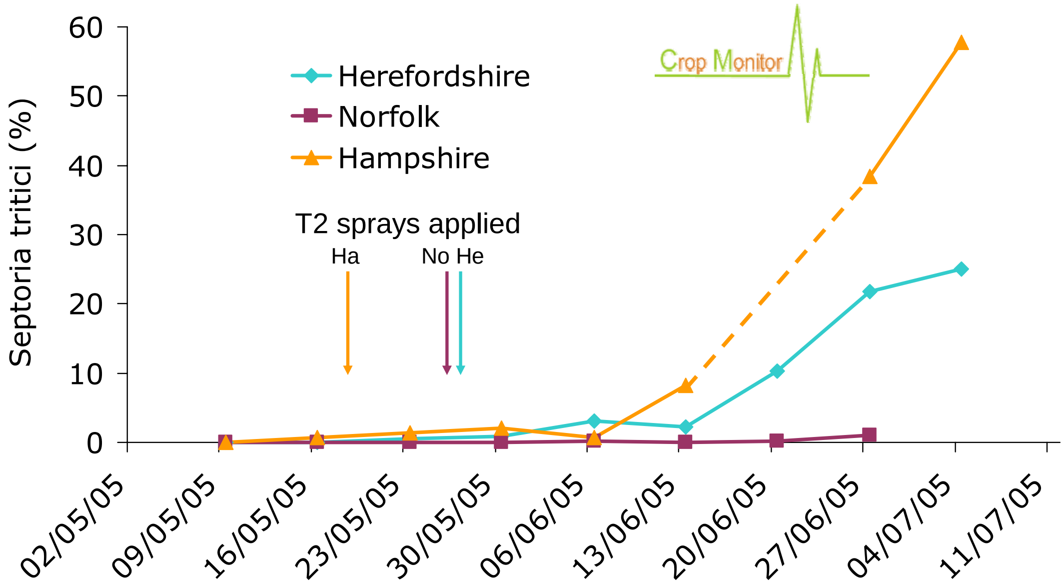


Fig. 5.2.3 Progress of *S. tritici* on final leaf 2 of Consort at three sites in 2005

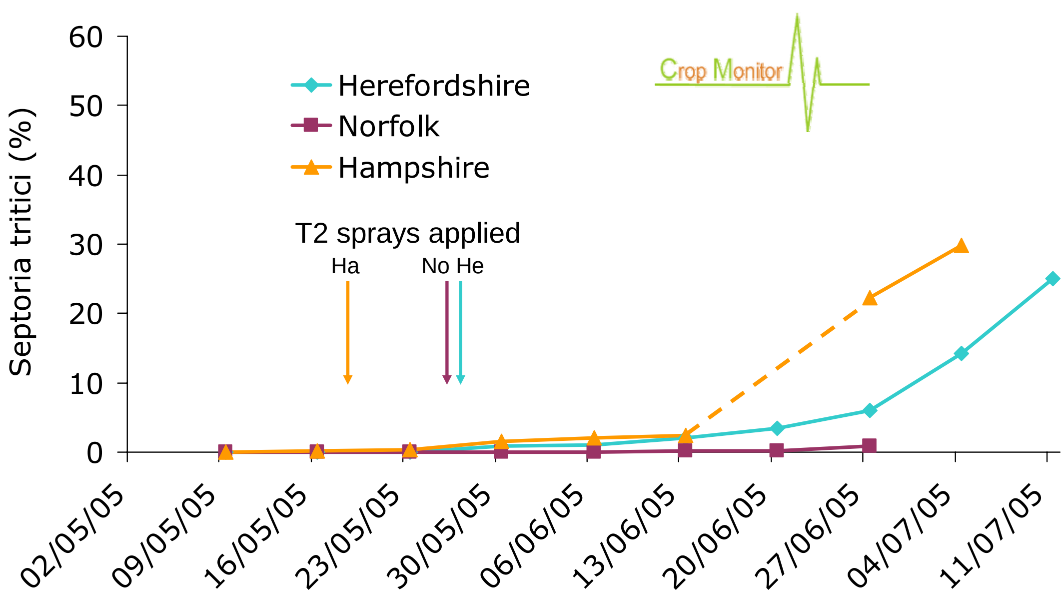


Fig. 5.2.4 Progress of *S. tritici* on final leaf 2 of Robigus at three sites in 2005

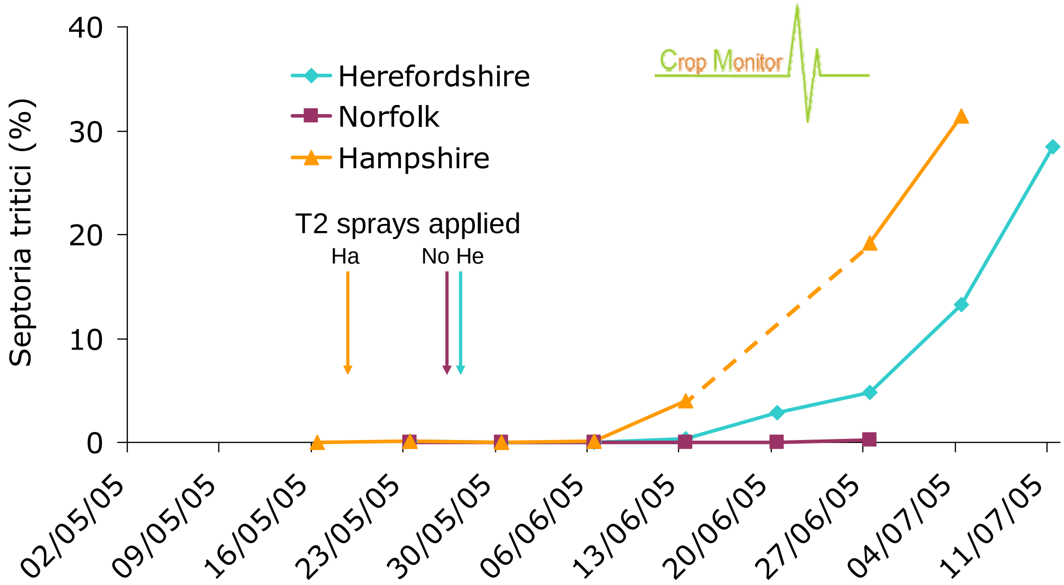


Fig. 5.2.5 Progress of *S. tritici* on the flag leaf of Consort at three sites in 2005

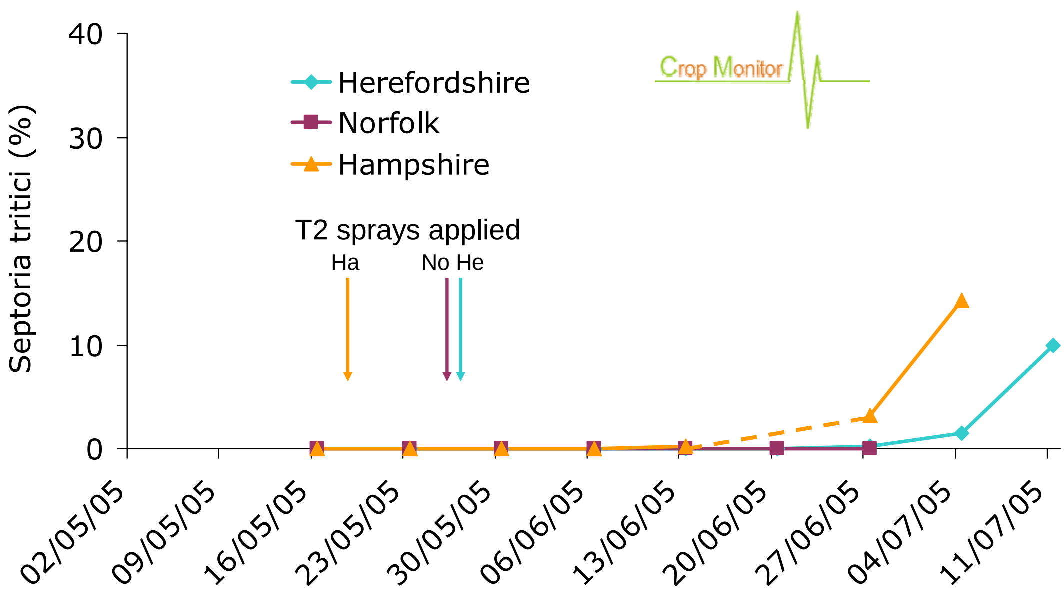


Fig. 5.2.6 Progress of *S. tritici* on the flag leaf of Robigus at three sites in 2005

5.3 Progress of *S. tritici* in 2006

In 2006, early septoria progress on leaf 3 in the Norfolk live monitoring experiment was slightly ahead of that in Hampshire (figures 5.3.1 and 5.3.2). Interestingly the sequences and mixtures trial in Norfolk was also the last to receive its T2 fungicide spray. However visible septoria levels on leaf 3 were relatively low at that stage.

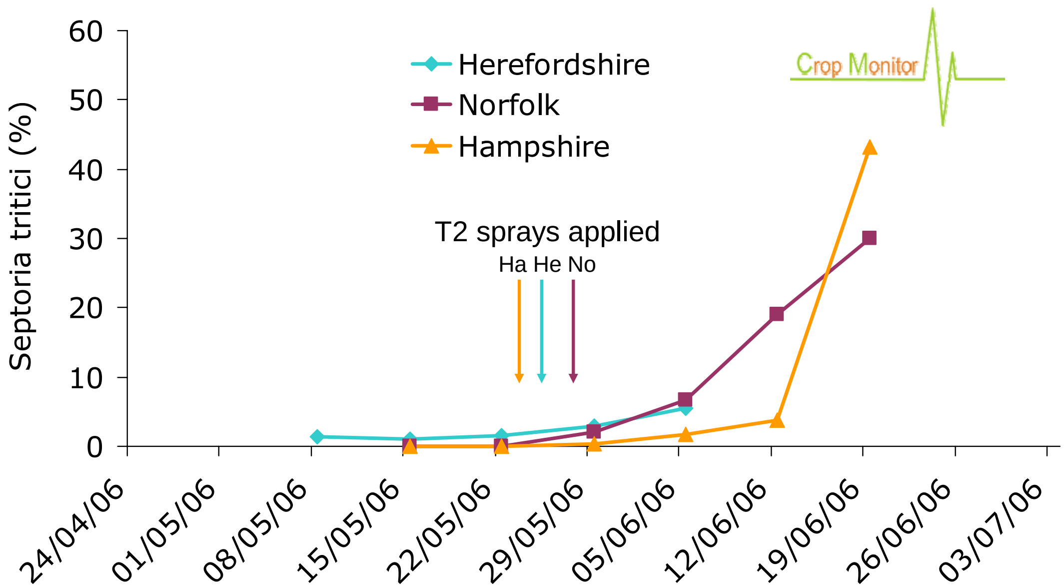


Fig. 5.3.1 Progress of *S. tritici* on final leaf 3 of Consort at three sites in 2006

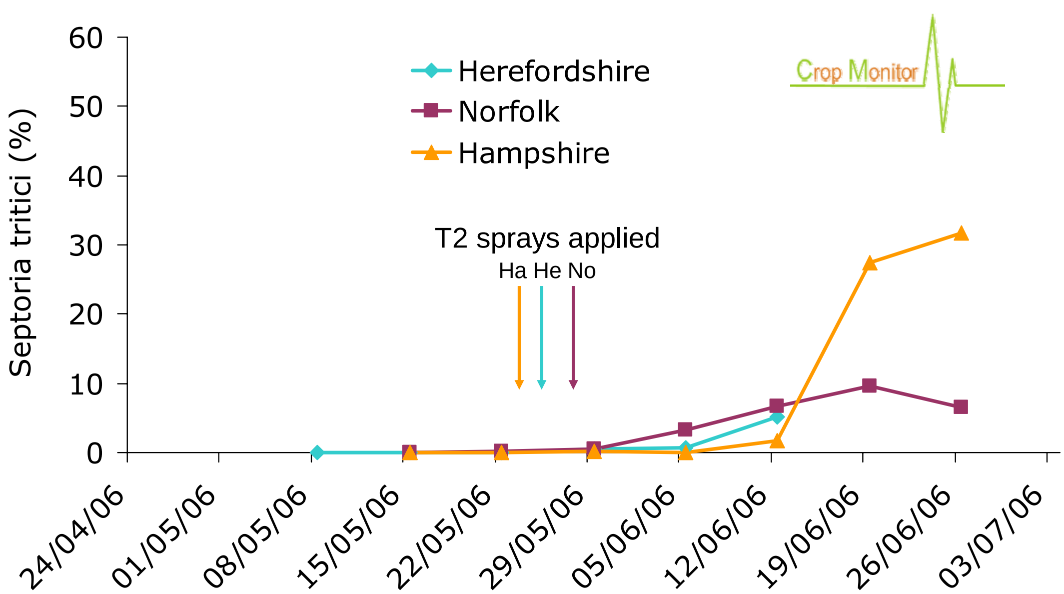


Fig. 5.3.2 Progress of *S. tritici* on final leaf 3 of Robigus at three sites in 2006

Septoria development on leaf 2 and the flag leaf in the Hampshire live monitoring experiment was typically slightly behind that recorded at the other two sites. However, disease levels tended to increase more rapidly towards the end of the growing season in Hampshire and Herefordshire, especially on Robigus. This probably explains why the septoria levels recorded in untreated plots in the sequences and mixtures experiments were lower in Norfolk, and therefore why optimum Opus doses were lower at this site than at the other two in 2006.

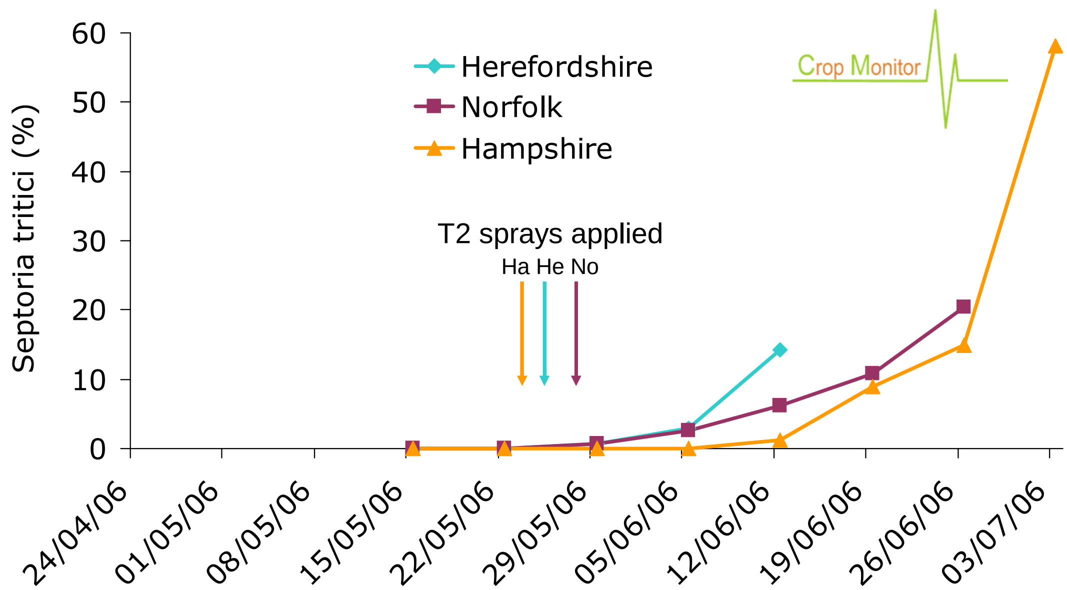


Fig. 5.3.3 Progress of *S. tritici* on final leaf 2 of Consort at three sites in 2006

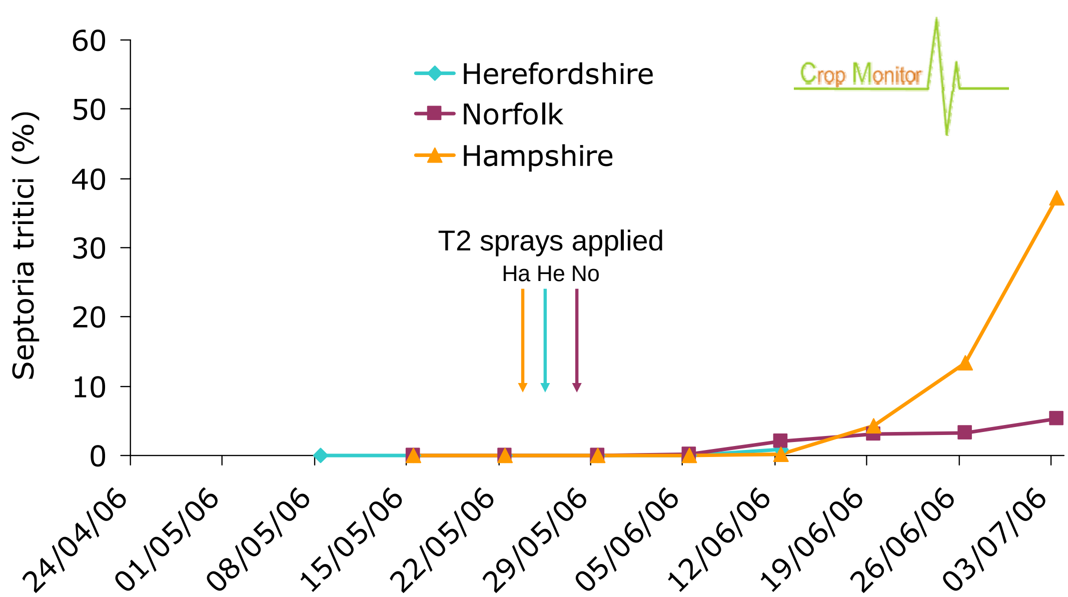


Fig. 5.3.4 Progress of *S. tritici* on final leaf 2 of Robigus at three sites in 2006

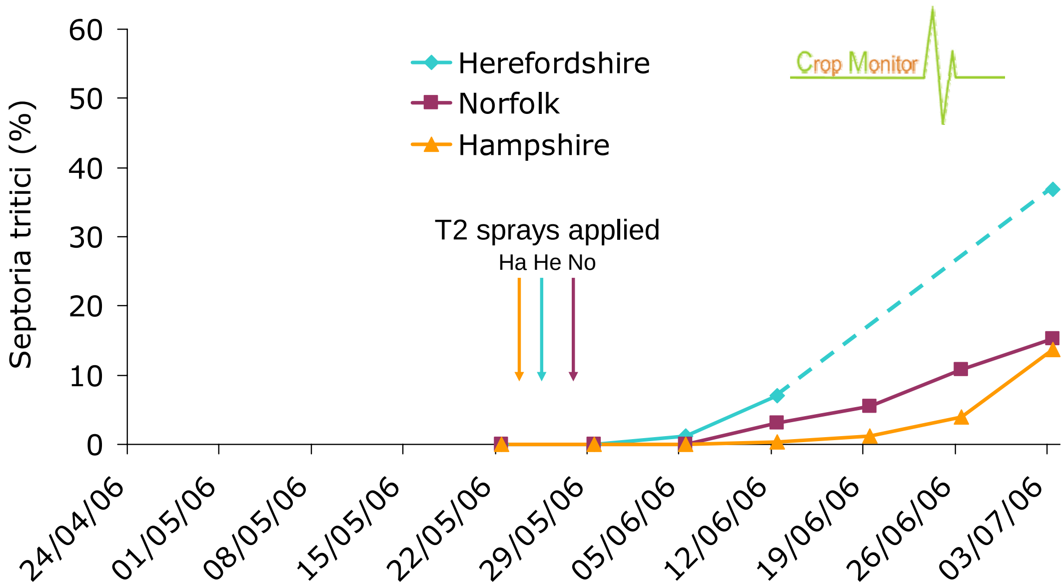


Fig. 5.3.5 Progress of *S. tritici* on the flag leaf of Consort at three sites in 2006

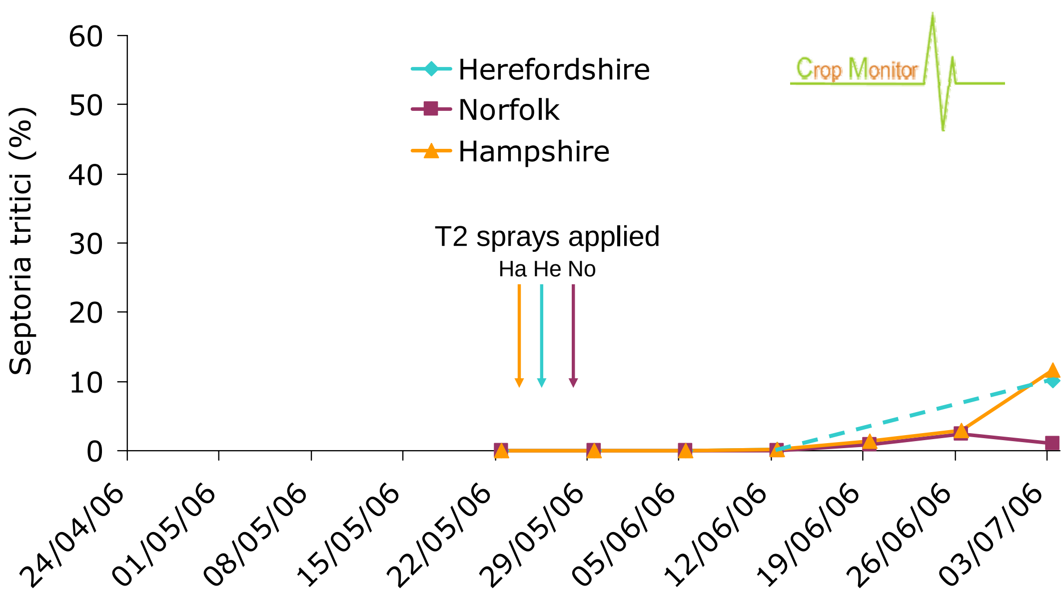


Fig. 5.3.6 Progress of *S. tritici* on the flag leaf of Robigus at three sites in 2006

5.4 Progress of *S. tritici* in 2007

In 2007, septoria development was clearly earlier and more rapid in the Herefordshire live monitoring experiment than at the other two sites, albeit that assessments ceased in mid June. At all three locations however, the sequences and mixtures experiments received their T2 fungicide sprays well before septoria started to appear on leaf 3. In Norfolk where there was a further assessment two weeks later than at the other sites there was an indication that disease levels were increasingly more rapidly towards the end of the growing season, especially on Robigus.

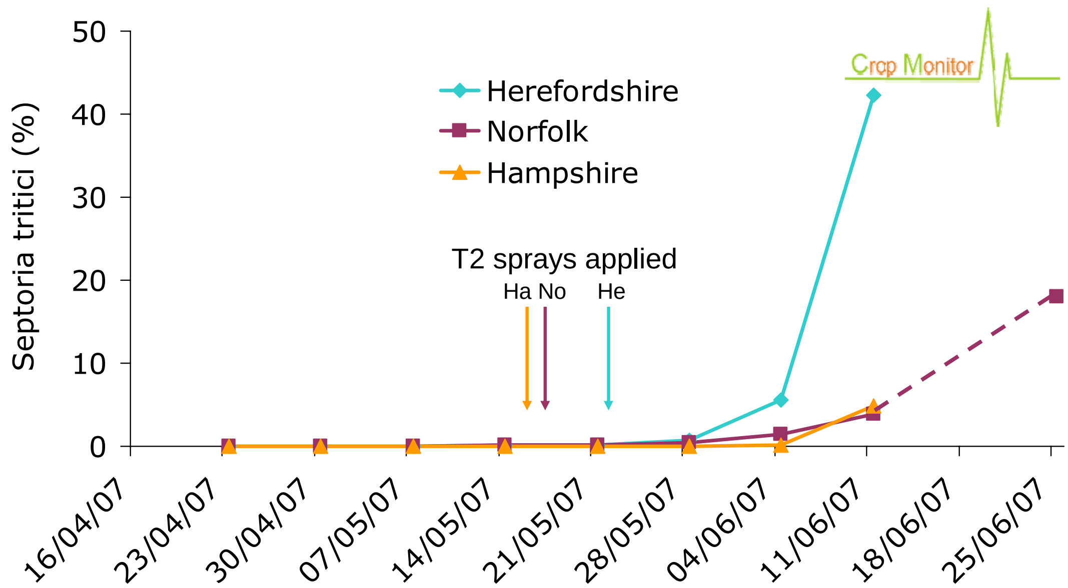


Fig. 5.4.1 Progress of *S. tritici* on leaf 3 of Ambrosia at three sites in 2007

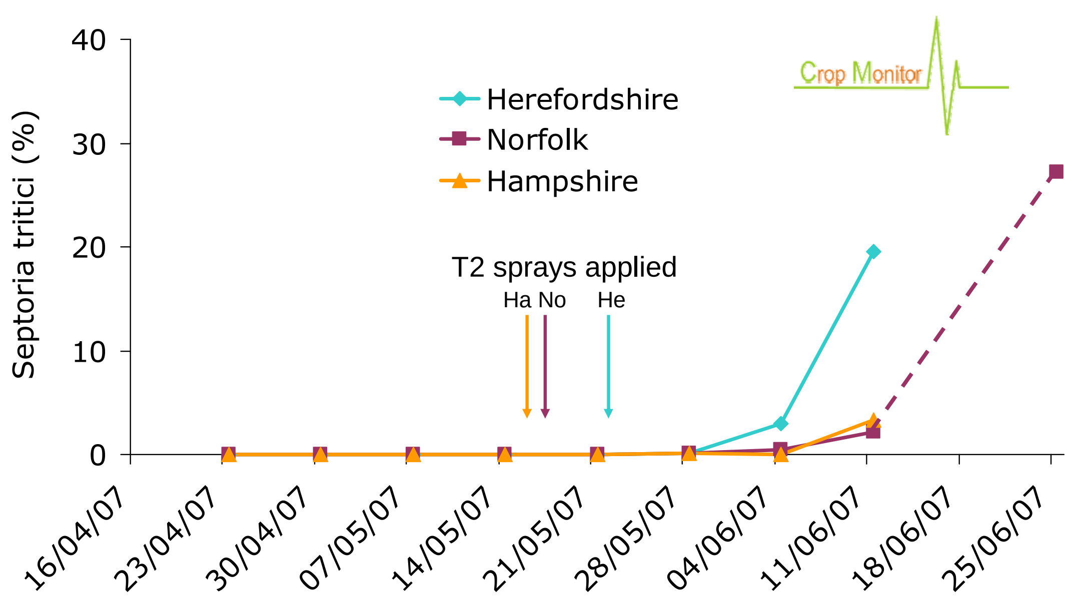


Fig. 5.4.2 Progress of *S. tritici* on leaf 3 of Robigus at three sites in 2007

In 2007, septoria was not the only disease that was influencing fungicide response. As a result, despite higher early septoria pressure in Herefordshire than in Norfolk, optimum Opus doses in the sequences and mixtures experiments were similar for the two sites on Consort, and higher in Norfolk for Robigus, probably due to a combination of brown rust and the late increase in septoria levels.

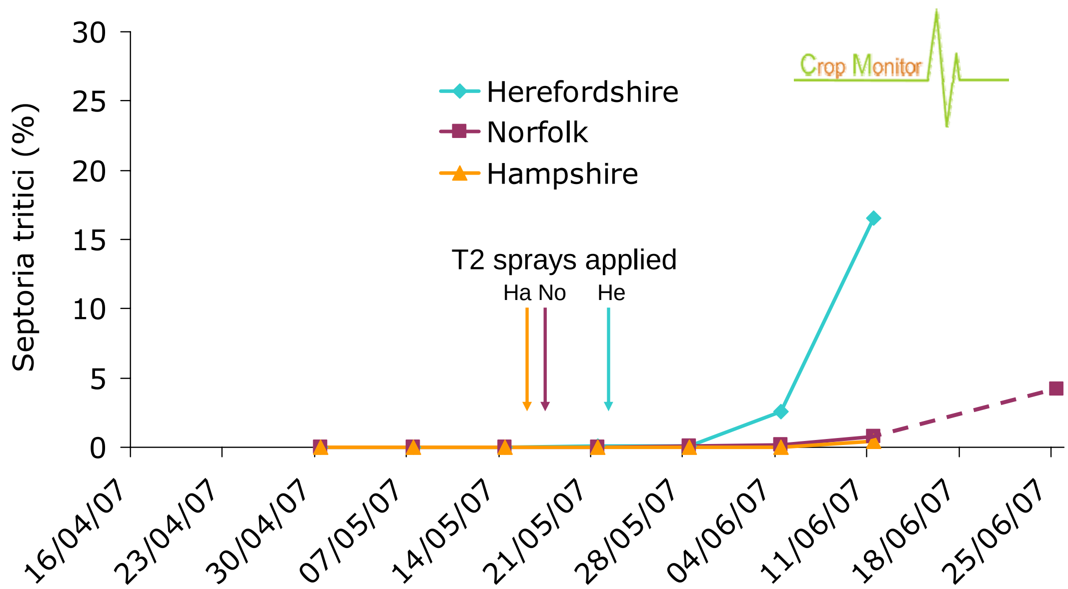


Fig. 5.4.3 Progress of *S. tritici* on leaf 2 of Ambrosia at three sites in 2007

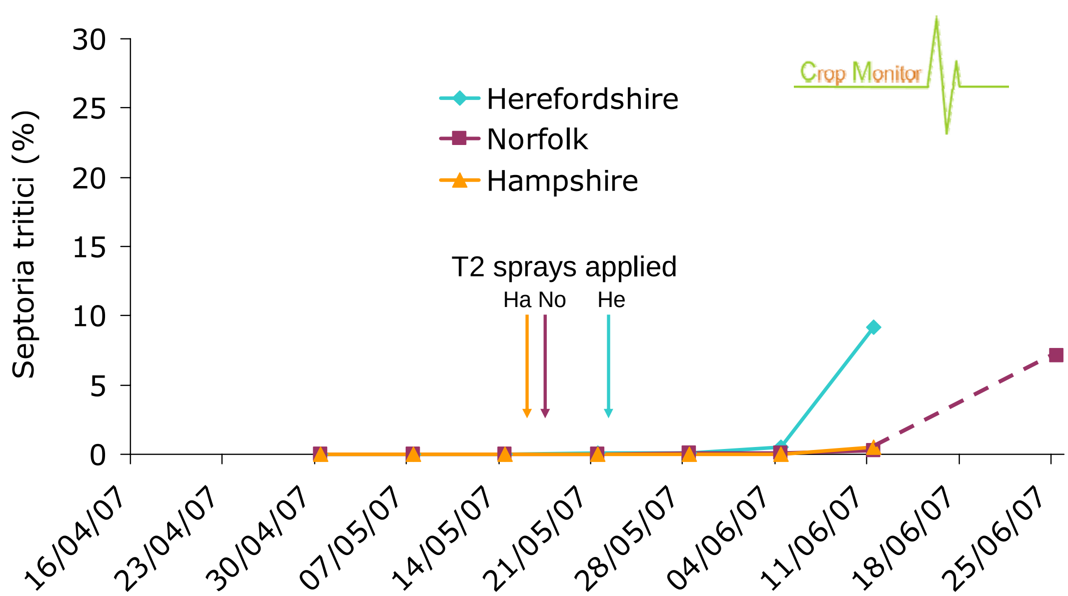


Fig. 5.4.4 Progress of *S. tritici* on leaf 2 of Robigus at three sites in 2007

6.0 Predicting the Performance of Fungicide Mixtures and Sequences

6.1 Introduction

Data from the field experiments were used to test the extent to which it was possible to predict yield responses to fungicide programmes. Predicted yield response values were obtained using a computer programme 'Wheat Disease Manager' (WDM), which accounted for local weather, the disease resistance of wheat varieties and observations of disease severity prior to spray decisions. Details of the mathematical models underlying the software are given in: Milne *et al.*, 2003 & 2007; Parsons & Te Beest, 2004; Audsley *et al*., 2005. Yields from each site and treatment in 2005 and 2006 were compared with yields predicted by WDM.

6.2 Materials and Methods

WDM was run according to the methods detailed in Anon., 2005. Weather data were collected from the Met Office network for the two growing seasons and three sites of the field experiments. Disease resistance rating data for Consort, Robigus and Einstein were obtained from the HGCA Recommended List for Winter Wheat. Observations of disease were entered into the observations dialog of WDM, for each spray programme. Details of the products, doses and spray timings for each fungicide treatment were entered into the system and the yield responses predicted for each spray programme were noted. WDM is constrained to work within label limits, so yield responses from double dose treatments could not be predicted.

The yields obtained in the double dose treatments in the field experiments were taken as representing the 'potential yield' for each variety for each site and were entered into WDM. This allowed the predicted yield responses for each spray programme to be plotted as predicted yield against the actual yields obtained from the experiments.

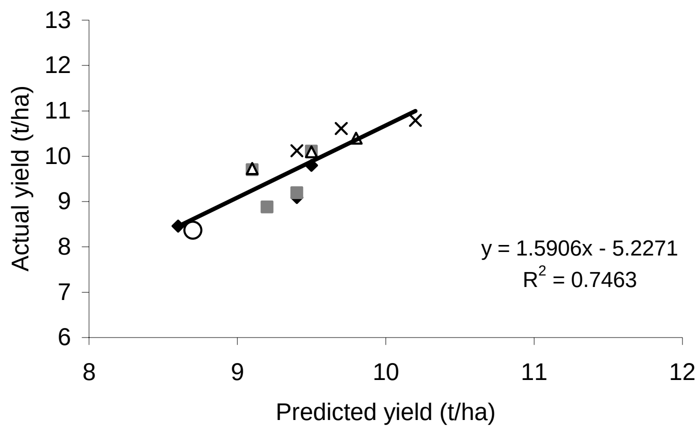
6.3 Results

6.3.1 2005

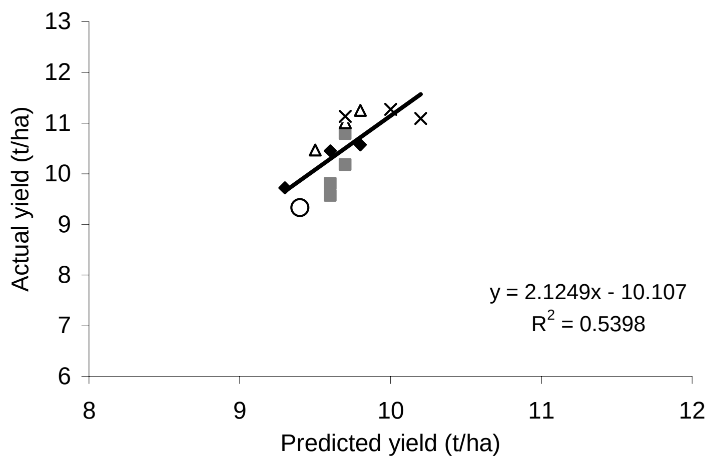
At Andover in 2005, the predicted and actual yields were well related for experiments for all three varieties, with R^2 values (indicating the proportion of variance in actual yield accounted for by predicted yield) ranging from 0.54 to 0.82 (Figure 6.1). In general, predicted yields were slightly lower than the actual yields obtained, and fungicide treatment resulted in yield increases of between 2.0 and 2.5 t/ha at the highest Opus rates, regardless of variety.

At Morley in 2005, Robigus showed a good correlation between the predicted and actual yields, with an R^2 of 0.71 (Figure 6.2). The predicted yield of the untreated was similar to the actual at 10 t/ha, however although a good correlation was observed, maximum yield responses to treatment at this site of 1.1 t/ha were predicted where actual yield responses were 2.0 t/ha. There was no relationship between the predicted and actual yields for Consort at this site. The relationship between predicted and actual yields for Einstein showed a generally logical trend of increasing yield with increasing fungicide input, but the data could not be fitted by linear regression. At Rosemaund, predicted and actual yields related well across all varieties with R^2 values between predicted and actual yields of between 0.58 and 0.61 (Figure 6.3). Values for actual yield on Consort matched closely those that were predicted, and predicted and actual responses to treatment fell within a similar range (2.5 t/ha and 2.3 t/ha). On Einstein, despite relating well, yield predictions underestimated the range of actual yields observed. The fully treated yield actual and predicted yields were close at around 11 t/ha. However where less robust fungicide strategies were employed predicted yields underestimated the loss of yield that was actually observed.

Consort



Einstein



Robigus

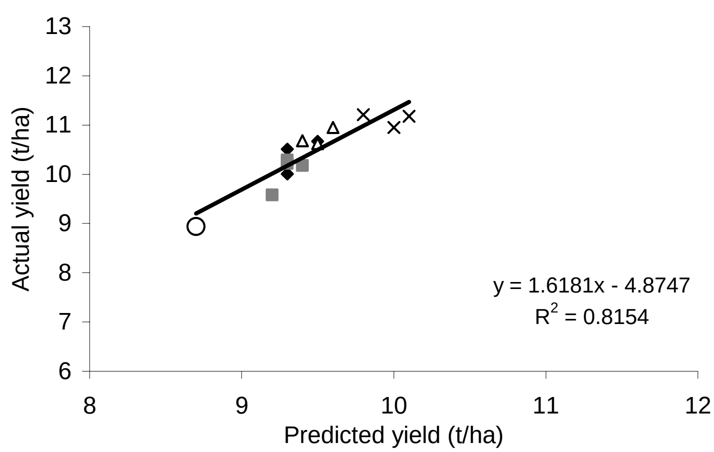


Figure 6.1. Comparison of predicted yields as calculated by WDM and actual yields from field experiments in 2005 at Andover. Open circle = untreated. ♦ = single spray Opus at T1, ■ = two spray Opus at T1 and T2, Δ = Opus + Bravo at T1 and T2, x = Opus + Bravo + Vivid at T1 and T2. Points within these sequences represent the different doses of Opus. Least Significant Differences (LSD) at P=0.05 for actual yields of Consort and Einstein = 0.472, and 0.280, respectively.

Robigus

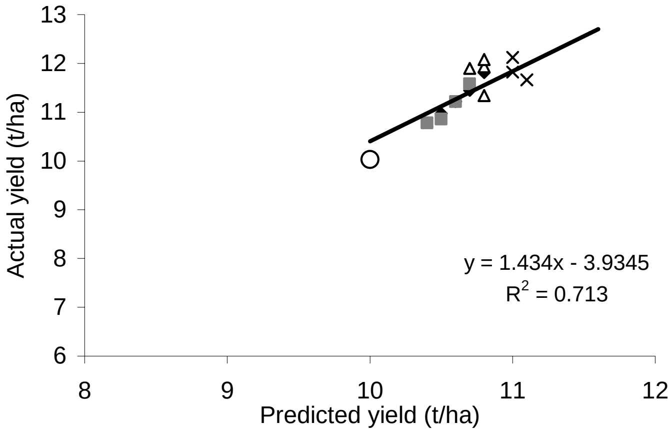
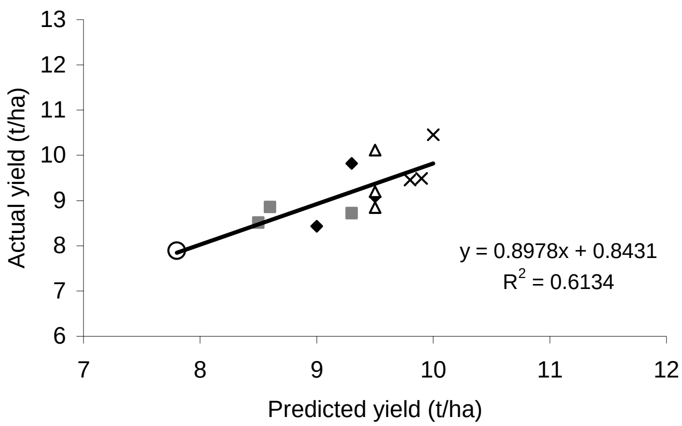
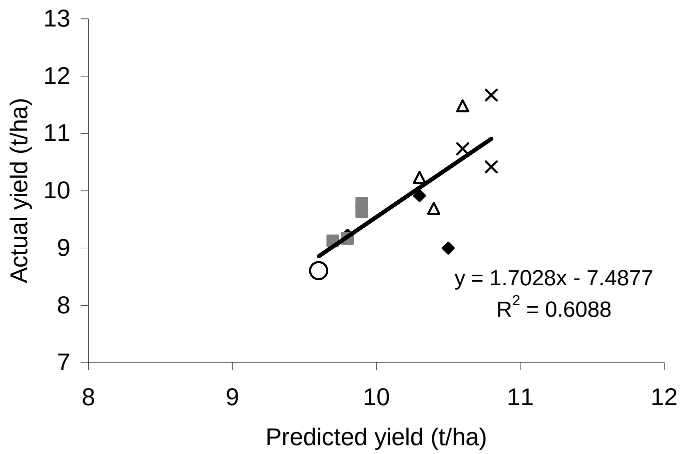


Figure 6.2. Comparison of predicted yields as calculated by WDM and actual yields from field experiments on Robigus in 2005 at Morley. Open circle = untreated. ♦ = single spray Opus at T1, ■ = two spray Opus at T1 and T2, Δ = Opus + Bravo at T1 and T2, x = Opus + Bravo + Vivid at T1 and T2. Points within these sequences represent the different doses of Opus. LSD for actual yield of Robigus = 0.338.

Consort



Einstein



Robigus

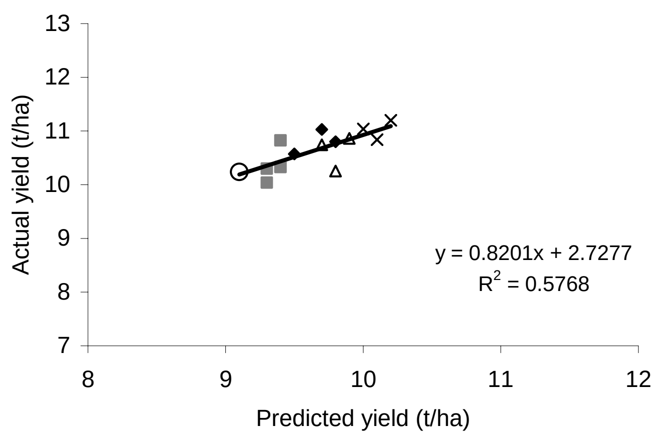


Figure 6.3. Comparison of predicted yields as calculated by WDM and actual yields from field experiments in 2005 at Rosemaund. Open circle = untreated. ♦ = single spray Opus at T1, ■ = two spray Opus at T1 and T2, Δ = Opus + Bravo at T1 and T2, x = Opus + Bravo + Vivid at T1 and T2. Points within these sequences represent the different doses of Opus. LSD’s for actual yields of Consort and Equinox were 0.496 and 0.370, respectively.

6.3.2 2006

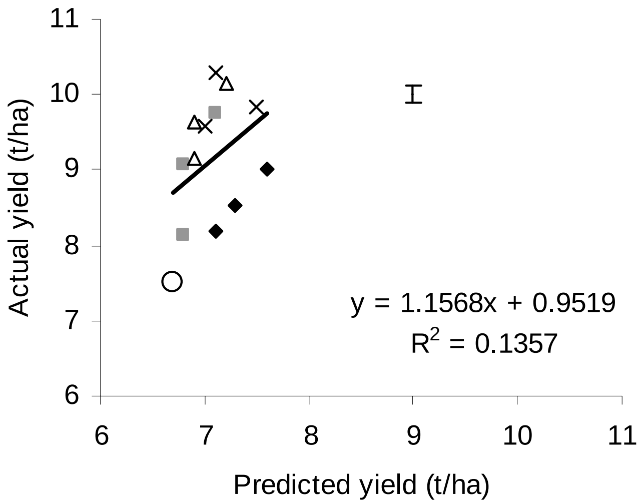
In 2006, two varieties with contrasting resistance in *S. tritici* were used for comparison: Consort (susceptible) and Robigus (resistant).

At Andover, a good relationship was obtained between actual and predicted yields, with Robigus (R^2 = 0.86), but not Consort (Figure 6.4). On Consort the range of predicted yields (6.7 – 7.6 t/ha) was smaller than the range in actual yields (7.7 – 10.3 t/ha). On Robigus, the actual and predicted yields had a similar range but predicted yields across all treatments were below the actual yields achieved.

At Morley on both varieties, predicted and actual yields were all between approximately 8 and 10 t/ha. R^2 values of 0.19 and 0.74 were found for Consort and Robigus respectively, although the data for the latter were somewhat clustered (Figure 6.5).

At Rosemaund on Consort, actual yields ranged from 6.6 t/ha for the untreated up to 9.7 t/ha, however a smaller range of predicted yields was observed from 7.7 t/ha to 8.6 t/ha (Figure 6.6) and the R^2 was 0.31. On Robigus the actual and predicted ranges of yields were in close agreement and a good correlation between the two was observed (R^2 = 0.83.)

Consort



Robigus

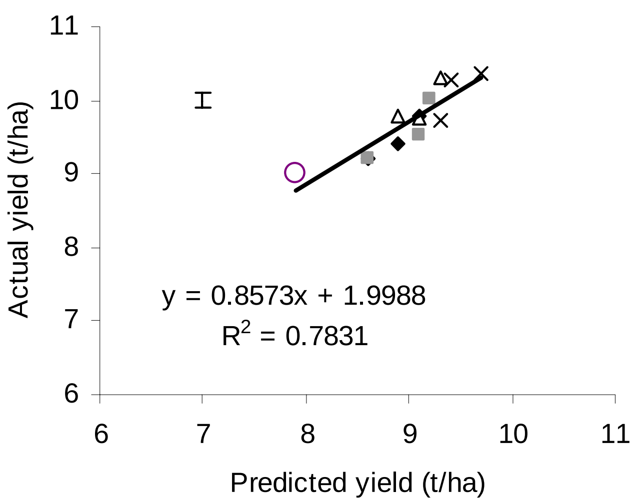
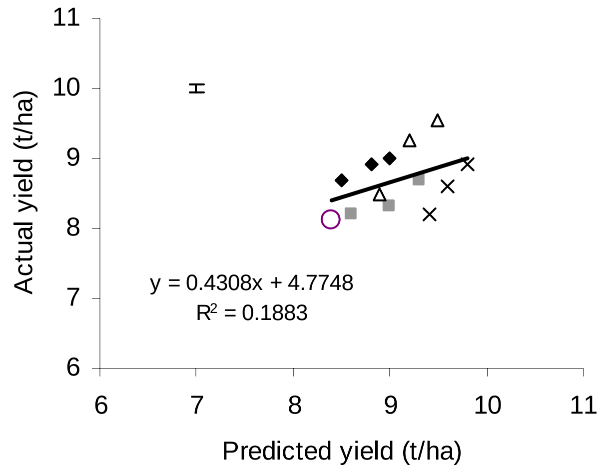


Figure 6.4. Comparison of predicted yields as calculated by WDM and actual yields from field experiments in 2006 at Andover. Open circle = untreated. ♦ = single spray Opus at T1, ■ = two spray Opus at T1 and T2, Δ = Opus + Bravo at T1 and T2, x = Opus + Bravo + Vivid at T1 and T2. Points within these sequences represent the different doses of Opus. Error bars indicate LSD’s for actual yield.

Consort



Robigus

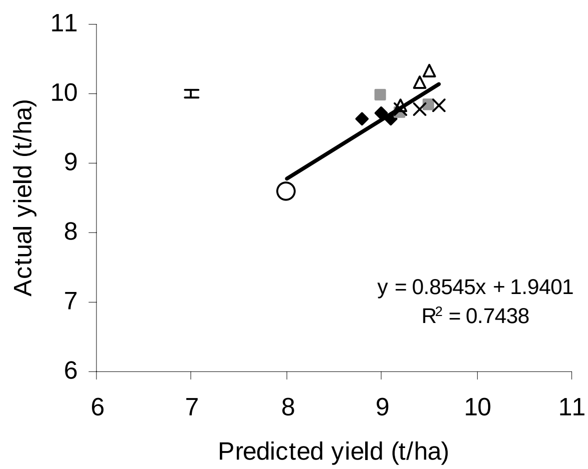
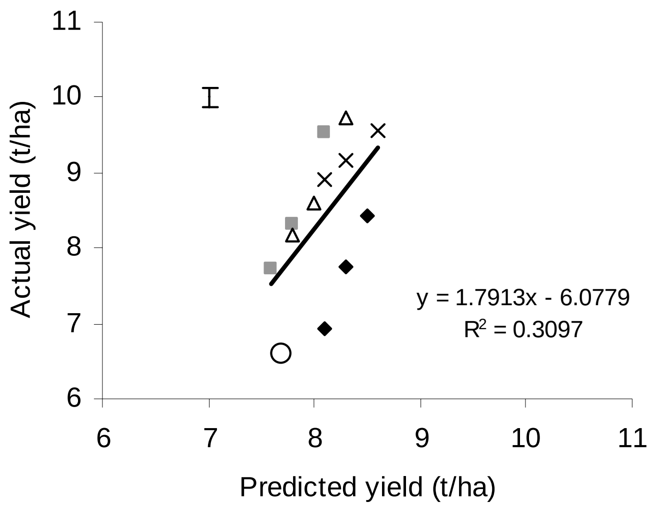


Figure 6.5. Comparison of predicted yields as calculated by WDM and actual yields from field experiments in 2006 at Morley. Open circle = untreated. ♦ = single spray Opus at T1, ■ = two spray Opus at T1 and T2, Δ = Opus + Bravo at T1 and T2, x = Opus + Bravo + Vivid at T1 and T2. Points within these sequences represent the different doses of Opus.

Consort



Robigus

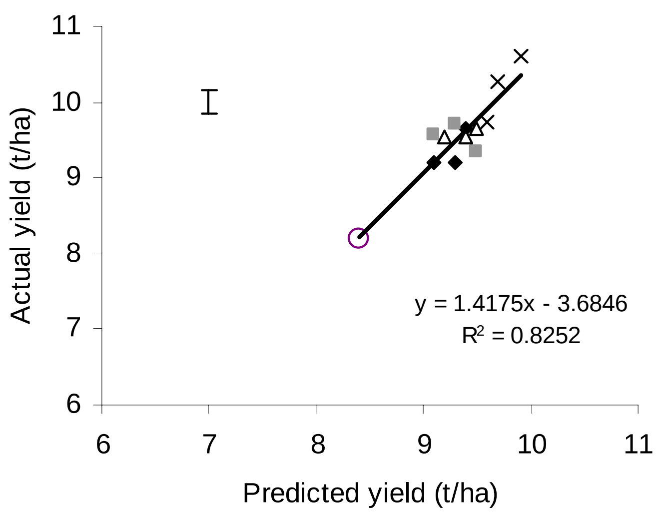


Figure 6.6. Comparison of predicted yields as calculated by WDM and actual yields from field experiments in 2006 at Rosemaund. Open circle = untreated. ♦ = single spray Opus at T1, ■ = two spray Opus at T1 and T2, Δ = Opus + Bravo at T1 and T2, x = Opus + Bravo + Vivid at T1 and T2. Points within these sequences represent the different doses of Opus.

7.0 Fungicide Mixture Calculator

Contribution by David Parsons, Cranfield University

7.1 Introduction

The aim of the fungicide mixture calculator was to take dose-response curves for individual fungicide active ingredients and combine them to produce dose-response curves for tank mixes or products with multiple actives and display them graphically. This would test the extent to which the performance of mixtures could be predicted with acceptable precision from the performance of their components.

7.2 Materials and Methods

7.2.1 Calculating dose-response for mixtures

The starting point was the dose response curves fitted to results from HGCA fungicide performance experiments (see example in figure 7.2.1). These are exponential curves of the form:

$$u = a + be^{-kx} \qquad (1)$$

where x is dose and u is the disease remaining (% of leaf area); a, b and k are positive fitted parameters. The interpretation of the parameters is that (a+b) is the disease level with no treatment, a is the disease that cannot be controlled even at

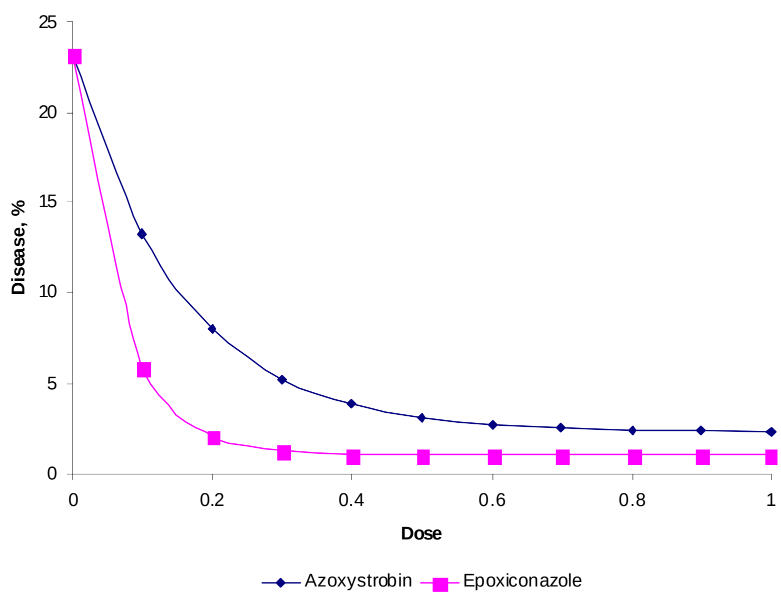


Fig. 7.2.1 Example of dose response curves for control of yellow rust from HGCA fungicide performance experiments in 2005

very high doses and *k* controls the steepness of the curve. If k is large, the curve falls very steeply, meaning that the fungicide achieves most of its potential efficacy at low doses. Note that (a+b) must be the same for all treatments of the same disease, since it is the untreated disease level, so there are only two independent parameters.

In order to combine dose-response curves, it is useful to convert the disease remaining to the proportion z of the original disease that survives (the survival rate), which is $u/(a+b)$, so

$$z = \frac{a + be^{kx}}{a + b} \qquad (2)$$

There are two ways of combining dose-response curves, known as the additive dose method (ADM) and the multiplicative survival method (MSM), both of which are used in the calculator (Milne *et al*., 2007). The MSM assumes that one fungicide controls the disease that survives the other with the same effectiveness as it would control the total disease. So if the survival rates for the two fungicides at particular doses are z_1 and z_2, the survival rate for the combined application is z_1z_2. This method is most appropriate when the two fungicides have different modes of action, because it assumes that the diseases respond independently to the two fungicides. In fact, it would give too high a value for control (too low a survival rate) for the notional case of two simultaneous applications of the same fungicide, except in the special case when the value of parameter a was 0.

The ADM addresses this deficiency, and is more suitable for chemicals of the same mode of action. First consider two identical fungicides applied simultaneously at doses x_1 and x_2. The combined effect is clearly that of a single application of dose x_1+x_2. This is generalised to two different chemicals by converting the less effective one into the equivalent (lower) dose of the more effective one, that is the dose giving the same survival rate, then adding the dose of the more effective chemical and calculating the resulting survival rate. If applied to fungicides with different modes of action, this may overestimate survival rate, because the predicted survival rate will never be lower than the minimum survival rate for the more effective chemical.

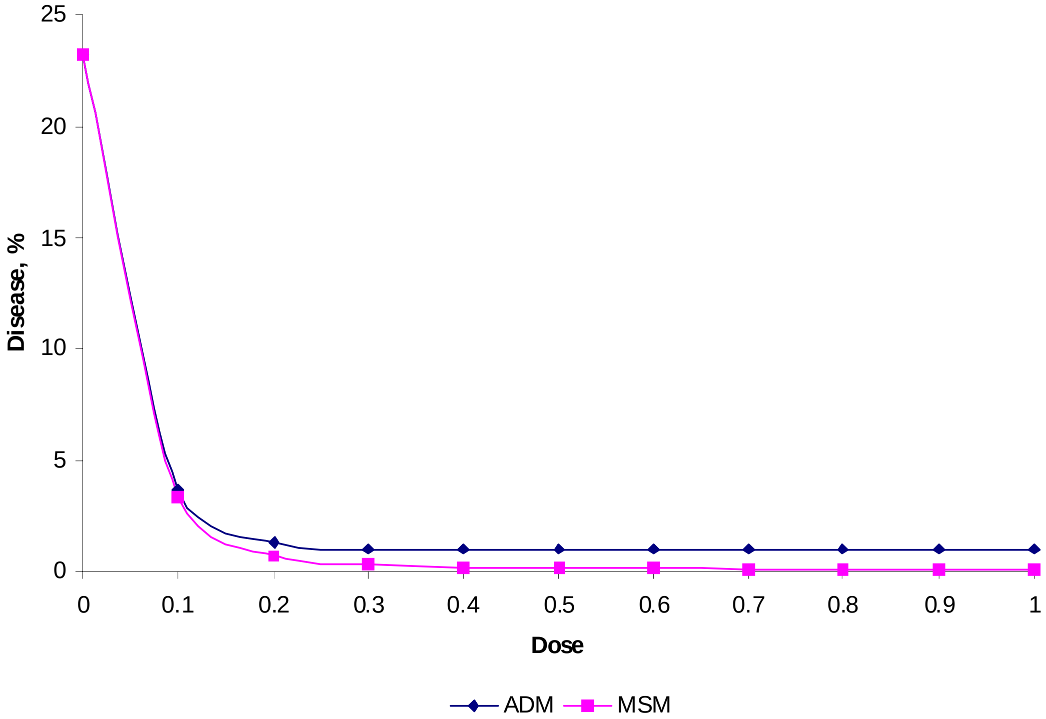


Fig. 7.2.2 Mixture dose response curves derived from Fig. 7.2.1 using the additive dose method (ADM) and the multiplicative survival method (MSM)

The difference is illustrated by comparing the resulting dose-response curves for the examples shown above using the two methods (figure 7.2.2). The fungicide calculator uses both methods: ADM when the mode of action is the same and MSM when it is different.

7.2.2 The fungicide calculator program

The fungicide calculator program was written to provide a simple method of visualising the dose response curves for mixtures described above. The program is written in Microsoft Visual C++ V6.0™ using the Microsoft Foundation Class ™ library (as a static library) for the user interface, to produce a fast, compact program with minimal dependencies on other components.

Using FungicideMix

The program has a single screen that can be shown in the standard (figure 7.2.3) or extended (figure 7.2.4) mode. The difference is the way that the results for the mixture are presented, as described below. The lower part of the screen shows the

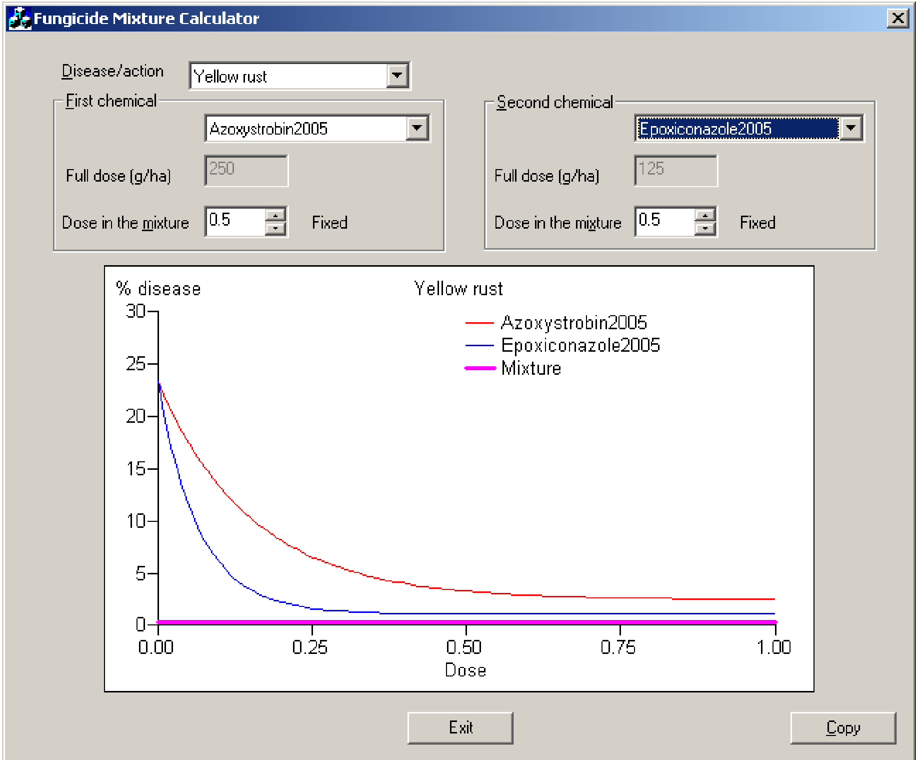


Fig. 7.2.3 Fungicide mixture calculator in standard mode

dose-response for the two chemicals and the mixture. When any of the selections or doses is changed, the graph is re-plotted immediately. The Copy button in the bottom right corner copies the graph to the clipboard so that it can be pasted into other documents.

At the top of the screen is a drop-down list to select the disease of interest. If data were available, this list would also distinguish between eradicant and protectant activity. Below this are identical groups of controls for the two chemicals. For each there is a drop down list to choose the chemical. At present many are included with parameters from both the 2005 and 2006 HGCA fungicide performance experiments. The example shows 2005 versions of both chemicals. The parameters *a* and *b* for 2006 have been scaled to give the same untreated disease level as the 2005 parameters. This is purely a matter of presentation, as the underlying model is in terms of the relative survival rate. The normal full dose for the fungicide, based on the dose in common products is shown below the name. Below this is the dose to be considered in the mixture. This is expressed as a fraction of the full dose, and can be changed by typing a new value (between 0 and 1) or in steps of 0.1 using the arrow buttons beside it. In standard mode, the label to the right of the dose says “Fixed”, meaning that the program calculates a single response for the mixture based on the chosen doses and plots this as a horizontal line on the graph. In the example (figure 7.2.3), the full doses are 250 g/ha and 125 g/ha, and the dose values are both set to 0.5 so the result is for 125 g/h azoxystrobin plus 62.5 g/ha epoxiconazole. The graphs for the individual chemicals are unaffected by the doses chosen for the mixture: 1.0 always means full dose.

In extended mode, the label next to dose says 'variable' and the program calculates the responses for the full range of doses of the mixture using the two chemicals in the given proportions. So in the example (figure 7.2.4), a dose of 1.0 for the mixture means the same as the single dose shown in the standard mode, 0.5 means 62.5 g/h azoxystrobin plus 31.25 g/ha epoxiconazole, and so on. As in standard mode, the graphs for the individual chemicals are unaffected by the doses chosen for the mixture.

The program normally operates in standard mode. To use extended mode, exit from the program and create a text file (e.g. using Notepad) in the same folder called FungicideMix.ini containing three lines

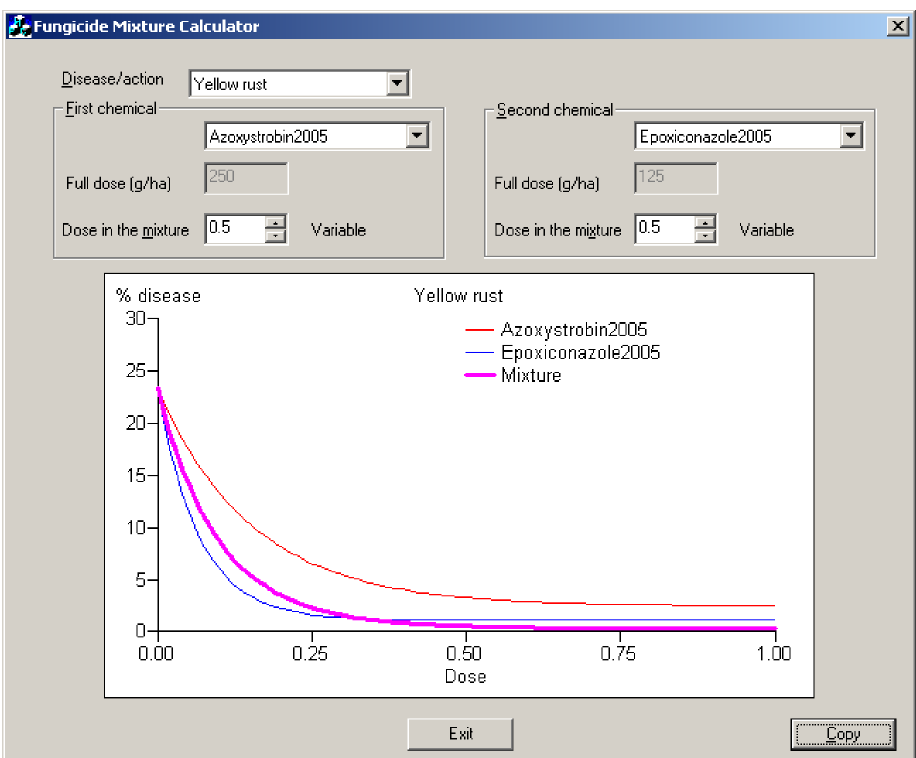


Fig. 7.2.4 Fungicide mixture calculator in extended mode

```
[FungicideMix]

FixDoseA = 0

FixDoseB = 0
```

and restart the program. To switch back, delete the file, or change the numbers on both lines to 1. Note that it is possible to examine the effect of adding a variable dose of one chemical to a fixed dose of the other, by setting one value to 0 and the other to 1.

Most of the fungicides used in the experiments were only tested against some of the diseases; where there are no data for a fungicide-disease combination, the program does not plot a graph for either the fungicide or the mixture. Some were tested in both years and results for both are included in the data file, distinguished by the year at the end of the name. The program will not plot a mixture curve if the two components are the same fungicide, even if they are from different years. Other than this, the mixture is always plotted: for this test version, no account is taken of recommended tank mixes.

Additional detailed methods can be found in appendix G.

7.3 Results

To test the calculator, data were required from the same experiments in which both single active ingredients and their mixtures had been applied. A few mixtures were tested in 2006, which enabled these combinations to be tested. However, in some cases one of the active ingredients had not been alone in the same experiments, so the only parameters available were from 2005. As some of the responses for other fungicides differed substantially between the two seasons, these were a less reliable way of testing the calculator. To allow a consistent comparison, all of the graphs presented here have the untreated disease level standardised to the 2005 value, which was generally higher than 2006 for the rust diseases and lower for *S. tritici* and *S. nodorum*. It should be noted that the variability in the disease levels observed is quite high, especially when the disease levels are low.

The effectiveness of a formulated mixture of prothioconazole and tebuconazole (Prosaro, Bayer CropScience), containing at full dose the equivalent of 0.75 and 0.6 respectively of the full doses of the two separate fungicides (Proline and Folicur, Bayer CropScience), was tested in HGCA fungicide performance experiments in 2006, and was the most complete dataset available. The predictions for *S. tritici* and *S. nodorum* were good, lying well within the experimental variability (figures 7.3.1–7.3.2).

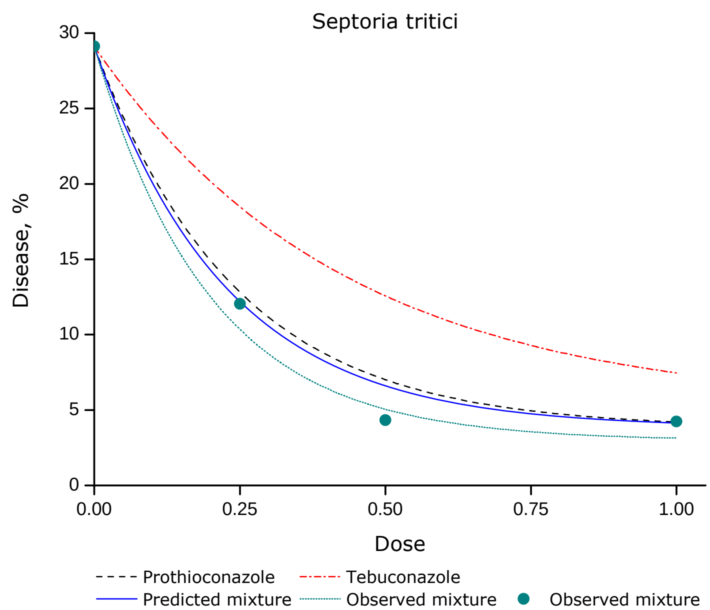


Fig. 7.3.1 Observed and predicted dose response curves for prothioconazole and tebuconazole on *S. tritici.*

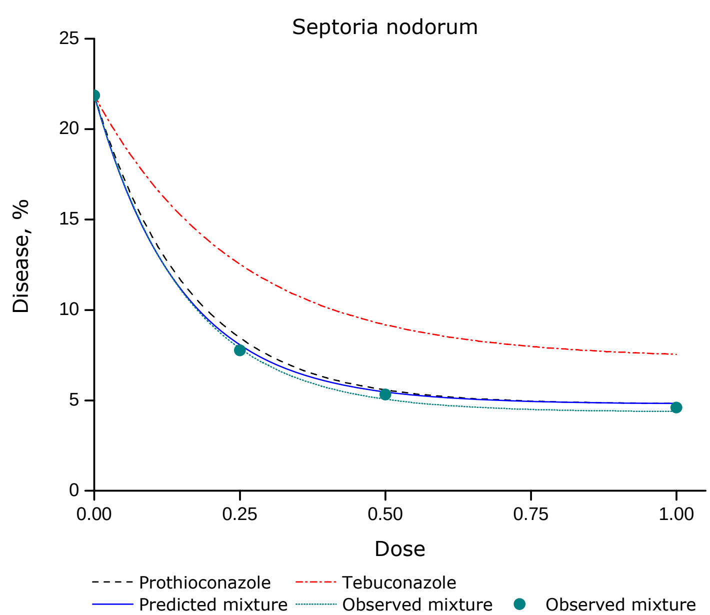


Fig. 7.3.2 Observed and predicted dose response curves for prothioconazole and tebuconazole on *S. nodorum*

Two other mixtures were tested on *S. nodorum* only in 2006: a formulated mixture (Amistar Opti, Syngenta Crop Protection) containing at full dose the equivalent of a 0.8 dose of Amistar (azoxystrobin, Syngenta Crop Protection) plus a full (1.0) dose of Bravo (chlorothalonil), and also a tank mix of Amistar plus Opus (epoxiconazole). Unfortunately, Amistar was not applied as a single fungicide in the 2006 trials, but it had been in 2005, so the parameters for that year were used. The results for the first mixture (figure 7.3.3) again show reasonable agreement between predictions and observations, given the variability in the data. The second (figure 7.3.4) predicts well at low doses, but over-predicts the effect of the mixture at high doses. This may be due to variability, or may illustrate a feature of the MSM when applied to *S. nodorum* and *S. tritici*. Experiments, including those from the HGCA performance in 2005 and 2006, rarely show control giving survival for these diseases below about 5%, in contrast to the rusts and mildew where lower levels are achieved. The model implicitly assumes that control to levels close to 0 is possible. To account for this, more sophisticated models sometimes set a base survival level for the disease, and use it as the reference point for control.

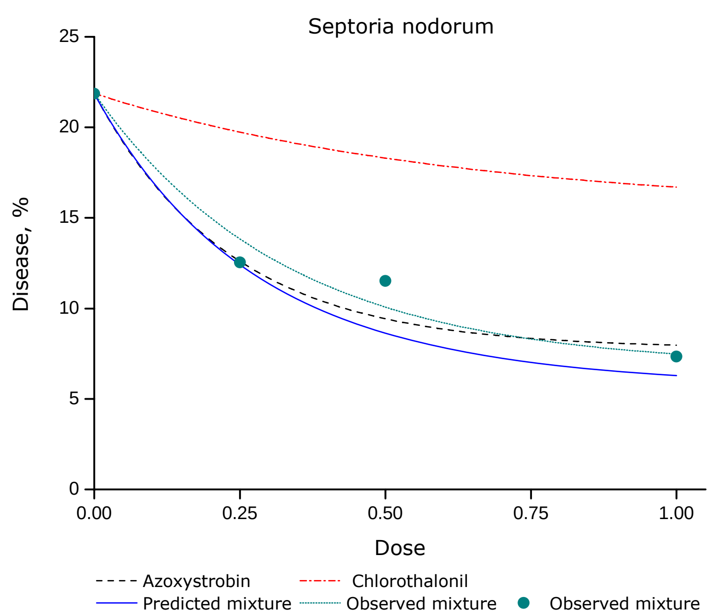


Fig. 7.3.3 Observed and predicted dose response curves for azoxystrobin and chlorothalonil on *S. nodorum*

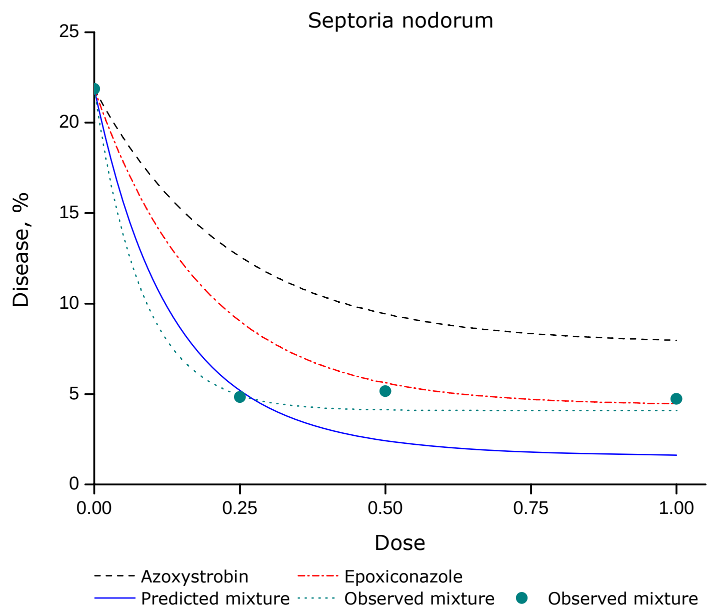


Fig. 7.3.4 Observed and predicted dose response curves for azoxystrobin and epoxiconazole on *S. nodorum*

8.0 Project Conclusions

In situations where the dominant foliar disease on winter wheat was *S. tritici*, the addition of Bravo (chlorothalonil) to Opus (epoxiconazole) in a 2-spray (T1 + T2) fungicide programme has:

- Reduced the dose of triazole (Opus) required to obtain equal disease control, often by 50% or more.
- Allowed optimum yields to be obtained at 15-30% lower doses of triazole (Opus), whilst improving margins.

Even when mixed with Bravo, optimum triazole (Opus) doses were an average of:

- 45-65% higher for the most septoria susceptible variety compared to the least.
- 40-60% higher under medium-high than under low septoria pressure.

Where brown or yellow rust were an equal or greater threat on one or more varieties:

- The strobilurin Vivid (pyraclostrobin) was of more benefit than Bravo as a mixture partner for Opus to control rusts.
- Adding Vivid as well as Bravo resulted in up to 70% lower optimum triazole (Opus) doses whilst in most cases maintaining or increasing margins

However it is important to note that choice of triazole at T1 and T2 (to reflect the target diseases) is important as well as triazole dose and choice of mixture partner(s).

A range of triazole (Opus) doses can deliver margins that are close to that achieved at the optimum dose. Therefore it is prudent to apply a dose that is slightly above the expected optimum, especially where relatively low doses are being considered on the assumption of low septoria pressure. This will provide a degree of insurance in the event of higher than expected disease levels, unexpected delays in application or buoyant grain prices. However, it should be noted that robust disease control is best achieved through using appropriate fungicide mixtures rather than routinely applying higher than necessary doses of triazole. This will also help to avoid a potential escalation in selection for resistant or less sensitive disease isolates.

All other things being equal, increasing the grain price from £80/t to £160/t increased the optimum dose of the triazole (Opus) typically by 25-30%. Increasing the triazole dose is though only one way of responding to higher grain prices. Other ways include applying an additional spray (for example at T0 or T3), or applying an appropriate mixture partner, where this was otherwise not planned. The results obtained in this project suggest that adding a suitable mixture partner which has activity against the major disease present will often be more cost-effective than simply increasing the triazole dose.

Comparison of the results obtained in the field experimentation within this project against indicators of disease pressure from within-season disease monitoring have highlighted the difficulties that exist in forecasting fungicide response based on septoria progress during the growing season. However, such information may have a role to play in monitoring the development of rusts, which can affect both the most appropriate mixture partner(s) for the triazole, and potentially the extent to which triazole doses can be reduced on varieties that are less susceptible to septoria.

Of the 15 site x season x variety combinations tested, using the computer programme WDM, significant relationships between predicted and actual yields were recorded in 13 cases. Predicted yield responses to fungicide treatments as a proportion of untreated yield loss were generally in agreement with actual responses, although predictions tended to underestimate losses where the crop was untreated. Therefore the model could be recalibrated to resolve the underestimation of yield loss and more accurately predict potential yields in the future.

Prediction of yield response - and hence economic return - from treatment is a prerequisite for objective treatment decisions. To be of value the prediction needs to be made with information available at the time of the treatment decision. WDM is thought to be the first system worldwide to explicitly predict yield responses from fungicide programmes containing multiple sprays and active substances, applied to varieties which differ in disease resistance, grown in varying environments. The degree of predictive value demonstrated here suggests that the system could help support treatment decisions if parts, or all, of the system could be delivered to users in an appropriate form.

Although only limited testing was possible with the available data in this project, a fungicide mixture calculator that was designed to take dose-response curves for two individual fungicide active ingredients and combine them to produce dose-response curves for a mixture of the two gave good results when predicting the disease control performance of a mixture of two triazoles against *S. tritici* (and *S. nodorum*). The performance of two other mixtures that included two chemicals with different modes of action was slightly over-predicted at high doses, but nevertheless this approach is also worthy of further development.

9.0 Acknowledgements

The authors gratefully acknowledge the assistance of colleagues within TAG, ADAS and SAC in carrying out the field experiments and in commenting on sections of the text; the help and cooperation of the host farmers for each of the sites; Bill Clark (formerly of ADAS and now Brooms Barn) for his contribution to the project in its first two years; Anne Ainsley and also Steve Parker and Stephane Pietravalle of CSL for carrying out statistical analysis and curve fitting; Judith Turner and Sharon Elcock of CSL for providing seasonal disease risk data from the Defra/CSL/HGCA funded CropMonitor project; and finally HGCA for funding project 3286 and for the guidance received from its staff and committee members.

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Appendices

Appendix A. Summary of key field experiment results by site, season and variety

2004/05 Borders

Consort

Treatment and group	Opus Dose	Septoria % L3 GS71	Septoria % L2 GS77	GLA % L2 GS77	GLA % L1 GS77	Yield (t/ha)	SPW (kg/hl)
untreated		27.6	58.6	25.9	60.4	7.12	67.1
Ut_Op	0.25	17.7	27.6	61.1	86.9	8.36	69.6
Ut_Op	0.5	11.8	54.1	33.9	75.8	7.86	68.9
Ut_Op	1.0	9.3	14.1	73.3	89.7	8.43	70.4
Ut_Op	2.0	12.3	15.9	75.8	92.6	8.31	68.1
Op_Op	0.25	11.5	26.4	55.0	83.5	7.97	69.2
Op_Op	0.5	9.9	22.5	57.0	85.1	8.61	71.5
Op_Op	1.0	6.7	9.8	75.2	89.2	8.90	70.1
Op_Op	2.0	4.5	4.4	90.0	96.3	9.74	70.2
OpB_OpB	0.25	7.8	12.3	66.8	90.0	8.63	69.0
OpB_OpB	0.5	9.3	18.4	72.7	87.9	8.57	70.1
OpB_OpB	1.0	4.6	3.2	92.0	97.2	9.55	70.1
OpB_OpB	2.0	4.7	2.8	89.7	95.2	8.63	69.6
OpBV_OpBV	0.25	4.5	9.2	80.3	92.0	8.85	69.2
OpBV_OpBV	0.5	4.7	6.3	81.4	93.9	9.23	69.9
OpBV_OpBV	1.0	4.0	2.3	92.5	96.4	9.46	69.7
OpBV_OpBV	2.0	4.6	1.3	95.2	97.2	9.80	67.1
F prob.							
treat		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
treat.group		<0.001	<0.001	<0.001	0.007	<0.001	0.111
treat.dose		0.007	<0.001	<0.001	0.001	0.003	0.045
trt.grp.dose		0.439	0.904	0.871	0.770	0.066	0.348
Covariates		0	0	0	0	0	0
logit transformed		Y	Y	Y	Y	N	N
SED							
treat vs untr.		0.170	0.377	0.375	0.314	0.217	0.570
treat.group	(max)	0.160	0.356	0.354	0.296	0.205	0.538
treat.dose	(max)	0.160	0.356	0.354	0.296	0.205	0.538
trt.grp.dose	(min)	0.321	0.712	0.708	0.592	0.409	1.075
RMS		0.154	0.760	0.752	0.526	0.251	1.734
d.f.		35	35	35	35	35	35

2004/05 Borders

Einstein

Treatment and group	Opus Dose	Septoria %		GLA %		Yield (t/ha)	SPW (kg/hl)
		L3 GS71	L2 GS77	L2 GS77	L1 GS77		
untreated		17.3	26.0	43.1	57.5	9.41	71.3
Ut_Op	0.25	12.7	21.3	31.0	49.1	9.21	71.3
Ut_Op	0.5	9.8	6.9	69.9	66.1	9.67	70.7
Ut_Op	1.0	10.0	4.4	74.8	74.7	9.42	70.5
Ut_Op	2.0	7.9	0.0	85.0	73.7	9.27	71.7
Op_Op	0.25	10.5	13.7	69.6	74.6	9.76	71.2
Op_Op	0.5	6.1	6.4	58.6	65.7	9.76	69.8
Op_Op	1.0	2.6	2.4	73.7	71.5	9.77	70.8
Op_Op	2.0	2.3	1.4	83.3	81.4	9.55	70.5
OpB_OpB	0.25	3.9	1.4	68.9	65.0	9.58	70.2
OpB_OpB	0.5	4.5	0.0	70.4	60.8	9.89	70.6
OpB_OpB	1.0	4.8	0.6	80.2	80.3	9.61	71.0
OpB_OpB	2.0	2.3	0.0	72.1	61.1	9.79	71.1
OpBV_OpBV	0.25	3.6	3.7	68.8	68.2	9.74	71.8
OpBV_OpBV	0.5	4.0	0.4	74.8	74.1	9.53	70.9
OpBV_OpBV	1.0	2.4	0.4	73.3	78.2	9.57	71.2
OpBV_OpBV	2.0	3.6	0.0	84.1	67.9	9.90	71.6
F prob.							
treat		<0.001	<0.001	<0.001	0.024	0.271	0.319
treat.group		<0.001	<0.001	0.296	0.252	0.112	0.091
treat.dose		0.045	<0.001	0.003	0.085	0.777	0.183
trt.grp.dose		0.372	0.061	0.119	0.218	0.722	0.555
Covariates		0	0	1	1	1	0
logit transformed		Y	Y	Y	Y	N	N
SED							
treat vs untr.		0.240	0.318	0.291	0.226	0.160	0.355
treat.group	(max)	0.226	0.300	0.270	0.210	0.148	0.335
treat.dose	(max)	0.226	0.300	0.267	0.208	0.146	0.335
trt.grp.dose	(min)	0.452	0.599	0.542	0.421	0.297	0.670
RMS		0.307	0.539	0.406	0.245	0.122	0.674
d.f.		35	35	32	32	32	35

2004/05 Borders

Robigus

Treatment and group	Opus Dose	Septoria % L3 GS71	Septoria % L2 GS77	GLA % L2 GS77	GLA % L1 GS77	Y Rust % L2 GS77	Yield (t/ha)	SPW (kg/hl)
untreated		13.4	23.7	43.5	63.9	20.5	8.30	70.0
Ut_Op	0.25	5.5	10.4	86.2	95.5	0.5	8.80	71.2
Ut_Op	0.5	8.9	9.8	87.2	94.4	1.2	8.39	70.4
Ut_Op	1.0	5.7	1.3	94.9	95.9	0.4	8.76	70.3
Ut_Op	2.0	8.2	8.6	80.4	92.5	1.5	9.93	69.3
Op_Op	0.25	5.6	13.8	70.7	91.7	0.6	8.50	69.7
Op_Op	0.5	5.8	12.1	86.9	94.6	1.1	9.26	69.7
Op_Op	1.0	3.1	6.3	90.3	97.5	1.0	9.32	69.3
Op_Op	2.0	1.8	0.4	95.2	98.0	0.0	9.53	71.4
OpB_OpB	0.25	3.1	2.3	89.7	98.0	0.0	8.53	70.5
OpB_OpB	0.5	2.6	0.4	94.6	97.8	0.0	9.22	70.6
OpB_OpB	1.0	5.9	3.6	86.4	94.3	1.1	8.90	69.9
OpB_OpB	2.0	1.7	0.0	97.2	98.0	0.6	9.03	70.3
OpBV_OpBV	0.25	3.3	0.0	97.5	98.0	0.0	9.21	71.1
OpBV_OpBV	0.5	1.9	0.7	98.0	98.4	0.0	9.34	71.1
OpBV_OpBV	1.0	3.6	0.4	96.4	97.7	0.0	9.30	70.3
OpBV_OpBV	2.0	1.9	0.4	95.2	97.2	0.0	9.30	70.6
F prob.								
treat		<0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.634
treat.group		0.020	<0.001	0.003	0.104	0.181	0.315	0.636
treat.dose		0.435	0.0721	0.449	0.983	0.879	0.029	0.687
trt.grp.dose		0.577	0.021	0.140	0.493	0.786	0.191	0.703
Covariates		0	0	0	0	0	0	0
logit transformed		Y	Y	Y	Y	Y	N	N
SED								
treat vs untr.		0.317	0.456	0.403	0.365	0.477	0.230	0.614
treat.group	(max)	0.299	0.430	0.380	0.344	0.450	0.217	0.579
treat.dose	(max)	0.299	0.430	0.380	0.344	0.450	0.217	0.579
trt.grp.dose	(min)	0.598	0.861	0.761	0.689	0.900	0.433	1.158
RMS		0.537	1.111	0.868	0.712	1.214	0.281	2.01
d.f.		34	34	34	34	34	34	35

2004/05 Hampshire

Consort

Treatment and group	Opus Dose	Septoria % L3 GS69	Septoria % L2 GS69	GLA % L3 GS69	GLA % L2 GS69	Yield (t/ha)	SPW (kg/hl)
untreated		25.4	8.7	34.9	75.6	7.74	70.9
Ut_Op	0.25	27.4	6.0	43.4	81.5	9.70	71.8
Ut_Op	0.5	17.0	2.1	53.3	91.0	8.88	71.7
Ut_Op	1.0	8.2	2.5	74.7	89.1	9.19	72.3
Ut_Op	2.0	7.8	1.0	84.0	96.0	10.11	73.6
Op_Op	0.25	14.2	2.2	81.4	92.3	8.46	72.4
Op_Op	0.5	10.4	2.1	74.0	90.0	9.09	72.0
Op_Op	1.0	4.1	0.7	57.9	93.4	9.80	73.9
Op_Op	2.0	2.5	0.4	91.8	96.4	10.5	73.5
OpB_OpB	0.25	4.2	0.6	84.5	95.5	9.73	72.6
OpB_OpB	0.5	4.3	0.3	85.4	95.4	10.10	73.2
OpB_OpB	1.0	1.9	0.3	90.4	96.4	10.40	74.3
OpB_OpB	2.0	1.7	0.4	88.2	96.7	10.78	73.6
OpBV_OpBV	0.25	4.6	0.5	89.8	96.5	10.12	74.0
OpBV_OpBV	0.5	3.9	0.2	91.8	97.0	10.61	73.8
OpBV_OpBV	1.0	1.7	0.3	93.0	97.2	10.79	74.9
OpBV_OpBV	2.0	1.3	0.4	90.4	96.7	11.23	73.4
F prob.							
treat		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
treat.group		<0.001	<0.001	<0.001	<0.001	<0.001	0.013
treat.dose		<0.001	0.013	0.066	0.007	<0.001	0.068
trt.grp.dose		0.953	0.221	0.133	0.176	0.191	0.512
Covariates		1	1	1	1	0	0
logit transformed		Y	Y	Y	Y	N	N
SED							
treat vs untr.		0.248	0.219	0.334	0.192	0.237	0.475
treat.group	(max)	0.237	0.208	0.320	0.182	0.223	0.448
treat.dose	(max)	0.240	0.211	0.324	0.184	0.223	0.448
trt.grp.dose	(min)	0.476	0.416	0.642	0.364	0.446	0.895
RMS		0.313	0.240	0.571	0.184	0.299	1.202
d.f.		31	32	31	32	31	35

2004/05 Hampshire

Einstein

Treatment and group	Opus Dose	Septoria %		Yield (t/ha)	SPW (kg/hl)
		L3 GS69	L2 GS69		
untreated		42.6	8.1	9.32	71.8
Ut_Op	0.25	26.4	3.3	9.57	73.0
Ut_Op	0.5	18.7	1.3	9.81	73.0
Ut_Op	1.0	18.7	1.2	10.18	73.1
Ut_Op	2.0	7.6	0.8	10.79	73.1
Op_Op	0.25	14.5	2.9	9.72	72.3
Op_Op	0.5	13.2	1.6	10.45	73.0
Op_Op	1.0	2.9	0.8	10.57	73.0
Op_Op	2.0	0.8	0.4	10.89	73.0
OpB_OpB	0.25	3.9	0.8	10.47	73.0
OpB_OpB	0.5	2.1	0.4	11.01	73.0
OpB_OpB	1.0	2.1	0.5	11.25	73.2
OpB_OpB	2.0	1.0	0.2	11.27	73.0
OpBV_OpBV	0.25	3.6	0.1	11.13	73.5
OpBV_OpBV	0.5	2.5	1.1	11.27	73.4
OpBV_OpBV	1.0	0.9	0.2	11.09	73.2
OpBV_OpBV	2.0	0.8	0.3	11.03	73.6
F prob.					
treat		<0.001	<0.001	<0.001	<0.001
treat.group		<0.001	<0.001	<0.001	0.002
treat.dose		<0.001	0.003	<0.001	0.550
trt.grp.dose		0.005	0.079	0.028	0.516
Covariates		0	1	0	0
logit transformed		Y	Y	N	N
SED					
treat vs untr.		0.181	0.205	0.140	0.159
treat.group	(max)	0.171	0.198	0.132	0.150
treat.dose	(max)	0.171	0.195	0.132	0.150
trt.grp.dose	(min)	0.342	0.398	0.263	0.299
RMS		0.175	0.218	0.104	0.134
d.f.		35	32	35	35

2004/05 Hampshire

Robigus

Treatment and group	Opus Dose	Septoria % L3 GS69	Septoria % L2 GS69	GLA % L3 GS69	GLA % L2 GS69	Yield (t/ha)	SPW (kg/hl)
untreated		8.2	2.7	96.6	33.6	8.96	73.1
Ut_Op	0.25	5.9	0.4	97.7	44.1	9.58	73.1
Ut_Op	0.5	4.2	0.2	97.7	34.9	10.22	72.9
Ut_Op	1.0	4.7	0.4	97.7	36.5	10.29	73.3
Ut_Op	2.0	5.9	1.0	96.9	39.7	10.18	72.4
Op_Op	0.25	4.2	0.7	98.1	37.7	10.01	73.0
Op_Op	0.5	5.0	0.2	97.8	39.7	10.51	73.4
Op_Op	1.0	0.2	0.1	97.7	46.6	10.68	73.3
Op_Op	2.0	0.6	0.3	97.2	55.0	10.78	73.2
OpB_OpB	0.25	1.0	0.2	98.4	41.4	10.68	74.0
OpB_OpB	0.5	1.6	0.2	97.7	38.1	10.62	73.5
OpB_OpB	1.0	0.1	0.1	97.4	46.6	10.95	73.5
OpB_OpB	2.0	0.5	0.1	97.7	34.9	11.21	73.6
OpBV_OpBV	0.25	0.6	0.1	99.0	45.0	10.95	73.6
OpBV_OpBV	0.5	0.3	0.1	97.7	46.6	11.21	73.8
OpBV_OpBV	1.0	0.8	0.0	98.0	41.3	11.18	73.9
OpBV_OpBV	2.0	0.3	0.1	97.4	46.6	11.60	73.6
F prob.							
treat		<0.001	<0.001	0.028	0.019	n/a	n/a
treat.group		<0.001	0.020	0.539	0.187		
treat.dose		0.002	0.286	0.086	0.662		
trt.grp.dose		0.003	0.707	0.926	0.226		
Covariates		0	1	0	0	0	0
logit transformed		Y	Y	Y	Y	N	N
SED							
treat vs untr.		0.228	0.188	0.170	0.146	n/a	n/a
treat.group	(max)	0.214	0.182	0.160	0.138		
treat.dose	(max)	0.214	0.188	0.160	0.138		
trt.grp.dose	(min)	0.429	0.366	0.321	0.276		
RMS		0.276	0.184	0.154	0.114	0.108	0.267
d.f.		35	32	35	35	33	35

n/a = not available

2004/05 Herefordshire

Consort

Treatment and group	Opus Dose	Septoria % L3 GS71	Septoria % L2 GS71	GLA % L3 GS71	GLA % L2 GS71	Yield (t/ha)	SPW (kg/hl)
untreated		24.8	11.0	1.1	80.1	7.92	77.4
Ut_Op	0.25	21.5	8.2	13.0	85.9	8.47	77.5
Ut_Op	0.5	10.0	3.3	32.6	93.3	8.86	78.6
Ut_Op	1.0	13.6	4.9	9.7	91.7	8.85	79.3
Ut_Op	2.0	15.7	2.5	8.3	94.4	9.37	79.0
Op_Op	0.25	26.4	5.1	14.6	88.1	8.87	78.0
Op_Op	0.5	15.6	2.6	46.1	93.7	8.94	78.8
Op_Op	1.0	13.0	1.9	75.7	94.9	9.33	78.4
Op_Op	2.0	5.8	0.7	69.9	95.5	9.71	79.4
OpB_OpB	0.25	10.5	2.5	59.9	94.8	8.73	78.4
OpB_OpB	0.5	4.1	0.9	83.6	95.9	9.27	78.9
OpB_OpB	1.0	3.8	0.3	90.7	95.9	10.08	79.1
OpB_OpB	2.0	2.6	0.5	92.2	95.7	10.14	79.2
OpBV_OpBV	0.25	5.4	1.2	72.6	96.0	9.52	79.1
OpBV_OpBV	0.5	6.0	0.8	80.4	95.2	10.47	79.3
OpBV_OpBV	1.0	1.9	0.1	88.2	95.7	9.73	79.4
OpBV_OpBV	2.0	3.1	0.6	86.6	95.2	9.97	79.3
F prob.							
treat		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
treat.group		<0.001	<0.001	<0.001	<0.001	<0.001	0.005
treat.dose		<0.001	<0.001	0.101	0.009	0.006	<0.001
trt.grp.dose		0.202	0.312	0.607	0.173	0.409	0.105
Covariates		0	0	0	0	1	1
logit transformed		Y	Y	Y	Y	N	N
SED							
treat vs untr.		0.235	0.221	0.625	0.155	0.248	0.202
treat.group	(max)	0.222	0.208	0.589	0.146	0.232	0.191
treat.dose	(max)	0.222	0.208	0.589	0.146	0.238	0.191
trt.grp.dose	(min)	0.444	0.416	1.179	0.292	0.476	0.386
RMS		0.295	0.260	2.083	0.128	0.306	0.204
d.f.		29	35	35	35	30	32

2004/05 Herefordshire

Equinox

Treatment and group	Opus Dose	Septoria %		GLA %		Yield (t/ha)	SPW (kg/hl)
		L3 GS71	L2 GS71	L3 GS71	L2 GS71		
untreated		-	17.3	0	72.9	8.39	71.4
Ut_Op	0.25	12.0	10.6	1.5	84.5	9.51	72.7
Ut_Op	0.5	15.5	12.2	1.5	77.4	8.86	72.6
Ut_Op	1.0	17.7	5.4	1.5	90.7	9.53	73.3
Ut_Op	2.0	12.8	6.1	29.7	90.2	9.76	74.4
Op_Op	0.25	34.2	5.3	1.3	91.2	9.21	73.1
Op_Op	0.5	19.8	7.5	19.3	87.9	9.05	72.8
Op_Op	1.0	18.6	5.1	43.0	91.5	10.21	72.9
Op_Op	2.0	8.8	2.6	80.6	94.2	10.77	74.3
OpB_OpB	0.25	13.4	3.4	61.6	92.6	9.76	73.4
OpB_OpB	0.5	7.9	2.3	75.1	95.5	9.97	73.9
OpB_OpB	1.0	4.1	1.1	89.3	96.3	11.00	74.2
OpB_OpB	2.0	3.2	0.8	91.9	96.6	11.47	74.0
OpBV_OpBV	0.25	7.1	2.1	88.5	95.6	10.21	74.5
OpBV_OpBV	0.5	4.4	1.3	87.6	96.8	10.80	74.4
OpBV_OpBV	1.0	3.0	0.2	92.1	96.8	11.27	74.7
OpBV_OpBV	2.0	3.5	0.6	92.0	96.9	11.14	71.9
F prob.							
treat		-	<0.001	<0.001	<0.001	<0.001	<0.001
treat.group		<0.001	<0.001	<0.001	<0.001	<0.001	0.463
treat.dose		0.006	<0.001	<0.001	<0.001	<0.001	0.880
trt.grp.dose		0.264	0.332	0.032	0.092	0.072	0.090
Covariates		0	0	0	0	1	0
logit transformed		Y	Y	Y	Y	N	N
SED							
treat vs untr.		-	0.174	0.502	0.137	0.185	0.543
treat.group	(max)	0.232	0.164	0.473	0.129	0.171	0.512
treat.dose	(max)	0.232	0.164	0.473	0.129	0.164	0.512
trt.grp.dose	(min)	0.464	0.329	0.946	0.259	0.342	1.023
RMS		0.323	0.162	1.342	0.101	0.149	1.57
d.f.		21	34	34	34	15	32

2004/05 Herefordshire

Robigus

Treatment and group	Opus Dose	Septoria %		GLA %		Yield (t/ha)	SPW (kg/hl)
		L3 GS71	L2 GS71	L3 GS71	L2 GS71		
untreated		7.8	3.0	39.8	91.8	10.11	76.5
Ut_Op	0.25	17.4	3.7	34.5	92.7	10.14	77.4
Ut_Op	0.5	12.5	3.5	62.4	92.6	10.03	76.7
Ut_Op	1.0	12.5	4.0	62.8	90.0	10.53	77.4
Ut_Op	2.0	13.8	2.7	74.5	92.7	10.88	77.4
Op_Op	0.25	9.2	2.9	63.5	94.3	10.10	76.7
Op_Op	0.5	10.4	4.0	55.0	90.0	10.84	77.1
Op_Op	1.0	8.5	2.1	82.1	95.4	10.75	77.4
Op_Op	2.0	3.7	0.7	91.9	96.2	11.10	77.0
OpB_OpB	0.25	5.2	0.5	90.3	96.6	10.29	77.4
OpB_OpB	0.5	3.5	0.2	90.7	96.8	11.06	77.6
OpB_OpB	1.0	2.5	0.3	93.3	96.8	10.69	77.3
OpB_OpB	2.0	1.5	0.1	91.4	96.8	11.04	77.5
OpBV_OpBV	0.25	2.9	0.3	86.8	96.8	11.14	77.9
OpBV_OpBV	0.5	1.5	0.2	85.3	96.3	11.21	78.1
OpBV_OpBV	1.0	1.8	0.2	90.0	96.7	11.19	77.6
OpBV_OpBV	2.0	0.9	0.1	90.0	97.1	10.94	77.9
F prob.							
treat		0.058	0.001	<0.001	0.002	n/a	<0.001
treat.group		<0.001	<0.001	0.001	<0.001		0.012
treat.dose		0.006	0.114	0.147	0.286		0.966
trt.grp.dose		0.740	0.813	0.869	0.398		0.650
Covariates		0	0	0	0	0	0
logit transformed		Y	Y	Y	Y	N	N
SED							
treat vs untr.		0.224	0.248	0.512	0.159	n/a	0.258
treat.group	(max)	0.211	0.234	0.483	0.150		0.243
treat.dose	(max)	0.211	0.234	0.483	0.150		0.243
trt.grp.dose	(min)	0.422	0.468	0.966	0.301		0.486
RMS		0.268	0.329	0.140	0.136		0.355
d.f.		34	35	35	35		35

2004/05 Norfolk

Consort

Treatment and group	Opus Dose	Septoria % L2 GS75	Septoria % L1 GS75	GLA % L2 GS75	GLA % L1 GS75	Yield (t/ha)	SPW (kg/hl)
untreated		25.0	16.2	2.4	28.9	6.49	68.3
Ut_Op	0.25	25.0	11.9	5.5	58.4	7.59	70.2
Ut_Op	0.5	23.0	6.6	9.3	76.2	8.21	72.7
Ut_Op	1.0	18.2	4.9	18.0	78.7	9.03	73.9
Ut_Op	2.0	14.6	2.8	56.0	83.7	9.98	76.1
Op_Op	0.25	21.3	7.4	7.9	68.2	7.84	72.0
Op_Op	0.5	20.0	4.3	16.3	80.1	8.80	73.8
Op_Op	1.0	13.6	2.6	51.0	85.3	9.88	75.5
Op_Op	2.0	9.2	1.0	66.1	87.4	10.84	76.8
OpB_OpB	0.25	16.3	4.7	38.0	79.4	8.81	73.3
OpB_OpB	0.5	11.9	2.6	58.5	84.3	9.83	73.9
OpB_OpB	1.0	9.3	1.8	66.7	85.7	10.68	75.2
OpB_OpB	2.0	5.0	1.1	76.8	87.5	11.30	76.3
OpBV_OpBV	0.25	14.0	3.6	47.6	80.7	9.34	74.7
OpBV_OpBV	0.5	11.3	2.8	61.7	83.7	10.31	76.0
OpBV_OpBV	1.0	9.9	1.9	58.5	86.4	10.84	76.6
OpBV_OpBV	2.0	5.3	1.4	73.0	86.4	11.59	76.6
F prob.							
treat		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
treat.group		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
treat.dose		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
trt.grp.dose		0.142	0.096	<0.001	0.012	<0.001	0.062
Covariates		0	0	0	0	1	0
logit transformed		Y	Y	Y	Y	N	N
SED							
treat vs untr.		0.068	0.093	0.174	0.082	0.057	0.400
treat.group	(max)	0.065	0.087	0.164	0.078	0.055	0.377
treat.dose	(max)	0.065	0.087	0.164	0.078	0.055	0.377
trt.grp.dose	(min)	0.129	0.175	0.328	0.155	0.113	0.754
RMS		0.025	0.046	0.161	0.036	0.017	0.853
d.f.		35	35	35	35	32	35

2004/05 Norfolk

Einstein

Treatment and group	Opus Dose	Septoria %		GLA %		Yield (t/ha)	SPW (kg/hl)
		L2 GS75	L1 GS75	L2 GS75	L1 GS75		
untreated		24.5	11.2	11.4	51.7	9.46	72.6
Ut_Op	0.25	20.0	7.9	15.7	61.7	10.38	74.2
Ut_Op	0.5	11.9	4.7	58.7	74.5	10.96	75.9
Ut_Op	1.0	8.0	1.5	68.4	80.7	11.41	76.6
Ut_Op	2.0	4.7	0.4	75.5	83.7	11.73	77.1
Op_Op	0.25	15.3	6.2	45.0	60.0	10.65	75.2
Op_Op	0.5	6.0	1.7	70.0	81.5	11.58	76.4
Op_Op	1.0	2.9	0.9	80.7	83.7	12.04	77.1
Op_Op	2.0	2.6	0.4	83.8	84.3	12.31	77.5
OpB_OpB	0.25	5.0	1.9	74.5	78.4	11.99	76.7
OpB_OpB	0.5	2.7	0.6	83.3	84.4	12.02	77.2
OpB_OpB	1.0	2.6	0.6	82.2	84.3	12.51	77.4
OpB_OpB	2.0	1.0	0.4	88.7	85.3	12.58	77.1
OpBV_OpBV	0.25	4.3	1.2	77.7	82.1	12.11	77.3
OpBV_OpBV	0.5	3.6	0.8	82.5	84.1	12.27	77.6
OpBV_OpBV	1.0	2.0	0.2	88.0	85.4	12.73	77.6
OpBV_OpBV	2.0	1.9	0.1	87.4	85.4	12.69	77.7
F prob.							
treat		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
treat.group		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
treat.dose		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
trt.grp.dose		0.001	<0.001	<0.001	<0.001	<0.001	0.001
Covariates		0	0	0	0	1	0
logit transformed		Y	Y	Y	Y	N	N
SED							
treat vs untr.		0.094	0.124	0.105	0.063	0.064	0.211
treat.group	(max)	0.089	0.117	0.099	0.060	0.058	0.199
treat.dose	(max)	0.089	0.117	0.099	0.060	0.060	0.199
trt.grp.dose	(min)	0.178	0.234	0.198	0.119	0.116	0.398
RMS		0.047	0.082	0.059	0.021	0.018	0.237
d.f.		35	35	35	35	32	35

2004/05 Norfolk

Robigus

Treatment and group	Opus Dose	Septoria %		GLA %		Yield (t/ha)	SPW (kg/hl)
		L2 GS75	L1 GS75	L2 GS75	L1 GS75		
untreated		13.1	3.6	53.7	82.4	9.88	74.4
Ut_Op	0.25	8.9	2.4	65.4	85.8	10.68	76.1
Ut_Op	0.5	5.6	0.9	75.0	89.5	10.88	76.2
Ut_Op	1.0	5.1	0.6	75.5	89.4	11.29	76.8
Ut_Op	2.0	3.9	0.2	77.1	93.4	11.59	76.9
Op_Op	0.25	6.8	1.0	74.1	90.1	10.87	76.4
Op_Op	0.5	3.6	0.4	76.8	91.2	11.21	76.5
Op_Op	1.0	2.9	0.1	80.8	92.7	11.51	76.7
Op_Op	2.0	2.4	0.1	80.5	91.1	11.90	77.4
OpB_OpB	0.25	2.6	0.3	80.3	92.2	11.42	77.0
OpB_OpB	0.5	2.0	0.2	82.4	91.6	11.79	77.2
OpB_OpB	1.0	1.1	0.0	83.5	93.7	11.92	77.0
OpB_OpB	2.0	0.5	0.0	84.0	92.7	12.03	77.7
OpBV_OpBV	0.25	2.4	0.4	78.7	91.4	11.67	77.1
OpBV_OpBV	0.5	1.6	0.2	80.5	91.7	11.92	77.6
OpBV_OpBV	1.0	1.1	0.0	84.5	93.7	12.10	77.3
OpBV_OpBV	2.0	1.2	0.0	84.1	93.4	12.18	77.4
F prob.							
treat		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
treat.group		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
treat.dose		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
trt.grp.dose		0.404	0.020	0.562	0.046	0.125	0.424
Covariates		1	0	1	0	1	1
logit transformed		Y	Y	Y	Y	N	N
SED							
treat vs untr.		0.109	0.099	0.070	0.081	0.069	0.165
treat.group	(max)	0.098	0.093	0.063	0.076	0.062	0.148
treat.dose	(max)	0.100	0.093	0.064	0.076	0.063	0.150
trt.grp.dose	(min)	0.201	0.187	0.128	0.152	0.127	0.302
RMS		0.055	0.052	0.022	0.035	0.022	0.124
d.f.		32	35	32	35	32	31

2005/06 Borders

Consort

Treatment and group	Opus Dose	Septoria % L4 GS65	Septoria % L3 GS73	GLA % L4 GS65	GLA % L3 GS73	Yield (t/ha)	SPW (kg/hl)
untreated		14.2	40.6	80.8	42.9	9.66	75.1
Ut_Op	0.25	14.8	4.6	71.2	94.5	10.26	75.6
Ut_Op	0.5	16.3	5.4	81.4	93.6	9.96	75.3
Ut_Op	1.0	5.0	1.7	96.3	97.4	9.98	75.4
Ut_Op	2.0	3.7	7.4	95.2	91.8	10.39	75.3
Op_Op	0.25	2.4	1.5	97.4	98.0	10.04	75.6
Op_Op	0.5	6.6	10.9	91.4	88.2	9.52	75.2
Op_Op	1.0	1.0	7.9	99.0	89.7	10.46	75.4
Op_Op	2.0	0.2	2.4	99.6	97.4	10.45	74.8
OpB_OpB	0.25	0.0	2.2	100.0	97.4	10.09	75.2
OpB_OpB	0.5	0.4	1.9	99.6	97.4	10.48	75.8
OpB_OpB	1.0	0.4	0.8	99.6	99.1	10.56	75.7
OpB_OpB	2.0	0.0	1.7	100.0	98.0	10.55	75.4
OpBV_OpBV	0.25	0.0	1.1	100.0	98.9	10.16	75.5
OpBV_OpBV	0.5	0.0	1.4	100.0	98.0	10.50	75.3
OpBV_OpBV	1.0	0.0	0.8	99.6	99.1	10.06	75.0
OpBV_OpBV	2.0	0.2	0.6	99.6	99.4	10.24	75.6
F prob.							
treat		<0.001	<0.001	<0.001	<0.001	<0.001	n/a
treat.group		<0.001	0.192	<0.001	0.211	0.071	
treat.dose		0.009	0.836	0.023	0.832	0.082	
trt.grp.dose		0.073	0.953	0.020	0.979	0.012	
Covariates		0	0	0	0	0	
logit transformed		Y	Y	Y	Y	N	
SED							
treat vs untr.		0.306	0.731	0.351	0.796	0.129	
treat.group	(max)	0.288	0.689	0.331	0.751	0.121	
treat.dose	(max)	0.288	0.689	0.331	0.751	0.121	
trt.grp.dose	(min)	0.576	1.378	0.663	1.502	0.243	
RMS		0.498	2.848	0.658	3.383	0.088	
d.f.		35	34	35	34	35	

2005/06 Borders

Einstein

Treatment and group	Opus Dose	Septoria %		GLA %		Yield (t/ha)	SPW (kg/hl)
		L4 GS65	L3 GS73	L4 GS65	L3 GS73		
untreated		4.7	22.6	94.3	65.1	10.65	75.7
Ut_Op	0.25	3.3	6.3	96.4	89.7	10.79	75.3
Ut_Op	0.5	4.7	1.8	96.4	97.4	10.65	75.8
Ut_Op	1.0	2.8	5.9	97.2	93.7	11.05	75.7
Ut_Op	2.0	1.4	0.6	98.6	99.4	11.13	75.9
Op_Op	0.25	2.6	6.0	97.5	89.7	10.85	76.1
Op_Op	0.5	1.7	2.8	98.1	95.0	10.95	75.8
Op_Op	1.0	0.0	0.0	100.0	100.0	10.96	76.2
Op_Op	2.0	0.0	0.0	100.0	99.4	10.95	75.2
OpB_OpB	0.25	0.0	0.6	100.0	99.4	10.89	75.8
OpB_OpB	0.5	0.0	0.0	100.0	100.0	10.99	75.9
OpB_OpB	1.0	0.0	0.0	100.0	100.0	10.86	75.5
OpB_OpB	2.0	0.0	0.0	100.0	100.0	10.89	75.8
OpBV_OpBV	0.25	0.0	0.0	100.0	100.0	11.10	75.8
OpBV_OpBV	0.5	0.0	0.4	100.0	99.4	11.40	75.9
OpBV_OpBV	1.0	0.0	0.0	100.0	100.0	10.82	75.9
OpBV_OpBV	2.0	0.0	0.0	100.0	100.0	10.96	75.9
F prob.							
treat		<0.001	<0.001	<0.001	<0.001	0.020	n/a
treat.group		<0.001	<0.001	<0.001	<0.001	0.349	
treat.dose		0.061	0.001	0.086	0.003	0.915	
trt.grp.dose		0.218	0.018	0.326	0.033	0.138	
Covariates		0	0	0	0	1	
logit transformed		Y	Y	Y	Y	N	
SED							
treat vs untr.		0.303	0.333	0.333	0.396	0.114	
treat.group	(max)	0.286	0.314	0.314	0.374	0.106	
treat.dose	(max)	0.286	0.314	0.314	0.374	0.108	
trt.grp.dose	(min)	0.571	0.627	0.627	0.748	0.212	
RMS		0.489	0.591	0.590	0.838	0.062	
d.f.		35	35	35	35	32	

2005/06 Borders

Robigus

Treatment and group	Opus Dose	Septoria %		GLA %		Yield (t/ha)	SPW (kg/hl)
		L4 GS65	L3 GS73	L4 GS65	L3 GS73		
untreated		5.7	19.7	94.1	51.5	10.38	74.8
Ut_Op	0.25	4.7	6.6	95.4	90.6	10.86	75.6
Ut_Op	0.5	3.3	0.8	95.2	98.1	11.08	74.5
Ut_Op	1.0	1.3	9.8	98.7	88.2	10.82	75.0
Ut_Op	2.0	5.2	2.4	93.9	97.4	10.85	74.7
Op_Op	0.25	1.4	5.9	98.6	93.7	10.89	74.8
Op_Op	0.5	0.6	2.4	99.6	97.4	11.08	76.1
Op_Op	1.0	0.4	0.8	99.6	99.1	11.08	75.4
Op_Op	2.0	0.0	0.2	100.0	99.6	11.41	75.6
OpB_OpB	0.25	0.0	0.6	100.0	99.4	11.20	74.9
OpB_OpB	0.5	0.0	1.0	100.0	98.6	10.97	75.3
OpB_OpB	1.0	0.0	0.0	100.0	100.0	11.50	75.7
OpB_OpB	2.0	0.0	1.0	100.0	98.7	11.14	75.5
OpBV_OpBV	0.25	0.0	0.4	100.0	99.6	11.27	75.4
OpBV_OpBV	0.5	0.4	0.4	99.6	99.6	11.40	74.9
OpBV_OpBV	1.0	0.0	0.0	100.0	100.0	11.22	75.0
OpBV_OpBV	2.0	0.4	0.0	99.6	100.0	11.24	75.0
F prob.							
treat		<0.001	<0.001	<0.001	<0.001	<0.001	n/a
treat.group		<0.001	<0.001	<0.001	<0.001	0.004	
treat.dose		0.554	0.264	0.543	0.317	0.711	
trt.grp.dose		0.662	0.189	0.619	0.344	0.115	
Covariates		0	0	0	0	0	
logit transformed		Y	Y	Y	Y	N	
SED							
treat vs untr.		0.367	0.464	0.374	0.503	0.107	
treat.group	(max)	0.346	0.438	0.353	0.474	0.101	
treat.dose	(max)	0.346	0.438	0.353	0.474	0.101	
trt.grp.dose	(min)	0.691	0.876	0.706	0.948	0.202	
RMS		0.717	1.150	0.748	1.348	0.061	
d.f.		35	35	35	35	35	

2005/06 Hampshire

Consort

Treatment and group	Opus Dose	Septoria % L2 GS73	Septoria % L1 GS73	GLA % L2 GS73	GLA % L1 GS73	Yield (t/ha)	SPW (kg/hl)
untreated		64.3	44.5	6.4	28.2	7.50	66.3
Ut_Op	0.25	60.3	36.4	10.3	39.7	8.18	69.1
Ut_Op	0.5	46.6	14.2	34.6	73.6	8.53	68.6
Ut_Op	1.0	32.2	6.0	50.0	84.0	9.00	69.0
Ut_Op	2.0	23.0	0.3	66.8	95.0	9.61	71.8
Op_Op	0.25	56.7	35.9	18.6	46.6	8.12	66.6
Op_Op	0.5	29.3	7.8	53.4	87.3	9.07	68.6
Op_Op	1.0	34.9	1.3	46.6	92.0	9.74	70.9
Op_Op	2.0	16.6	0.5	67.2	92.6	10.42	71.9
OpB_OpB	0.25	26.4	7.1	60.3	85.5	9.16	69.9
OpB_OpB	0.5	20.1	1.6	69.1	89.7	9.64	70.3
OpB_OpB	1.0	13.2	0.4	77.0	95.0	10.16	71.1
OpB_OpB	2.0	8.0	0.0	80.0	95.0	10.38	72.5
OpBV_OpBV	0.25	27.0	6.5	57.0	87.3	9.57	70.9
OpBV_OpBV	0.5	27.6	5.9	62.0	87.3	9.83	70.2
OpBV_OpBV	1.0	6.4	0.0	83.1	95.0	10.30	71.1
OpBV_OpBV	2.0	6.4	0.0	80.3	96.3	10.69	72.0
F prob.							
treat		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
treat.group		<0.001	<0.001	<0.001	<0.001	<0.001	0.004
treat.dose		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
trt.grp.dose		0.069	0.026	0.003	<0.001	0.050	0.097
Covariates		0	1	0	0	1	1
logit transformed		Y	Y	Y	Y	N	N
SED							
treat vs untr.		0.178	0.242	0.172	0.151	0.121	0.519
treat.group	(max)	0.168	0.233	0.162	0.142	0.116	0.498
treat.dose	(max)	0.168	0.238	0.162	0.142	0.119	0.511
trt.grp.dose	(min)	0.336	0.469	0.324	0.284	0.234	1.005
RMS		0.169	0.303	0.158	0.121	0.076	1.394
d.f.		35	32	35	35	32	32

2005/06 Hampshire

Einstein

Treatment and group	Opus Dose	Septoria % L2 GS73	Septoria % L1 GS73	GLA % L2 GS73	GLA % L1 GS73	Yield (t/ha)	SPW (kg/hl)
untreated		35.2	5.2	7.1	50.0	8.97	72.8
Ut_Op	0.25	29.3	2.3	10.3	69.3	8.85	73.3
Ut_Op	0.5	14.2	0.8	24.1	67.6	9.35	74.2
Ut_Op	1.0	10.0	0.3	19.8	78.8	9.42	74.3
Ut_Op	2.0	4.1	0.3	27.0	82.3	9.86	74.9
Op_Op	0.25	19.7	1.8	19.7	62.7	9.20	73.6
Op_Op	0.5	16.9	0.6	27.6	75.3	9.42	74.3
Op_Op	1.0	11.2	0.6	31.6	77.0	9.61	75.1
Op_Op	2.0	3.6	0.1	64.0	89.3	10.17	75.4
OpB_OpB	0.25	7.1	0.3	29.3	75.3	9.81	74.6
OpB_OpB	0.5	7.1	0.3	31.6	78.4	9.60	74.5
OpB_OpB	1.0	5.4	0.3	42.7	76.3	9.50	75.8
OpB_OpB	2.0	2.3	0.1	50.4	79.3	9.97	75.4
OpBV_OpBV	0.25	12.8	0.3	19.2	77.3	9.67	74.6
OpBV_OpBV	0.5	4.2	0.1	46.6	78.4	10.65	75.0
OpBV_OpBV	1.0	3.6	0.1	61.2	78.0	10.11	74.9
OpBV_OpBV	2.0	2.1	0.3	53.9	82.4	10.62	75.5
F prob.							
treat		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
treat.group		<0.001	0.013	0.027	0.516	<0.001	<0.001
treat.dose		<0.001	0.007	0.008	0.003	<0.001	<0.001
trt.grp.dose		0.796	0.282	0.848	0.330	0.026	0.314
Covariates		0	0	0	1	0	1
logit transformed		Y	Y	Y	Y	N	N
SED							
treat vs untr.		0.289	0.216	0.408	0.194	0.123	0.232
treat.group	(max)	0.272	0.203	0.385	0.185	0.116	0.221
treat.dose	(max)	0.272	0.203	0.385	0.180	0.116	0.215
trt.grp.dose	(min)	0.545	0.407	0.770	0.367	0.231	0.438
RMS		0.445	0.248	0.888	0.183	0.080	0.262
d.f.		35	35	35	32	35	32

2005/06 Hampshire

Robigus

Treatment and group	Opus Dose	Septoria %		GLA %		Yield (t/ha)	SPW (kg/hl)
		L2 GS73	L1 GS73	L2 GS73	L1 GS73		
untreated		28.6	6.0	18.3	77.2	9.01	71.1
Ut_Op	0.25	14.2	2.3	26.4	84.0	9.22	71.4
Ut_Op	0.5	21.1	1.9	34.9	85.5	9.40	72.1
Ut_Op	1.0	11.2	1.5	37.4	93.7	9.78	73.0
Ut_Op	2.0	15.2	1.2	57.0	90.3	9.95	72.9
Op_Op	0.25	29.8	3.6	16.9	83.1	9.22	71.4
Op_Op	0.5	17.3	2.3	28.6	89.7	9.52	71.9
Op_Op	1.0	7.1	0.5	78.1	95.0	10.01	73.3
Op_Op	2.0	4.8	0.8	49.2	95.0	10.53	73.1
OpB_OpB	0.25	6.4	1.3	62.9	93.7	9.79	72.2
OpB_OpB	0.5	10.2	1.0	53.2	88.8	9.76	71.5
OpB_OpB	1.0	6.4	1.0	71.2	93.7	10.30	72.7
OpB_OpB	2.0	4.0	0.3	69.5	91.8	10.29	72.9
OpBV_OpBV	0.25	10.0	1.9	57.0	88.8	9.73	72.8
OpBV_OpBV	0.5	8.9	1.0	72.4	93.7	10.29	72.9
OpBV_OpBV	1.0	10.3	0.8	83.5	93.7	10.35	72.4
OpBV_OpBV	2.0	2.6	0.5	87.3	95.0	10.36	73.3
F prob.							
treat		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
treat.group		0.004	0.012	<0.001	0.141	<0.001	0.196
treat.dose		0.003	<0.001	<0.001	0.004	<0.001	<0.001
trt.grp.dose		0.162	0.269	0.250	0.305	0.102	0.137
Covariates		0	0	0	0	0	0
logit transformed		Y	Y	Y	Y	N	N
SED							
treat vs untr.		0.284	0.173	0.345	0.223	0.108	0.280
treat.group	(max)	0.268	0.163	0.325	0.210	0.102	0.264
treat.dose	(max)	0.268	0.163	0.325	0.210	0.102	0.264
trt.grp.dose	(min)	0.536	0.325	0.651	0.421	0.205	0.528
RMS		0.431	0.159	0.636	0.265	0.063	0.419
d.f.		35	35	30	35	35	35

2005/06 Herefordshire

Consort

Treatment and group	Opus Dose	Septoria % L2 GS73	Septoria % L1 GS73	GLA % L2 GS73	GLA % L1 GS73	Yield (t/ha)	SPW (kg/hl)
untreated		75.8	26.4	0.3	44.9	6.59	74.4
Ut_Op	0.25	52.8	9.6	19.5	77.8	6.94	74.9
Ut_Op	0.5	33.2	6.9	38.0	87.4	7.74	75.6
Ut_Op	1.0	23.8	4.0	53.4	88.6	8.42	76.8
Ut_Op	2.0	11.7	1.3	75.6	93.8	9.31	77.6
Op_Op	0.25	15.6	8.1	31.6	82.9	7.71	78.3
Op_Op	0.5	14.0	3.5	71.0	93.8	8.33	76.4
Op_Op	1.0	7.3	0.5	88.4	91.7	9.52	77.3
Op_Op	2.0	4.5	0.0	85.8	95.3	10.02	78.2
OpB_OpB	0.25	20.3	7.1	47.8	88.0	8.17	76.5
OpB_OpB	0.5	19.4	2.9	59.2	89.2	8.61	76.3
OpB_OpB	1.0	13.1	0.3	79.1	95.0	9.74	77.4
OpB_OpB	2.0	2.2	0.0	88.4	95.5	10.26	78.3
OpBV_OpBV	0.25	16.2	2.9	65.3	91.4	8.92	76.5
OpBV_OpBV	0.5	10.1	2.4	84.0	94.4	9.17	77.2
OpBV_OpBV	1.0	2.1	0.3	78.7	90.1	9.57	78.0
OpBV_OpBV	2.0	4.3	0.4	84.1	95.3	10.28	78.4
F prob.							
treat		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
treat.group		<0.001	<0.001	<0.001	0.074	<0.001	<0.001
treat.dose		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
trt.grp.dose		0.341	0.518	0.317	0.586	0.032	0.034
Covariates		0	0	0	0	0	0
logit transformed		Y	Y	Y	Y	N	N
SED							
treat vs untr.		0.307	0.295	0.327	0.247	0.123	0.305
treat.group	(max)	0.289	0.278	0.309	0.233	0.116	0.288
treat.dose	(max)	0.289	0.278	0.309	0.233	0.116	0.288
trt.grp.dose	(min)	0.578	0.555	0.617	0.465	0.232	0.575
RMS		0.501	0.463	0.572	0.324	0.081	0.496
d.f.		30	35	35	35	35	35

2005/06 Herefordshire

Einstein

Treatment and group	Opus Dose	Septoria % L2 GS73	Septoria % L1 GS73	GLA % L2 GS73	GLA % L1 GS73	Yield (t/ha)	SPW (kg/hl)
untreated		14.8	5.5	61.8	89.9	9.00	78.7
Ut_Op	0.25	4.6	2.7	80.9	93.5	9.49	79.9
Ut_Op	0.5	6.3	1.1	81.9	94.6	9.87	79.1
Ut_Op	1.0	6.7	2.1	80.1	92.2	10.17	79.9
Ut_Op	2.0	2.9	0.5	82.7	93.8	10.36	79.8
Op_Op	0.25	5.5	1.5	84.7	87.1	9.65	79.3
Op_Op	0.5	6.9	2.2	87.3	93.9	10.12	79.5
Op_Op	1.0	5.6	0.4	86.0	92.9	10.48	79.6
Op_Op	2.0	1.4	0.8	91.1	93.1	10.60	80.5
OpB_OpB	0.25	4.9	0.9	85.7	94.9	10.65	79.4
OpB_OpB	0.5	4.4	1.8	84.8	90.5	10.18	79.8
OpB_OpB	1.0	0.7	0.4	92.0	93.8	10.34	79.9
OpB_OpB	2.0	0.2	0.0	94.1	94.6	10.91	80.2
OpBV_OpBV	0.25	5.8	1.3	89.0	94.4	10.93	80.1
OpBV_OpBV	0.5	1.9	0.6	94.6	95.4	10.88	79.6
OpBV_OpBV	1.0	0.9	0.3	93.3	94.4	10.90	79.2
OpBV_OpBV	2.0	0.1	0.3	91.0	93.9	11.05	80.2
F prob.							
treat		<0.001	<0.001	<0.001	0.012	<0.001	<0.001
treat.group		<0.001	0.033	0.020	0.169	<0.001	0.926
treat.dose		<0.001	0.002	0.482	0.791	0.002	0.042
trt.grp.dose		0.019	0.298	0.865	0.216	0.148	0.292
Covariates		0	0	0	0	0	0
logit transformed		Y	Y	Y	Y	N	N
SED							
treat vs untr.		0.233	0.255	0.315	0.172	0.150	0.251
treat.group	(max)	0.220	0.240	0.297	0.162	0.142	0.236
treat.dose	(max)	0.220	0.240	0.297	0.162	0.142	0.236
trt.grp.dose	(min)	0.439	0.480	0.593	0.324	0.283	0.472
RMS		0.289	0.346	0.528	0.158	0.120	0.335
d.f.		35	35	35	35	35	34

2005/06 Herefordshire

Robigus

Treatment and group	Opus Dose	Septoria % L2 GS73	Septoria % L1 GS73	GLA % L2 GS73	GLA % L1 GS73	Yield (t/ha)	SPW (kg/hl)
untreated		10.7	2.9	66.3	91.7	8.19	76.2
Ut_Op	0.25	7.1	0.7	89.6	95.4	9.20	77.0
Ut_Op	0.5	4.9	0.4	91.5	96.2	9.20	77.5
Ut_Op	1.0	3.7	0.3	93.3	96.0	9.65	77.8
Ut_Op	2.0	3.1	0.2	94.3	96.7	9.92	77.1
Op_Op	0.25	3.4	0.6	90.1	96.8	9.57	77.7
Op_Op	0.5	3.5	0.3	94.0	96.1	9.70	77.5
Op_Op	1.0	1.2	0.0	96.2	96.4	9.33	77.8
Op_Op	2.0	0.5	0.0	96.5	96.8	10.22	78.0
OpB_OpB	0.25	4.0	1.7	91.9	95.9	9.54	77.6
OpB_OpB	0.5	1.8	0.0	95.2	96.6	9.54	77.7
OpB_OpB	1.0	0.7	0.0	96.5	96.7	9.64	78.1
OpB_OpB	2.0	0.4	0.0	96.3	96.8	10.61	78.8
OpBV_OpBV	0.25	2.5	0.4	94.5	95.7	9.73	77.9
OpBV_OpBV	0.5	1.7	0.0	95.3	96.4	10.28	78.3
OpBV_OpBV	1.0	0.7	0.0	96.5	96.8	10.61	78.2
OpBV_OpBV	2.0	0.0	0.0	96.3	96.5	10.48	78.6
F prob.							
treat		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
treat.group		<0.001	0.451	0.055	0.685	<0.001	0.015
treat.dose		<0.001	0.004	0.008	0.313	<0.001	0.201
trt.grp.dose		0.490	0.811	0.993	0.925	0.114	0.744
Covariates		0	0	0	0	0	0
logit transformed		Y	Y	Y	Y	N	N
SED							
treat vs untr.		0.196	0.264	0.224	0.108	0.150	0.289
treat.group	(max)	0.185	0.249	0.212	0.102	0.144	0.272
treat.dose	(max)	0.185	0.249	0.212	0.102	0.144	0.272
trt.grp.dose	(min)	0.370	0.497	0.423	0.203	0.288	0.545
RMS		0.206	0.371	0.268	0.062	0.125	0.445
d.f.		35	35	35	34	35	34

2005/06 Norfolk

Consort

Treatment and group	Opus Dose	Septoria %		GLA %		Yield (t/ha)	SPW (kg/hl)
		L3 GS69	L2 GS69	L3 GS69	L2 GS69		
untreated		13.1	10.5	12.0	81.9	8.11	70.5
Ut_Op	0.25	10.5	5.4	18.6	84.0	8.90	71.3
Ut_Op	0.5	12.9	3.5	42.2	88.7	9.00	71.7
Ut_Op	1.0	13.9	5.1	28.6	89.1	8.81	73.2
Ut_Op	2.0	10.7	3.3	66.7	88.7	9.49	73.5
Op_Op	0.25	11.9	3.6	47.9	90.3	8.81	71.7
Op_Op	0.5	10.5	2.6	77.6	92.2	9.04	72.4
Op_Op	1.0	6.9	1.2	74.6	91.5	9.33	73.3
Op_Op	2.0	1.5	0.2	91.5	97.4	9.64	73.5
OpB_OpB	0.25	7.4	2.9	73.6	88.5	9.05	72.2
OpB_OpB	0.5	4.7	2.1	81.0	92.0	9.25	72.7
OpB_OpB	1.0	2.9	0.4	88.0	95.8	9.55	73.2
OpB_OpB	2.0	1.3	0.2	87.1	96.4	9.52	73.0
OpBV_OpBV	0.25	5.6	4.4	78.9	90.8	8.93	72.2
OpBV_OpBV	0.5	4.7	1.6	81.2	94.5	9.70	73.4
OpBV_OpBV	1.0	4.2	0.8	85.7	95.8	9.88	74.2
OpBV_OpBV	2.0	2.1	0.3	84.6	96.4	9.54	73.7
F prob.							
treat		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
treat.group		<0.001	<0.001	<0.001	<0.001	0.005	0.252
treat.dose		<0.001	<0.001	<0.001	<0.001	<0.001	0.004
trt.grp.dose		<0.001	0.037	0.042	0.031	0.159	0.972
Covariates		0	0	0	0	1	0
logit transformed		Y	Y	Y	Y	N	N
SED							
treat vs untr.		0.135	0.192	0.232	0.131	0.136	0.506
treat.group	(max)	0.128	0.181	0.219	0.124	0.127	0.477
treat.dose	(max)	0.128	0.181	0.219	0.124	0.125	0.477
trt.grp.dose	(min)	0.255	0.362	0.438	0.248	0.256	0.955
RMS		0.098	0.196	0.288	0.092	0.090	1.367
d.f.		35	35	34	35	32	35

2005/06 Norfolk

Einstein

Treatment and group	Opus Dose	Septoria %		GLA %		Yield (t/ha)	SPW (kg/hl)
		L3 GS69	L2 GS69	L3 GS69	L2 GS69		
untreated		6.5	1.8	80.4	94.6	9.80	74.5
Ut_Op	0.25	5.9	1.7	83.0	95.1	9.85	75.0
Ut_Op	0.5	3.9	1.3	84.1	95.4	9.95	75.2
Ut_Op	1.0	2.8	0.4	88.0	96.4	10.23	75.5
Ut_Op	2.0	2.6	0.1	87.1	96.1	10.12	75.6
Op_Op	0.25	5.0	1.1	81.8	96.4	9.97	74.8
Op_Op	0.5	2.6	1,1	87.8	96.0	9.91	75.4
Op_Op	1.0	1.1	0.1	88.0	96.4	10.37	75.7
Op_Op	2.0	0.8	0.1	90.8	96.4	10.24	75.6
OpB_OpB	0.25	1.9	0.1	87.1	96.7	9.67	75.2
OpB_OpB	0.5	1.5	0.2	85.5	97.0	10.23	75.3
OpB_OpB	1.0	0.3	0.1	90.0	96.7	10.05	75.5
OpB_OpB	2.0	0.3	0.1	93.0	96.7	10.24	75.9
OpBV_OpBV	0.25	1.9	0.1	87.5	97.1	9.89	75.6
OpBV_OpBV	0.5	1.1	0.3	88.5	97.0	10.12	75.4
OpBV_OpBV	1.0	0.6	0.1	89.4	97.4	10.62	75.8
OpBV_OpBV	2.0	0.4	0.0	90.1	96.7	10.35	75.6
F prob.							
treat		<0.001	<0.001	<0.001	<0.001	0.003	<0.001
treat.group		<0.001	<0.001	0.040	0.003	0.220	0.289
treat.dose		<0.001	<0.001	<0.001	0.666	<0.001	0.007
trt.grp.dose		0.854	0.004	0.528	0.867	0.116	0.689
Covariates		0	0	0	0	1	1
logit transformed		Y	Y	Y	Y	N	N
SED							
treat vs untr.		0.188	0.118	0.124	0.091	0.101	0.167
treat.group	(max)	0.177	0.111	0.117	0.086	0.094	0.154
treat.dose	(max)	0.177	0.111	0.117	0.086	0.102	0.166
trt.grp.dose	(min)	0.354	0.222	0.234	0.172	0.196	0.320
RMS		0.188	0.074	0.082	0.044	0.052	0.139
d.f.		35	35	35	35	32	32

2005/06 Norfolk

Robigus

Treatment and group	Opus Dose	Septoria % L3 GS69	Septoria % L2 GS69	GLA % L3 GS69	GLA % L2 GS69	Yield (t/ha)	SPW (kg/hl)
untreated		9.3	3.4	28.3	86.9	8.57	70.7
Ut_Op	0.25	5.7	2.3	63.2	93.3	9.63	73.5
Ut_Op	0.5	6.6	3.0	54.1	94.4	9.71	72.9
Ut_Op	1.0	5.4	3.3	47.2	94.7	9.63	73.1
Ut_Op	2.0	4.6	1.3	74.6	94.7	9.98	74.0
Op_Op	0.25	6.0	2.3	53.0	95.2	9.98	73.6
Op_Op	0.5	2.6	0.5	59.1	95.4	9.71	72.6
Op_Op	1.0	2.7	0.5	65.9	96.0	9.83	73.2
Op_Op	2.0	1.9	0.7	78.0	95.9	9.67	73.6
OpB_OpB	0.25	1.1	0.5	66.2	95.2	9.84	73.2
OpB_OpB	0.5	2.7	0.3	75.9	96.0	10.18	74.2
OpB_OpB	1.0	1.2	0.3	73.8	96.1	10.34	74.2
OpB_OpB	2.0	2.4	0.1	86.2	95.7	9.73	73.0
OpBV_OpBV	0.25	1.9	0.6	77.7	95.8	9.78	73.0
OpBV_OpBV	0.5	2.2	0.3	61.9	95.1	9.78	73.2
OpBV_OpBV	1.0	1.1	0.3	70.3	95.8	9.84	73.5
OpBV_OpBV	2.0	0.8	0.2	88.2	96.4	9.94	74.2
F prob.							
treat		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
treat.group		<0.001	<0.001	<0.001	0.011	0.334	0.744
treat.dose		<0.001	0.011	<0.001	0.242	0.926	0.541
trt.grp.dose		0.007	0.245	0.469	0.967	0.597	0.322
Covariates		1	0	1	1	0	0
logit transformed		Y	Y	Y	Y	N	N
SED							
treat vs untr.		0.128	0.173	0.224	0.108	0.169	0.380
treat.group	(max)	0.112	0.163	0.197	0.094	0.159	0.359
treat.dose	(max)	0.116	0.163	0.204	0.098	0.159	0.359
trt.grp.dose	(min)	0.226	0.327	0.397	0.191	0.318	0.717
RMS		0.069	0.160	0.213	0.049	0.152	0.772
d.f.		31	34	31	31	34	34

2006/07 Borders

Consort

Treatment and group	Opus Dose	Septoria %		GLA %		Yield (t/ha)	SPW (kg/hl)
		L3 GS65	L1 GS73	L3 GS65	L1 GS73		
untreated		41.7	39.2	36.7	31.7	5.88	64.9
Ut_Op	0.25	13.0	20.0	76.7	75.0	7.39	67.9
Ut_Op	0.5	21.0	24.0	73.3	71.7	7.54	65.9
Ut_Op	1.0	14.0	16.3	81.7	70.0	8.00	66.0
Ut_Op	2.0	15.3	8.3	83.3	88.3	8.18	67.7
Op_Op	0.25	19.3	19.7	76.7	76.7	7.30	66.7
Op_Op	0.5	13.3	9.3	83.3	88.3	7.92	69.5
Op_Op	1.0	3.3	6.0	93.3	93.3	8.48	68.4
Op_Op	2.0	0.7	1.3	100.0	98.7	8.78	67.5
OpB_OpB	0.25	18.3	21.7	78.3	56.7	7.70	67.4
OpB_OpB	0.5	8.7	12.7	90.0	86.7	7.84	67.2
OpB_OpB	1.0	0	1.0	100.0	98.3	8.64	70.1
OpB_OpB	2.0	0	1.0	100.0	98.7	8.79	67.9
OpBV_OpBV	0.25	8.3	16.0	90.0	81.7	7.88	67.4
OpBV_OpBV	0.5	6.3	9.3	91.7	88.3	8.38	68.0
OpBV_OpBV	1.0	2.7	10.7	96.7	86.7	8.46	69.2
OpBV_OpBV	2.0	0	0.7	100.0	99.0	8.76	67.1
F prob.							
treat		0	0	0	0	0	0.009
treat.group		0.007	0.005	0.004	0.036	0.001	0.53
treat.dose		0.003	0	0.003	0	0	0.71
trt.grp.dose		0.42	0.33	0.89	0.16	0.51	0.66
SED							
treat vs untr.	(max)	1.133	0.895	1.498	1.700	0.047	0.238
treat.group	(max)	2.266	1.789	2.997	3.400	0.095	0.477
treat.dose	(max)	2.266	1.789	2.997	3.400	0.095	0.477
trt.grp.dose	(min)	4.532	3.579	5.993	6.799	0.189	0.954
RMS		61.62	38.43	107.8	138.7	0.107	5.273
d.f.		35	35	35	35	34	35

2006/07 Borders

Einstein

Treatment and group	Opus Dose	Septoria % L3 GS65	Septoria % L1 GS73	GLA % L3 GS65	GLA % L1 GS73	Yield (t/ha)	SPW (kg/hl)
untreated		27.5	32.0	61.7	59.2	7.48	72.4
Ut_Op	0.25	14.7	15.0	83.3	83.3	7.77	72.8
Ut_Op	0.5	11.7	0.0	85.0	100	8.46	73.5
Ut_Op	1.0	8.3	1.3	88.3	98.7	7.65	73.3
Ut_Op	2.0	5.0	1.7	93.3	98.3	7.88	72.0
Op_Op	0.25	4.0	5.0	96.0	95.0	8.41	73.1
Op_Op	0.5	11.7	5.0	85.0	93.3	8.26	73.0
Op_Op	1.0	1.3	0.0	96.7	100	8.69	73.0
Op_Op	2.0	0.0	0.3	100	99.3	8.50	73.0
OpB_OpB	0.25	2.0	1.3	96.7	98.0	8.24	72.7
OpB_OpB	0.5	3.3	1.3	95.0	98.7	8.77	73.6
OpB_OpB	1.0	3.0	0.7	95.0	99.3	8.25	73.5
OpB_OpB	2.0	0.7	0.0	98.3	100	8.41	72.6
OpBV_OpBV	0.25	4.3	0.0	95.0	100	8.16	73.3
OpBV_OpBV	0.5	2.7	1.7	96.7	98.3	8.49	72.8
OpBV_OpBV	1.0	0.0	0.0	100	100	8.80	73.5
OpBV_OpBV	2.0	0.0	0.0	100	100	9.17	72.4
F prob.							
treat		0	0	0	0	0.001	0.16
treat.group		0.001	0.28	0.007	0.51	0.019	0.96
treat.dose		0.016	0.13	0.091	0.33	0.37	0.11
trt.grp.dose		0.52	0.32	0.82	0.67	0.44	0.85
SED							
treat vs untr.	(max)	0.687	0.806	1.047	1.164	0.078	0.129
treat.group	(max)	1.374	1.612	2.094	2.329	0.156	0.257
treat.dose	(max)	1.374	1.612	2.094	2.329	0.156	0.257
trt.grp.dose	(min)	2.749	3.223	4.188	4.657	0.313	0.514
RMS		22.67	31.17	52.63	65.06	0.294	0.794
d.f.		35	35	35	35	35	35

2006/07 Borders

Robigus

Treatment and group	Opus Dose	Septoria % L1 GS73	Y Rust % L2 GS65	Y Rust % L1 GS65	GLA % L1 GS73	Yield (t/ha)	SPW (kg/hl)
untreated		25.8	49.2	33.3	10.8	4.05	60.2
Ut_Op	0.25	15.7	6.3	4.0	70.0	7.54	66.5
Ut_Op	0.5	11.7	6.7	3.0	76.7	8.05	67.6
Ut_Op	1.0	10.3	4.3	3.0	83.3	8.13	69.0
Ut_Op	2.0	3.0	4.0	2.0	96.0	8.47	69.1
Op_Op	0.25	6.0	2.0	1.0	83.3	8.17	67.5
Op_Op	0.5	3.7	1.0	0.7	92.7	8.59	66.6
Op_Op	1.0	4.0	0.7	0.7	95.0	8.80	66.5
Op_Op	2.0	1.0	0.0	0.0	98.0	8.98	66.5
OpB_OpB	0.25	9.3	6.0	8.3	75.0	7.91	66.5
OpB_OpB	0.5	2.3	1.3	0.4	97.0	8.68	68.2
OpB_OpB	1.0	4.7	1.7	0.0	92.7	8.62	66.1
OpB_OpB	2.0	1.3	0.0	0.0	97.0	8.82	67.7
OpBV_OpBV	0.25	3.3	2.0	1.0	94.3	8.89	66.4
OpBV_OpBV	0.5	2.0	1.0	0.1	92.7	8.87	66.1
OpBV_OpBV	1.0	2.3	0.0	0.0	98.3	8.94	67.9
OpBV_OpBV	2.0	0.0	0.0	0.0	98.3	8.92	67.0
F prob.							
treat		0	0	0	0	0	0
treat.group		0	0.035	0.31	0	0	0.39
treat.dose		0.004	0.3	0.25	0	0	0.74
trt.grp.dose		0.79	0.99	0.77	0.02	0.22	0.67
SED							
treat vs untr.	(max)	0.635	0.594	0.583	0.827	0.041	0.285
treat.group	(max)	1.27	1.188	1.167	1.654	0.082	0.570
treat.dose	(max)	1.27	1.188	1.167	1.654	0.082	0.570
trt.grp.dose	(min)	2.541	2.375	2.334	3.309	0.164	1.140
RMS		19.37	16.92	16.34	32.84	0.081	3.900
d.f.		35	35	35	35	35	35

2006/07 Hampshire

Consort

Treatment and group	Opus Dose	Septoria %		GLA %		Yield (t/ha)	SPW (kg/hl)
		L2 GS77	L1 GS77	L2 GS77	L1 GS77		
untreated		-	-	0.0	0.0	4.81	67.7
Ut_Op	0.25	-	-	0.0	0.0	5.20	69.2
Ut_Op	0.5	-	46.7	0.0	6.7	5.97	70.2
Ut_Op	1.0	27.5	22.5	11.7	40.0	6.04	72.0
Ut_Op	2.0	19.3	6.0	48.3	80.0	7.04	72.7
Op_Op	0.25	-	-	0.0	0.0	5.08	68.3
Op_Op	0.5	40.0	28.3	1.7	36.7	6.10	71.0
Op_Op	1.0	31.7	12.3	33.3	66.7	7.22	72.2
Op_Op	2.0	18.3	8.3	56.7	75.0	8.31	73.2
OpB_OpB	0.25	-	53.3	0.0	6.7	6.38	70.5
OpB_OpB	0.5	36.7	16.7	18.3	50.0	5.84	71.1
OpB_OpB	1.0	35.0	9.7	31.7	71.7	7.73	73.4
OpB_OpB	2.0	15.0	4.3	61.7	83.3	7.32	72.4
OpBV_OpBV	0.25	40.0	26.7	10.0	35.0	7.20	72.7
OpBV_OpBV	0.5	31.7	14.3	31.7	55.0	7.91	73.2
OpBV_OpBV	1.0	20.0	6.0	58.3	76.7	8.37	74.2
OpBV_OpBV	2.0	16.7	5.0	65.0	78.3	8.48	74.2
F prob.							
treat		n/a	n/a	<0.001	<0.001	<0.001	<0.001
treat.group				<0.001	<0.001	<0.001	<0.001
treat.dose				<0.001	<0.001	<0.001	<0.001
trt.grp.dose				0.18	<0.001	0.18	0.64
SED							
treat vs untr.				1.574	1.606	0.109	0.204
treat.group	(max)			3.147	3.212	0.218	0.408
treat.dose	(max)			3.147	3.212	0.218	0.408
trt.grp.dose	(min)			6.295	6.423	0.435	0.816
RMS				118.9	123.8	0.568	1.999
d.f.				35	35	35	35

2006/07 Hampshire

Einstein

Treatment and group	Opus Dose	Sept % L1 GS77	Brown Rust % L2 GS77	Brown Rust % L1 GS77	GLA % L1 GS77	Yield (t/ha)	SPW (kg/hl)
untreated		18.3	38.3	21.3	15.8	5.82	73.2
Ut_Op	0.25	7.3	21.7	11.0	61.7	6.36	73.6
Ut_Op	0.5	3.7	23.3	5.7	78.3	6.36	73.7
Ut_Op	1.0	0.7	3.3	0.7	90.0	6.33	74.3
Ut_Op	2.0	0.3	2.2	0.5	96.0	6.34	75.2
Op_Op	0.25	5.3	13.3	5.3	76.7	5.99	73.3
Op_Op	0.5	6.3	9.3	5.3	85.0	6.27	73.1
Op_Op	1.0	0.7	2.3	1.1	91.7	6.64	73.3
Op_Op	2.0	0.3	0.6	<0.1	97.0	6.86	73.5
OpB_OpB	0.25	1.7	16.7	4.3	88.3	6.32	73.9
OpB_OpB	0.5	2.0	16.7	4.0	86.7	6.86	74.3
OpB_OpB	1.0	1.3	5.3	2.7	92.7	6.56	74.4
OpB_OpB	2.0	0.0	0.7	0.2	98.0	6.66	73.4
OpBV_OpBV	0.25	1.0	7.7	4.7	90.7	6.96	73.1
OpBV_OpBV	0.5	0.7	3.0	0.7	91.7	6.74	74.1
OpBV_OpBV	1.0	1.0	1.0	0.5	93.3	6.78	72.9
OpBV_OpBV	2.0	0.3	1.2	0.3	97.0	6.68	73.3
F prob.							
treat		<0.001	<0.001	<0.001	<0.001	<0.001	0.25
treat.group		0.57	<0.001	0.59	<0.001	0.12	0.058
treat.dose		0.27	<0.001	<0.001	<0.001	0.68	0.77
trt.grp.dose		0.95	<0.001	0.93	<0.001	0.61	0.46
SED							
treat vs untr.	(max)	0.740	0.715	0.742	0.932	0.067	0.136
treat.group	(max)	1.479	1.430	1.485	1.864	0.135	0.271
treat.dose	(max)	1.479	1.430	1.485	1.864	0.135	0.271
trt.grp.dose	(min)	2.959	2.860	2.97	3.729	0.269	0.542
RMS		26.27	24.54	26.46	41.71	0.217	0.882
d.f.		35	32	35	35	35	35

2006/07 Hampshire

Robigus

Treatment and group	Opus Dose	Septoria %		GLA %		Yield (t/ha)	SPW (kg/hl)
		L2 GS77	L1 GS77	L2 GS77	L1 GS77		
untreated		-	59.4	0.0	4.2	6.93	72.5
Ut_Op	0.25	60.0	60.6	3.3	3.3	7.19	73.4
Ut_Op	0.5	40.0	40.0	6.7	23.3	7.72	73.5
Ut_Op	1.0	25.0	16.7	41.7	63.3	8.07	74.2
Ut_Op	2.0	11.7	5.0	70.0	85.0	8.34	73.9
Op_Op	0.25	40.0	51.7	6.7	15.0	7.27	73.7
Op_Op	0.5	55.5	31.7	13.3	38.3	7.96	74.3
Op_Op	1.0	23.3	10.0	51.7	80.0	8.62	74.8
Op_Op	2.0	8.3	4.3	78.3	90.0	8.22	73.8
OpB_OpB	0.25	43.3	30.0	16.7	31.7	7.84	74.1
OpB_OpB	0.5	23.3	13.3	56.7	70.0	7.56	73.7
OpB_OpB	1.0	11.7	7.3	71.7	85.0	8.13	74.0
OpB_OpB	2.0	6.7	4.3	81.7	90.0	8.50	74.6
OpBV_OpBV	0.25	25.0	23.3	50.0	60.0	8.44	74.4
OpBV_OpBV	0.5	18.3	10.0	58.3	75.0	8.52	74.4
OpBV_OpBV	1.0	6.7	5.7	83.3	86.7	8.17	74.4
OpBV_OpBV	2.0	9.3	6.7	81.7	86.7	8.68	73.5
F prob.							
treat		n/a	<0.001	<0.001	<0.001	<0.001	0.001
treat.group			<0.001	<0.001	<0.001	<0.001	0.71
treat.dose			<0.001	<0.001	<0.001	<0.001	0.64
trt.grp.dose			<0.001	<0.001	<0.001	<0.001	0.82
SED							
treat vs untr.	(max)		0.944	1.116	0.987	0.054	0.143
treat.group	(max)		1.888	2.231	1.974	0.108	0.285
treat.dose	(max)		1.888	2.231	1.974	0.108	0.285
trt.grp.dose	(min)		3.776	4.462	3.948	0.216	0.571
RMS			42.77	59.74	46.76	0.141	0.978
d.f.			30	35	35	35	35

2006/07 Herefordshire

Consort

Treatment and group	Opus Dose	Septoria % L2 GS71	Septoria % L1 GS71	GLA % L2 GS71	GLA % L1 GS71	Yield (t/ha)	SPW (kg/hl)
untreated		19.0	22.0	28.3	44.2	4.94	72.7
Ut_Op	0.25	20.0	12.7	20.0	65.0	5.02	71.5
Ut_Op	0.5	15.7	4.0	43.3	85.0	5.54	73.3
Ut_Op	1.0	18.3	9.3	30.0	76.7	6.00	74.1
Ut_Op	2.0	11.7	3.0	68.3	87.3	6.62	75.4
Op_Op	0.25	17.5	12.7	40.0	66.7	5.54	72.8
Op_Op	0.5	15.0	14.0	36.7	63.3	6.03	73.8
Op_Op	1.0	5.3	2.0	83.3	91.7	6.90	76.0
Op_Op	2.0	3.0	0.7	88.3	96.0	8.53	77.9
OpB_OpB	0.25	15.0	6.7	50.0	78.3	6.22	74.8
OpB_OpB	0.5	7.7	2.0	78.3	90.7	7.33	77.6
OpB_OpB	1.0	1.3	1.2	76.7	93.3	7.64	77.9
OpB_OpB	2.0	0.7	0.3	94.0	95.7	7.84	77.6
OpBV_OpBV	0.25	5.3	5.7	76.7	85.7	7.34	77.3
OpBV_OpBV	0.5	2.7	1.3	85.0	93.3	7.73	77.4
OpBV_OpBV	1.0	1.3	1.2	94.3	95.0	8.48	78.2
OpBV_OpBV	2.0	3.0	1.3	90.0	94.3	8.68	78.1
F prob.							
treat		<0.001	0	<0.001	<0.001	<0.001	<0.001
treat.group		<0.001	0.032	<0.001	<0.001	<0.001	<0.001
treat.dose		<0.001	0.005	<0.001	<0.001	<0.001	<0.001
trt.grp.dose		0.23	0.31	<0.001	0.19	<0.001	<0.001
SED							
treat vs untr.	(max)	0.732	0.769	2.034	1.578	0.058	0.162
treat.group	(max)	1.464	1.539	4.068	3.156	0.116	0.324
treat.dose	(max)	1.464	1.539	4.068	3.156	0.116	0.324
trt.grp.dose	(min)	2.928	3.078	8.135	6.312	0.233	0.649
RMS		25.71	28.42	198.5	119.5	0.163	1.262
d.f.		29	35	29	35	35	35

2006/07 Herefordshire

Einstein

Treatment and group	Opus Dose	Sept % L2 GS71	B Rust % L1 GS71	GLA % L2 GS71	GLA % L1 GS71	Yield (t/ha)	SPW (kg/hl)
untreated		17.2	6.8	39.2	70.0	7.82	74.0
Ut_Op	0.25	16.0	2.8	62.5	80.0	8.45	73.9
Ut_Op	0.5	16.0	3.0	58.3	73.3	8.75	74.9
Ut_Op	1.0	5.3	0.8	59.3	90.0	9.02	75.2
Ut_Op	2.0	4.3	0.2	83.3	96.0	9.59	76.0
Op_Op	0.25	9.2	4.0	71.7	84.7	8.55	73.9
Op_Op	0.5	8.3	2.0	80.0	83.3	8.66	75.5
Op_Op	1.0	3.0	0.5	85.0	96.0	9.56	76.5
Op_Op	2.0	0.5	0.2	94.0	98.3	9.91	76.6
OpB_OpB	0.25	1.7	0.7	90.0	90.0	9.41	74.3
OpB_OpB	0.5	2.2	0.0	86.7	92.7	9.66	75.7
OpB_OpB	1.0	0.8	0.0	94.0	96.0	9.85	77.1
OpB_OpB	2.0	0.2	0.0	95.0	96.0	9.70	76.6
OpBV_OpBV	0.25	0.7	0.0	95.7	97.0	9.48	77.2
OpBV_OpBV	0.5	0.8	0.2	91.7	94.3	10.16	77.0
OpBV_OpBV	1.0	0.5	0.0	95.7	97.3	10.22	77.6
OpBV_OpBV	2.0	1.8	0.2	81.7	96.0	9.51	76.9
F prob.							
treat		0	0	0	0	<0.001	0.002
treat.group		0	0.29	0.001	0.043	<0.001	0.003
treat.dose		0.03	0.37	0.49	0.029	<0.001	0.008
trt.grp.dose		0.41	0.96	0.60	0.73	<0.001	0.72
SED							
treat vs untr.	(max)	0.759	0.396	2.322	1.409	0.061	0.194
treat.group	(max)	1.517	0.791	4.644	2.818	0.122	0.387
treat.dose	(max)	1.517	0.791	4.644	2.818	0.122	0.387
trt.grp.dose	(min)	3.034	1.582	9.289	5.636	0.243	0.774
RMS		27.62	7.511	258.9	95.30	0.178	1.799
d.f.		33	35	33	35	35	35

2006/07 Herefordshire

Robigus

Treatment and group	Opus Dose	Sept % L2 GS71	B Rust % L1 GS71	GLA % L2 GS71	GLA % L1 GS71	Yield (t/ha)	SPW (kg/hl)
untreated		20.0	12.2	36.7	55.8	6.68	73.9
Ut_Op	0.25	15.0	2.3	53.3	71.7	6.81	73.1
Ut_Op	0.5	10.0	2.7	56.7	86.7	7.46	75.1
Ut_Op	1.0	6.3	1.0	78.3	93.3	8.16	76.0
Ut_Op	2.0	3.3	0.0	86.7	97.3	8.64	76.5
Op_Op	0.25	14.0	3.3	60.0	81.7	7.32	76.1
Op_Op	0.5	5.3	1.2	82.7	91.0	8.06	75.9
Op_Op	1.0	0.7	0.2	96.0	98.3	8.80	75.1
Op_Op	2.0	0.7	0.5	96.0	97.0	8.14	77.7
OpB_OpB	0.25	1.7	2.0	91.7	94.0	8.22	75.9
OpB_OpB	0.5	1.3	0.0	94.3	98.0	8.73	77.7
OpB_OpB	1.0	0.3	0.0	98.0	98.3	9.12	77.2
OpB_OpB	2.0	0.3	0.0	96.0	96.3	9.69	77.4
OpBV_OpBV	0.25	5.2	5.0	77.7	92.7	9.37	77.6
OpBV_OpBV	0.5	0.2	0.0	96.3	96.0	9.00	77.6
OpBV_OpBV	1.0	0.5	0.0	94.3	94.3	9.35	77.6
OpBV_OpBV	2.0	0.0	0.0	96.0	99.0	9.65	77.4
F prob.							
treat		<0.001	0	<0.001	0	<0.001	0
treat.group		<0.001	0.86	<0.001	0.039	<0.001	0
treat.dose		<0.001	0.07	<0.001	0.004	<0.001	0.016
trt.grp.dose		0.28	0.96	0.36	0.42	0.19	0.11
SED							
treat vs untr.	(max)	0.592	0.437	1.908	1.199	0.08	0.162
treat.group	(max)	1.183	0.873	3.817	2.398	0.160	0.324
treat.dose	(max)	1.183	0.873	3.817	2.398	0.160	0.324
trt.grp.dose	(min)	2.366	1.747	7.634	4.796	0.320	0.649
RMS		16.80	9.155	174.8	69.01	0.307	1.263
d.f.		35	35	35	35	34	35

2006/07 Norfolk

Consort

Treatment and group	Opus Dose	Sept % L2 GS73	B Rust % L2 GS73	GLA % L2 GS73	GLA % L1 GS73	Yield (t/ha)	SPW (kg/hl)
untreated		26.7	20.0	15.0	50.0	5.34	65.8
Ut_Op	0.25	20.0	15.0	33.3	68.3	5.71	66.5
Ut_Op	0.5	16.7	6.7	51.7	80.0	5.97	67.4
Ut_Op	1.0	13.3	2.8	63.3	81.7	6.84	69.8
Ut_Op	2.0	5.7	0.7	76.7	88.3	7.66	72.2
Op_Op	0.25	16.7	11.7	45.0	80.0	6.27	66.2
Op_Op	0.5	10.0	2.1	71.7	86.7	6.93	68.7
Op_Op	1.0	5.1	1.1	78.3	88.3	7.47	71.0
Op_Op	2.0	0.3	0.3	86.7	91.7	8.34	73.0
OpB_OpB	0.25	15.0	8.0	58.3	81.7	6.71	67.6
OpB_OpB	0.5	4.0	1.7	78.3	88.3	7.30	69.8
OpB_OpB	1.0	2.3	0.2	83.3	90.0	7.92	71.5
OpB_OpB	2.0	0.2	<0.1	86.7	91.7	8.41	73.0
OpBV_OpBV	0.25	4.7	0.4	78.3	86.7	7.36	69.3
OpBV_OpBV	0.5	1.7	0.4	85.0	91.7	7.66	70.7
OpBV_OpBV	1.0	0.6	0.0	88.3	93.3	8.17	71.9
OpBV_OpBV	2.0	0.2	<0.1	90.0	93.3	8.52	72.6
F prob.							
treat		<0.001	0	<0.001	0	<0.001	<0.001
treat.group		<0.001	0.001	<0.001	0.01	<0.001	<0.001
treat.dose		<0.001	0	<0.001	0.007	<0.001	<0.001
trt.grp.dose		<0.001	0.085	<0.001	0.98	<0.001	<0.001
SED							
treat vs untr.	(max)	0.457	0.500	1.126	1.175	0.034	0.115
treat.group	(max)	0.915	0.999	2.252	2.351	0.069	0.229
treat.dose	(max)	0.915	0.999	2.252	2.351	0.069	0.229
trt.grp.dose	(min)	1.830	1.998	4.505	4.702	0.137	0.458
RMS		10.05	11.98	60.87	66.32	0.056	0.630
d.f.		35	35	35	35	35	35

2006/07 Norfolk

Einstein

Treatment and group	Opus Dose	Sept % L2 GS73	B Rust % L2 GS73	GLA % L2 GS73	GLA % L1 GS73	Yield (t/ha)	SPW (kg/hl)
untreated		14.2	8.7	45.8	76.7	7.27	75.6
Ut_Op	0.25	9.7	6.0	58.3	78.3	7.73	75.5
Ut_Op	0.5	9.0	2.1	61.7	80.0	8.07	76.7
Ut_Op	1.0	3.3	0.6	75.0	81.7	8.23	77.0
Ut_Op	2.0	3.0	0.2	81.7	85.0	8.72	76.7
Op_Op	0.25	3.7	0.8	76.7	85.0	8.43	76.0
Op_Op	0.5	0.4	0.1	85.0	83.3	8.53	75.9
Op_Op	1.0	0.1	0.2	83.3	85.0	8.72	76.1
Op_Op	2.0	0.0	0.0	86.7	85.0	8.93	75.6
OpB_OpB	0.25	2.0	1.7	78.3	83.3	8.37	77.0
OpB_OpB	0.5	1.2	0.4	81.7	83.3	8.65	76.8
OpB_OpB	1.0	0.1	<0.1	86.7	85.0	9.03	76.6
OpB_OpB	2.0	0.1	0.3	83.3	86.7	8.99	75.9
OpBV_OpBV	0.25	0.2	<0.1	85.0	85.0	9.28	76.9
OpBV_OpBV	0.5	<0.1	0.0	85.0	85.0	8.90	77.0
OpBV_OpBV	1.0	0.0	<0.1	85.0	83.3	9.28	76.9
OpBV_OpBV	2.0	0.0	0.0	88.3	85.0	9.05	76.2
F prob.							
treat		<0.001	0	<0.001	<0.001	<0.001	0.004
treat.group		<0.001	0.002	<0.001	<0.001	<0.001	0.008
treat.dose		<0.001	0.003	<0.001	<0.001	<0.001	0.13
trt.grp.dose		0.14	0.039	<0.001	0.14	0.31	0.15
SED							
treat vs untr.	(max)	0.314	0.197	0.798	0.287	0.05	0.09
treat.group	(max)	0.627	0.395	1.596	0.573	0.101	0.181
treat.dose	(max)	0.627	0.395	1.596	0.573	0.101	0.181
trt.grp.dose	(min)	1.254	0.789	3.192	1.146	0.201	0.361
RMS		4.718	1.869	30.57	3.942	0.122	0.392
d.f.		35	35	35	35	35	35

2006/07 Norfolk

Robigus

Treatment and group	Opus Dose	Sept % L2 GS73	B Rust % L2 GS73	GLA % L2 GS73	GLA % L1 GS73	Yield (t/ha)	SPW (kg/hl)
untreated		26.3	22.5	22.5	45.0	5.81	67.8
Ut_Op	0.25	28.3	20.0	23.3	45.0	6.16	69.0
Ut_Op	0.5	25.0	15.0	28.3	63.3	5.97	69.3
Ut_Op	1.0	15.0	5.7	58.3	78.3	7.06	71.4
Ut_Op	2.0	8.0	0.8	70.0	81.7	7.82	72.8
Op_Op	0.25	14.0	14.0	50.0	76.7	6.74	69.4
Op_Op	0.5	6.0	5.7	61.7	78.3	7.26	69.8
Op_Op	1.0	1.3	1.0	80.0	85.0	8.08	72.2
Op_Op	2.0	0.4	0.1	87.7	91.7	8.49	73.3
OpB_OpB	0.25	23.3	20.0	30.0	63.3	6.79	68.7
OpB_OpB	0.5	11.7	8.3	60.0	80.0	7.34	70.4
OpB_OpB	1.0	0.6	0.6	81.7	88.7	8.67	72.8
OpB_OpB	2.0	0.0	0.0	88.3	92.7	9.08	73.2
OpBV_OpBV	0.25	1.2	0.2	80.0	87.7	8.35	72.6
OpBV_OpBV	0.5	0.6	<0.1	83.3	86.7	8.56	72.9
OpBV_OpBV	1.0	<0.1	<0.1	87.7	90.0	8.98	73.4
OpBV_OpBV	2.0	0.0	0.0	90.0	92.5	9.10	73.6
F prob.							
treat		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
treat.group		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
treat.dose		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
trt.grp.dose		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
SED							
treat vs untr.	(max)	0.713	0.402	0.838	0.773	0.043	0.103
treat.group	(max)	1.425	0.804	1.676	1.546	0.086	0.207
treat.dose	(max)	1.425	0.804	1.676	1.546	0.086	0.207
trt.grp.dose	(min)	2.850	1.609	3.351	3.092	0.173	0.414
RMS		24.37	7.765	33.69	28.68	0.089	0.514
d.f.		34	34	34	34	34	34

Appendix B. Pre-spray disease assessments (untreated)

Leaf numbers shown at T1 are either actual or eventual, as indicated. Leaf numbers shown at T2 are eventual. Newest leaf emerging at time of assessment is shown.

2004/05 Borders

T1 (GS32) (Assessment missing or not done)

Variety	**Date**	**GS**	**% Septoria tritici**			**% Green Leaf Area**				
			Leaf	Leaf	Leaf	Leaf	Leaf	Leaf		
Consort	missing									
Einstein	missing									
Robigus	missing									

Emerging Leaf =

T2 (GS39)

Variety	**Date**	**GS**	**% Septoria tritici**			**% Green Leaf Area**				
(Eventual leaf number)			Leaf 5	Leaf 4	Leaf 3	Leaf 5	Leaf 4	Leaf 3		
Consort	07/06/05	38-47	-	15.8	4.5	-	71.9	89.4		
Einstein	07/06/05	39-49	-	11.8	-	-	74.2	-		
Robigus	07/06/05	39-45	-	5.6	-	-	83.7	-		

Emerged Leaf = Flag Leaf

2004/05 Hampshire

T1 (GS32)

Variety	**Date**	**GS**	**% Septoria tritici**			**% Green Leaf Area**				
(Eventual leaf number)			Leaf 6	Leaf 5	Leaf 4	Leaf 6	Leaf 5	Leaf 4		
Consort	19/04/05	31-32	8.0	6.0	4.0	-	-	-		
Einstein	19/04/05	31-32	5.0	4.0	2.0	-	-	-		
Robigus	19/04/05	31-32	2.0	-	-	-	-	-		

Emerging Leaf = Leaf 3

T2 (GS39)

Variety	**Date**	**GS**	**% Septoria tritici**			**% Green Leaf Area**				
(Eventual leaf number)			Leaf 5	Leaf 4	Leaf 3	Leaf 5	Leaf 4	Leaf 3		
Consort	16/05/06	37-39	57.9	10.1	-	42.1	89.9	-		
Einstein	16/05/06	37-39	37.1	2.5	-	59.8	97.5	-		
Robigus	17/05/06	37-39	34.7	2.0	-	65.3	98.0	-		

Emerged Leaf = Flag Leaf

2004/05 Herefordshire

T1 (GS32)

Variety	**Date**	**GS**	**% Septoria tritici**			**% Green Leaf Area**			**% Mildew**	
(Eventual leaf number)			Leaf 6	Leaf 5	Leaf 4	Leaf 6	Leaf 5	Leaf 4	Leaf 6	Leaf 5
Consort	30/04/05	31-32	56.7	20.2	0.2	9.2	74.8	98.4	5.0	6.4
Equinox	30/04/05	31-32	43.8	16.2	0.2	13.8	79.2	99.8	27.1	2.8
Robigus	30/04/05	31-32	41.9	10.8	0.4	41.2	88.4	99.6	2.8	0.4

Emerging Leaf = Leaf 4

T2 (GS39)

Variety	**Date**	**GS**	**% Septoria tritici**			**% Green Leaf Area**				
(Eventual leaf number)			Leaf 4	Leaf 3	Leaf 2	Leaf 4	Leaf 3	Leaf 2		
Consort	01/06/05	39-59	12.8	10.4	2.2	2.1	83.9	95.2		
Equinox	01/06/05	39-59	13.2	18.1	4.9	2.5	63.7	90.8		
Robigus	01/06/05	39-59	10.7	4.3	1.1	43.3	93.0	97.3		

Emerged Leaf = Flag Leaf

2004/05 Norfolk

T1 (GS32)

Variety	**Date**	**GS**	**% Septoria tritici**			**% Green Leaf Area**				
(Eventual leaf number)			Leaf 6	Leaf 5	Leaf 4	Leaf 6	Leaf 5	Leaf 4		
Consort	21/04/05	32	-	20.0	0.1	-	55.5	-		
Einstein	21/04/05	32	15.0	0.1	0.0	-	-	-		
Robigus	21/04/05	32	25.0	1.5	0.1	-	-	-		

Emerging Leaf = Leaf 3

T2 (GS39)

Variety	**Date**	**GS**	**% Septoria tritici**			**% Green Leaf Area**				
(Eventual leaf number)			Leaf 5	Leaf 4	Leaf 3	Leaf 5	Leaf 4	Leaf 3		
Consort	25/05/05	39-41	50.0	19.6	4.7	2.7	50.1	89.7		
Einstein	24/05/05	41-43	39.9	14.5	-	17.1	66.4	-		
Robigus	23/05/05	37-41	26.6	7.8	-	30.8	79.6	-		

Emerged Leaf = Flag Leaf

2005/06 Borders

T1 (GS32)

Variety	**Date**	**GS**	**% Septoria tritici**			**% Green Leaf Area**				
(Actual leaf number)			Leaf 3	Leaf 2	Leaf 1	Leaf 3	Leaf 2	Leaf 1		
Consort	04/05/06	31	50.1	3.1	0	-	-	-		
Einstein	04/05/06	31	38.1	1.6	0	-	-	-		
Robigus	04/05/06	31	19.5	0.02	0	-	-	-		

Emerging Leaf = Leaf 4

T2 (GS39)

Variety	**Date**	**GS**	**% Septoria tritici**			**% Green Leaf Area**				
(Eventual leaf number)			Leaf 6	Leaf 5	Leaf 4	Leaf 6	Leaf 5	Leaf 4		
Consort	07/06/06	49-53	-	15.3	-	-	60.3	-		
Einstein	07/06/06	49-53	14.8	-	-	54.6	-	-		
Robigus	07/06/06	49-53	3.7	-	-	87.9	-	-		

Emerged Leaf = Flag Leaf

2005/06 Hampshire

T1 (GS32)

Variety	**Date**	**GS**	**% Septoria tritici**			**% Green Leaf Area**				
(Eventual leaf number)			Leaf 6	Leaf 5	Leaf 4	Leaf 6	Leaf 5	Leaf 4		
Consort	26/04/06	31-32	-	5	4	-	-	-		
Einstein	26/04/06	31-32	25	8	-	65	85	-		
Robigus	26/04/06	31-32	20	5	-	60	90	-		

Emerging Leaf = Leaf 3

T2 (GS39)

Variety	**Date**	**GS**	**% Septoria tritici**			**% Green Leaf Area**				
(Eventual leaf number)			Leaf 5	Leaf 4	Leaf 3	Leaf 5	Leaf 4	Leaf 3		
Consort	26/05/06	39-45	59.8	7.7	0.3	7.5	85.7	98.7		
Einstein	26/05/06	39-45	36.4	3.5	-	26.2	95.0	-		
Robigus	26/05/06	39-45	26.2	3.4	-	27.8	94.4	-		

Emerged Leaf = Flag Leaf

2005/06 Herefordshire

T1 (GS32)

Variety	**Date**	**GS**	**% Septoria tritici**			**% Green Leaf Area**				
(Actual leaf number)			Leaf 4	Leaf 3	Leaf 2	Leaf 4	Leaf 3	Leaf 2		
Consort	23/04/06	31-32	30	18.6	-	25	54.4	-		
Einstein	23/04/06	31-32	25	8.5	-	36.7	72.4	-		
Robigus	23/04/06	31	11	4.1	-	63.3	85.5	-		

Emerging Leaf = Leaf 3

T2 (GS39)

Variety	**Date**	**GS**	**% Septoria tritici**			**% Green Leaf Area**				
(Eventual leaf number)			Leaf 5	Leaf 4	Leaf 3	Leaf 5	Leaf 4	Leaf 3		
Consort	24/05/06	39-41	-	6.0	-	-	83.8	-		
Einstein	24/05/06	39-41	-	3.0	-	-	94.1	-		
Robigus	24/05/06	39-41	-	1.2	-	-	96.7	-		

Emerged Leaf = Flag Leaf

2005/06 Norfolk

T1 (GS32)

Variety	**Date**	**GS**	**% Septoria tritici**			**% Green Leaf Area**				
(Eventual leaf number)			Leaf 6	Leaf 5	Leaf 4	Leaf 6	Leaf 5	Leaf 4		
Consort	05/05/06	32	8	3	3	75	90	97		
Einstein	26/04/06	32	3	0.5	1	85	98	99		
Robigus	26/04/06	32	2	0.1	0.01	90	99	99		

Emerging Leaf = Leaf 3 (20% Consort, 25% Einstein, 25% Robigus)

T2 (GS39)

Variety	**Date**	**GS**	**% Septoria tritici**			**% Green Leaf Area**				
(Eventual leaf number)			Leaf 5	Leaf 4	Leaf 3	Leaf 5	Leaf 4	Leaf 3		
Consort	30/05/06	39-43	-	2.9	0.2	-	90.5	97.3		
Einstein	25/05/06	39-43	-	5.8	-	-	86.0	-		
Robigus	26/05/06	39-43	-	2.0	-	-	93.5	-		

Emerged Leaf = Flag Leaf

2006/07 Borders

T1 (GS32)

Variety	**Date**	**GS**	**% Septoria tritici**			**% Green Leaf Area**				
(Eventual leaf number)			Leaf 7	Leaf 6	Leaf 5	Leaf 7	Leaf 6	Leaf 5		
Consort	06/04/07		100	20	-	-	-	-		
Einstein	06/04/07		60	15	-	-	-	-		
Robigus	06/04/07		12	2	-	-	-	-		

Emerging Leaf = Leaf 3/4

T2 (GS39)

Variety	**Date**	**GS**	**% Septoria tritici**			**% Green Leaf Area**			**% Y Rust**	
(Eventual leaf number)			Leaf 5	Leaf 4	Leaf 3	Leaf 5	Leaf 4	Leaf 3	Leaf 3	Leaf 2
Consort	14/05/07	37-39	27.0	2.8	-	41.7	96.7	-	-	-
Einstein	14/05/07	39	25.0	1.5	-	44.2	98.5	-	-	-
Robigus	14/05/07	37-39	19.2	-	-	33.3	80.8	87.5	8.3	1.2

Emerging Leaf = Flag Leaf

2006/07 Hampshire

T1 (GS32)

Variety	**Date**	**GS**	**% Septoria tritici**			**% Green Leaf Area**				
(Eventual leaf number)			Leaf 6	Leaf 5	Leaf 4	Leaf 6	Leaf 5	Leaf 4		
Consort	25/04/07	32-33	-	7.0	-	-	-	-		
Einstein	25/04/07	32-33	-	7.0	-	-	-	-		
Robigus	25/04/07	32-33	-		-	-	-	-		

Emerging Leaf = Leaf 3

T2 (GS39)

Variety	**Date**	**GS**	**% Septoria tritici**			**% Green Leaf Area**			**% Y Rust**	
(Eventual leaf number)			Leaf 5	Leaf 4	Leaf 3	Leaf 5	Leaf 4	Leaf 3	Leaf 5	Leaf 4
Consort	17/05/07	45-51	2.3	-	-	95.3	-	97.5	-	-
Einstein	17/05/07	45-51	3.0	0.2	-	51.7	89.7	97.5	-	-
Robigus	17/05/07	45-51	5.0	1.3	-	85.8	95.5	99.7	2.8	0.8

Emerged Leaf = Flag Leaf

2006/07 Herefordshire

T1 (GS32)

Variety	**Date**	**GS**	**% Septoria tritici**			**% Green Leaf Area**				
(Actual leaf number)			Leaf 5	Leaf 4	Leaf 3	Leaf 5	Leaf 4	Leaf 3		
Consort	30/04/07	31-33	-	31.6	9.1	-	16.6	78.7		
Einstein	30/04/07	31-33	-	11.8	2.6	-	45.7	94.8		
Robigus	30/04/07	31-33	-	5.0	0.4	-	81.6	98.9		

Emerging Leaf = Leaf 3

T2 (GS39)

Variety	**Date**	**GS**	**% Septoria tritici**			**% Green Leaf Area**				
(Eventual leaf number)			Leaf 4	Leaf 3	Leaf 2	Leaf 4	Leaf 3	Leaf 2		
Consort	28/05/07	49-52	9.2	3.7	1.9	92.3	92.3	95.5		
Einstein	28/05/07	49-52	14.7	2.9	0.9	68.3	93.3	97.5		
Robigus	28/05/07	49-52	9.7	1.8	0.1	80.2	96.3	99.0		

Emerged Leaf = Flag Leaf

2006/07 Norfolk

T1 (GS32)

Variety	**Date**	**GS**	**% Septoria tritici**			**% Green Leaf Area**			**% B Rust**
(Eventual leaf number)			Leaf 6	Leaf 5	Leaf 4	Leaf 6	Leaf 5	Leaf 4	Leaf 5
Consort	20/04/07	32	75	3	0.1	20	96	97	0
Einstein	20/04/07	32	60	8	0.1	8	80	98	0
Robigus	20/04/07	32	15	2	0.1	40	97	99	0.5

Emerging Leaf = Leaf 3

T2 (GS39)

Variety	**Date**	**GS**	**% Septoria tritici**			**% Green Leaf Area**			**% B/Y Rust**	
(Eventual leaf number)			Leaf 4	Leaf 3	Leaf 2	Leaf 4	Leaf 3	Leaf 2	Leaf 4	Leaf 3
Consort	21/05/07	49-51	2.0	0.1	-	92.5	97.8	-	0.9	0.2
Einstein	21/05/07	55	1.3	0.1	-	96.0	98.8	-	0.1	-
Robigus	21/05/07	49-53	6.2	0.6	-	59.2	81.5	87.5	2.4	2.8

Emerged Leaf = Flag Leaf   Rusts: Consort/Einstein = Brown, Robigus = Yellow

Appendix C. Fungicide Spray Application Dates and Growth Stages

2004/05 Borders

	Date Applied		Growth Stage		Leaf Emerging (%)	
	T1	**T2**	**T1**	**T2**	**T1**	**T2**
Consort	02/05/05	30/05/05	32	39	-	flag
Einstein	02/05/05	30/05/05	32	39	-	flag
Robigus	02/05/05	30/05/05	32	39	-	flag

2004/05 Hampshire

	Date Applied		Growth Stage		Leaf Emerging (%)	
	T1	**T2**	**T1**	**T2**	**T1**	**T2**
Consort	20/04/05	18/05/05	32	39	3	flag
Einstein	20/04/05	18/05/05	32	39	3	flag
Robigus	20/04/05	18/05/05	31-32	39	3	flag

2004/05 Herefordshire

	Date Applied		Growth Stage		Leaf Emerging (%)	
	T1	**T2**	**T1**	**T2**	**T1**	**T2**
Consort	01/05/05	27/05/05	31-32	41-45	4	flag
Equinox	01/05/05	27/05/05	31-32	41-45	4	flag
Robigus	01/05/05	27/05/05	31-32	41-45	4	flag

2004/05 Morley

	Date Applied		Growth Stage		Leaf Emerging (%)	
	T1	**T2**	**T1**	**T2**	**T1**	**T2**
Consort	21/04/05	26/05/05	32	47-49	-	flag
Einstein	21/04/05	26/05/05	32	47-49	-	flag
Robigus	25/04/05	27/05/05	32	39-45	-	flag

2005/06 Borders

	Date Applied		Growth Stage		Leaf Emerging (%)	
	T1	**T2**	**T1**	**T2**	**T1**	**T2**
Consort	09/05/06	03/06/06	32	39	-	flag
Einstein	09/05/06	03/06/06	32	39	-	flag
Robigus	09/05/06	03/06/06	32	39	-	flag

2005/06 Hampshire

	Date Applied		Growth Stage		Leaf Emerging (%)	
	T1	**T2**	**T1**	**T2**	**T1**	**T2**
Consort	02/05/06	23/05/06	32	39	3	flag
Einstein	02/05/06	23/05/06	32	39	3	flag
Robigus	28/04/06	23/05/06	32	39	3	flag

2005/06 Herefordshire

	Date Applied		Growth Stage		Leaf Emerging (%)	
	T1	**T2**	**T1**	**T2**	**T1**	**T2**
Consort	27/04/06	25/05/06	31-32	39-41	-	flag
Einstein	27/04/06	25/05/06	31-32	39-41	-	flag
Robigus	27/04/06	24/05/06	31-32	39-41	-	flag

2005/06 Morley

	Date Applied		Growth Stage		Leaf Emerging (%)	
	T1	**T2**	**T1**	**T2**	**T1**	**T2**
Consort	05/05/06	28/05/06	32	39-43	3 (20)	flag (100)
Einstein	26/04/06	25/05/06	32	39	3 (30)	flag (100)
Robigus	26/04/06	25/05/06	32	39-43	3 (30)	flag (100)

2006/07 Borders

	Date Applied		Growth Stage		Leaf Emerging (%)	
	T1	**T2**	**T1**	**T2**	**T1**	**T2**
Consort	12/04/07	14/05/07	32	39	-	flag
Einstein	05/04/07	14/05/07	32	39	-	flag
Robigus	12/04/07	14/05/07	32	39	-	flag

2006/07 Hampshire

	Date Applied		Growth Stage		Leaf Emerging (%)	
	T1	**T2**	**T1**	**T2**	**T1**	**T2**
Consort	26/04/07	16/05/07	32-33	45	3	flag
Einstein	26/04/07	16/05/07	32-33	45	3	flag
Robigus	26/04/07	16/05/07	32-33	45	3	flag

2005/06 Herefordshire

	Date Applied		Growth Stage		Leaf Emerging (%)	
	T1	**T2**	**T1**	**T2**	**T1**	**T2**
Consort	30/04/07	22/05/07	32	52	-	flag (100)
Einstein	30/04/07	22/05/07	32	52	-	flag (100)
Robigus	30/04/07	22/05/07	32	52	-	flag (100)

2006/07 Morley

	Date Applied		Growth Stage		Leaf Emerging (%)	
	T1	**T2**	**T1**	**T2**	**T1**	**T2**
Consort	20/04/07	16/05/07	31-32	43	3	flag (100)
Einstein	20/04/07	16/05/07	32-33	51	3	flag (100)
Robigus	20/04/07	18/05/07	32	43-45	3	flag (100)

Appendix D. Key Site Details and Spring Inputs

Borders

2004/05

Location	Whitsome, Borders
Soil Type	Clay Loam
Soil Series	Whitsome
Previous Crop	2004 Winter Wheat, 2003 Winter Oilseed Rape
Sowing Date	07 October 2004
See Rate	350 seeds/m2
Harvest Date	23 August 2005
Plot Size	10 m x 2 m
Total Nitrogen Applied	210 kg N/ha (50 on 09/03, 80 on 07/04, 80 on 25/04)
Plant Growth Regulators	2.5 l/ha 5C Cycocel on 21/04 (GS31) 0.5 l/ha Terpal on 31/05 (GS37)
Spring Herbicides	Monitor 25 g/ha on 21/04 (GS31)
Trace Elements	Manganese 1.5 l/ha on 21/04 and 12/05

2005/06

Location	Whitsome, Borders
Soil Type	Clay Loam
Soil Series	Whitsome
Previous Crop	2005 Spring Beans, 2004 W Wheat, 2003 W Oilseed Rape
Sowing Date	06 October 2005
See Rate	400 seeds/m2
Harvest Date	23 August 2006
Plot Size	10 m x 2 m
Total Nitrogen Applied	180 kg N/ha (90 on 06/04, 90 on 28/04)
Plant Growth Regulators	2.5 l/ha 5C Cycocel on 27/04 0.5 l/ha Terpal on 03/06
Trace Elements	Manganese 1.5 l/ha on 27/04

2006/07

Location	Swinton Hill, Borders
Soil Type	Clay Loam
Soil Series	Whitsome
Previous Crop	2006 Spring Beans, 2005 W Wheat, 2004 W Oilseed Rape
Sowing Date	28 September 2006
See Rate	360 seeds/m2
Harvest Date	27 August 2007
Plot Size	10 m x 2 m
Total Nitrogen Applied	180 kg N/ha (70 on 13/03, 110 on 12/04)
Plant Growth Regulators	5C Cycocel 2.5 l/ha on 05/04 Terpal 0.75 l/ha on 26/04
Spring Herbicides	Grasp 1.0 l/ha on 15/05

Hampshire

2004/05

Location	Lower Norton Farm, Sutton Scotney, Hampshire
Soil Type	shallow silty clay loam over chalk
Soil Series	Andover 1 series
Previous Crop	2004 NR Set-aside, 2003 S Barley, 2002 W Wheat
Sowing Date	01 October 2004
Seed Rate	350 seeds/m2
Harvest Date	16 August 2005
Plot Size	10 m x 2 m
Total Nitrogen Applied	225 kg N/ha (50 on 07/03, 175 on 19/04)
Plant Growth Regulators	Chlormequat 2.4 l/ha on 11/04
Insecticide	Dursban WDG 0.6 kg/ha on 02/06

2005/06

Location	Lower Norton Farm, Sutton Scotney, Hampshire
Soil Type	shallow silty clay loam over chalk
Soil Series	Andover 1 series
Previous Crop	2005 W Oilseed Rape, 2004 W Wheat
Sowing Date	11 October 2005
Seed Rate	350 seeds/m2
Harvest Date	11 August 2006
Plot Size	10 m x 2 m
Total Nitrogen Applied	195 kg N/ha (50 on 17/03, 145 on 26/04)
Plant Growth Regulators	5C Cycocel 1.75 l/ha on 24/04, 0.75 l/ha on 10/05)
Spring Herbicides	Ally Max 30 g/ha + HBN 1.0 l/ha on 15/03
Insecticide	Dursban WDG 0.6 kg/ha on 01/06

2006/07

Location	Lower Norton Farm, Sutton Scotney, Hampshire
Soil Type	shallow silty clay loam over chalk
Soil Series	Andover 1 series
Previous Crop	2006 NR set-aside, 2005 W Wheat
Sowing Date	15 October 2006
Seed Rate	350 seeds/m2
Harvest Date	03 August 2007
Plot Size	10 m x 2 m
Total Nitrogen Applied	175 kg N/ha (50 on 19/03, 125 on 18/04)
Plant Growth Regulators	5C Quintacel (chlormequat) 1.75 l/ha on 26/03
Spring Herbicides	Atlantis WG 0.4 kg/ha on 08/03

Herefordshire

2004/05

Location	ADAS Rosemaund, Herefordshire
Soil Type	Silty clay loam
Soil Series	Bromyard
Previous Crop	2004 Spring OSR, 2003 Maize, 2002 Potatoes
Sowing Date	28 September 2004
Seed Rate	300 seeds/m2
Harvest Date	07 August 2005
Plot Size	10 m x 2 m
Total Nitrogen Applied	188 kg N/ha (15 on 11/03, 38 on 08/04, 99 on 21/04, 36 on 12/05)
Plant Growth Regulators	Chlormequat 1.25 l/ha + Moddus 0.2 l/ha on 23/03
Spring Herbicides	Platform S 0.6 kg/ha on 12/04

2005/06

Location	ADAS Rosemaund, Herefordshire
Soil Type	Silty clay loam
Soil Series	Bromyard
Previous Crop	2005 Spring Beans, 2004 Winter Wheat, 2003 Potatoes
Sowing Date	06 October 2005
Seed Rate	300 seeds/m2
Harvest Date	08 August 2006
Plot Size	10 m x 2 m
Total Nitrogen Applied	151 kg N/ha (103 on 12/04, 48 on 30/05)
Plant Growth Regulators	Chlormequat 1.69 l/ha on 18/04
Spring Herbicides	Atlantis 0.4 kg/ha + Platform S 0.9 kg/ha on 02/02 Ally 30 g/ha + Starane 2 1.0 l/ha on 31/05

2006/07

Location	Rosemaund, Herefordshire
Soil Type	Silty clay loam
Soil Series	Bromyard
Previous Crop	2006 Spring Beans, 2005 Winter Wheat, 2004 Spring OSR
Sowing Date	25 September 2006
See Rate	300 seeds/m2
Harvest Date	12 August 2007
Plot Size	10 m x 2 m
Total Nitrogen Applied	170 kg N/ha (16 on 11/04, 102 on 17/04, 52 on 09/05)
Plant Growth Regulators	Chlormequat 1.1 l/ha + Moddus 0.2 l/ha on 11/04
Spring Herbicides	Axial 0.45 l/ha + Ally 30 g/ha on 14/03 Starane 2 0.75 l/ha on 27/04
Insecticides	Hallmark 0.1 l/ha on 14/03

Norfolk

2004/05

Location	Morley, Norfolk
Soil Type	sandy loam over chalky boulder clay
Soil Series	Ashley series
Previous Crop	2005 Winter Oilseed Rape
Sowing Date	07 October 2004
See Rate	350 seeds/m2
Harvest Date	17 August 2005
Plot Size	10 m x 2 m
Total Nitrogen Applied	224 kg N/ha (50 on 21/03, 104 on 12/04, 70 on 05/05)
Plant Growth Regulators	Mirquat (chlormequat) 2.25 l/ha on 11/04 Terpal 1.25 l/ha on 23/05
Spring Herbicides	Topik 0.1 l/ha on 11/04 Starane 2 1.0 l/ha + Ally 15 g/ha on 25/04
Insecticide	Dursban WDG 0.6 kg/ha on 07/06

2005/06

Location	Morley, Norfolk
Soil Type	sandy loam over chalky boulder clay
Soil Series	Ashley series
Previous Crop	2005 Winter Beans
Sowing Date	06 October 2005
Seed Rate	350 seeds/m2
Harvest Date	06 August 2006
Plot Size	10 m x 2 m
Total Nitrogen Applied	220 kg N/ha (50 on 13/03, 100 on 10/04, 70 on 10/05)
Plant Growth Regulators	Hive (chlormequat) 1.5 l/ha on 21/04, 0.75 l/ha on 08/05 Terpal 1.0 l/ha on 23/05
Spring Herbicides	Platform S 0.75 kg/ha on 21/04 Axial 0.3 l/ha + Ally 14 g/ha on 24/04 Starane 2 0.5 l/ha on 25/05
Insecticide	Dursban WDG 0.5 kg/ha on 06/06

2006/07

Location	Morley, Norfolk
Soil Type	sandy loam over chalky boulder clay
Soil Series	Ashley series
Previous Crop	2006 W Beans, 2005 W Wheat, 2004 W Oilseed Rape
Sowing Date	10 October 2006
Seed Rate	350 seeds/m2
Harvest Date	09 August 2007
Plot Size	10 m x 2 m
Total Nitrogen Applied	220 kg N/ha (40 on 16/03, 110 on 12/04, 70 on 04/05)
Plant Growth Regulators	Hive (chlormequat) 2.25 l/ha on 07/04 Terpal 1.0 l/ha on 15/05
Spring Herbicides	Atlantis WG 0.4 kg/ha on 07/04 Ally Max 15 g/ha on 23/04
Insecticide	Mavrik 0.15 l/ha on 11/06

Appendix E. Rainfall Records

Fig. E1 Weekly rainfall (mm) for Edinburgh 2004/05 season (from 1 Dec)

[redacted]

Fig. E2 Weekly rainfall (mm) for Edinburgh 2005/06 season (from 1 Sept)

[redacted]

Fig. E3 Weekly rainfall (mm) for Edinburgh 2006/07 season (from 1 Sept)

[redacted]

Fig. E4 Weekly rainfall (mm) for Hampshire site 2004/05 season (from 1 Jan)

Fig. E5 Weekly rainfall (mm) for Hampshire site 2005/06 season (from 1 Sept)

Fig. E6 Weekly rainfall (mm) for Hampshire site 2006/07 season (from 1 Sept)

Fig. E7 Weekly rainfall (mm) for Herefordshire site 2004/05 season (from 1 Jan)

Fig. E8 Weekly rainfall (mm) for Herefordshire site 2005/06 season (from 1 Sept)

Fig. E9 Weekly rainfall (mm) for Herefordshire site 2006/07 season (from 1 Sept)

Fig. E10 Weekly rainfall (mm) for Norfolk site 2004/05 season (from 1 Nov)

Fig. E11 Weekly rainfall (mm) for Norfolk site 2005/06 season (from 1 Sept)

Fig. E12 Weekly rainfall (mm) for Norfolk site 2006/07 season (from 1 Sept)

Appendix F. Parameters and Statistics for Individual Fitted Curves

Notes:

None_Op = 1-spray Opus, Op_Op = 2-spray Opus, OpB_OpB = 2-spray Opus + Bravo, OpBV_OpBV = 2-spray Opus + Bravo + Vivid

R^2 values are shown without the effects of replicates (*i.e.* they represent a measure of uncertainty around the fit of the mean data to the model, not variability of the data). Parameters shown below are for the original curves fitted against the T2 Opus dose, not the total Opus dose as shown on the x axis of the curves in the report section 3. Fitting against total Opus dose rather than T2 dose does not affect the fitted values or their SEs, as the T1 dose increases proportionally to the T2 dose. The adjusted R2, parameter B and its SE are also unaffected. The parameter K and its SE would be decreased by the ratio of the total Opus dose / the T2 Opus dose *i.e.* divide by 1.6.

Septoria tritici

Figure 3.1.1 2005 Norfolk Consort Septoria

GROUP	k	b	a+b	a+be**k	Adj_R2	n
None_Op	-0.85	16.63	23.21	13.66	98.41	3
Op_Op	-1.55	18.87	23.21	8.35	99.65	3
OpB_OpB	-3.5	19.4	23.21	4.4	98.82	3
OpBV_OpBV	-4.47	18.89	23.21	4.53	97.89	3

Figure 3.1.2 2005 Norfolk Einstein Septoria

GROUP	k	b	a+b	a+be**k	Adj_R2	n
None_Op	-1.45	16.26	18.7	6.25	98.44	3
Op_Op	-2.8	16.77	18.7	2.95	97.88	3
OpB_OpB	-7.5	17.32	18.7	1.39	99.74	3
OpBV_OpBV	-8.84	17.22	18.7	1.49	99.17	3

Figure 3.1.3 2005 Norfolk Robigus Septoria

GROUP	k	b	a+b	a+be**k	Adj_R2	n
None_Op	-2.04	6.99	10.2	4.12	96.23	3
Op_Op	-3.39	8.01	10.2	2.46	99.67	3
OpB_OpB	-8.86	8.77	10.2	1.43	99.39	3
OpBV_OpBV	-8.71	8.78	10.2	1.42	99.32	3

Figure 3.1.4 2005 Hampshire Einstein Septoria

GROUP	k	b	a+b	a+be**k	Adj_R2	n
None_Op	-3.88	16.69	20.5	4.15	97.8	2
Op_Op	-4.27	19.23	20.5	1.53	98.06	2
OpB_OpB	-11.54	19.64	20.5	0.86	99.92	2
OpBV_OpBV	-16	19.65	20.5	0.84	99.55	2

Figure 3.1.5 2006 Hampshire Consort Septoria

GROUP	k	b	a+b	a+be**k	Adj_R2	n
None_Op	-1.03	58.84	54.55	16.78	95.35	2
Op_Op	-1.71	54.43	54.55	9.96	89.23	2
OpB_OpB	-5.76	52.09	54.55	2.63	99.8	2
OpBV_OpBV	-5.05	51.66	54.55	3.23	95.75	2

Figure 3.1.6 2006 Herefordshire Consort Septoria

GROUP	k	b	a+b	a+be**k	Adj_R2	n
None_Op	-3.08	45.4	51.44	8.13	98.97	2
Op_Op	-6.4	48.87	51.44	2.65	99.18	2
OpB_OpB	-5.95	48.87	51.44	2.71	98.9	2
OpBV_OpBV	-8.71	49.31	51.44	2.14	99.47	2

Figure 3.1.7 2007 Hampshire Robigus Septoria

GROUP	k	k (se)	b	b (se)	a+b	a+be**k	a+be**k (se)	Adj_R2	n
None_Op	-0.56	0.49	84.95	47.74	60	23.7	78.48	90.6	2
Op_Op	-1.14	0.42	64.75	11.31	60	15.95	16.03	94.42	2
OpB_OpB	-3.3	0.22	55.6	1.09	60	6.45	0.5	99.66	2
OpBV_OpBV	-4.66	0.25	54.3	0.68	60	6.21	0.13	99.83	2

Figure 3.1.8 2007 Herefordshire Robigus Septoria

GROUP	k	k (se)	b	b (se)	a+b	a+be**k	a+be**k (se)	Adj_R2	n
None_Op	-1.55	0.14	17.47	0.66	20	6.23	0.79	99.46	2
Op_Op	-2.09	0.54	20.64	1.91	20	1.92	1.76	95.5	2
OpB_OpB	-11.4	1.98	19.38	0.27	20	0.62	0	99.73	2
OpBV_OpBV	-5.71	0.62	20.06	0.44	20	0	0.04	99.42	2

Brown Rust and Yellow Rust

Figure 3.2.1 2007 Hampshire Einstein Brown Rust

GROUP	k	k (se)	b	b (se)	a+b	a+be**k	a+be**k (se)	Adj_R2	n
None_Op	-1.57	0.65	39.05	6.6	38.33	7.41	7.84	89.45	2
Op_Op	-3.95	0.62	36.73	1.51	38.33	2.32	0.46	98.29	2
OpB_OpB	-2.47	0.72	36.63	3.59	38.33	4.82	2.69	93.16	2
OpBV_OpBV	-6.9	0.28	37.07	0.25	38.33	1.3	0.01	99.94	2

Figure 3.2.2 2007 Norfolk Robigus Brown Rust Flag Leaf

GROUP	k	k (se)	b	b (se)	a+b	a+be**k	a+be**k (se)	Adj_R2	n
None_Op	-0.99	0.2	18.93	1.95	16.5	4.61	2.91	98.46	2
Op_Op	-3.01	0.1	16.31	0.16	16.5	1	0.09	99.92	2
OpB_OpB	-2.04	0.72	17.63	2.27	16.5	1.16	2.14	91.94	2
OpBV_OpBV	-19.21		16.4	0.08	16.5	0.1	0	99.96	2

Figure 3.2.3 2007 Norfolk Robigus Brown Rust Leaf 2

GROUP	k	k (se)	b	b (se)	a+b	a+be**k	a+be**k (se)	Adj_R2	n
None_Op	-0.65	0.31	30.74	8.96	22.5	7.86	14.52	95.91	2
Op_Op	-2.27	0.34	23.24	1.2	22.5	1.66	1	98.37	2
OpB_OpB	-1.38	0.67	25.57	5.36	22.5	3.37	6.92	89.11	2
OpBV_OpBV	-19.19		22.49	0.01	22.5	0.01	0	100	2

Figure 3.2.4 2007 Borders Robigus Yellow Rust

GROUP	k	k (se)	b	b (se)	a+b	a+be**k	a+be**k (se)	Adj_R2	n
None_Op	-13.53	3.75	44.22	0.69	49.17	4.95	0	99.65	2
Op_Op	-13.93	1.29	48.63	0.24	49.17	0.53	0	99.97	2
OpB_OpB	-8.93	0.62	48.35	0.42	49.17	0.82	0	99.9	2
OpBV_OpBV	-13.32	1.21	48.87	0.26	49.17	0.3	0	99.96	2

Green Leaf Area

Figure 3.3.1 2005 Norfolk Consort Green Leaf Area

GROUP	k	b	a+b	a+be**k	Adj_R2	n
None_Op	-0.15	-185.03	4.73	29.74	98.31	3
Op_Op	-0.74	-91.82	4.73	52.72	96.68	3
OpB_OpB	-4.31	-76.75	4.73	80.45	98.96	3
OpBV_OpBV	-5.3	-74	4.73	78.36	98.61	3

Figure 3.3.2 2005 Norfolk Einstein Green Leaf Area

GROUP	k	b	a+b	a+be**k	Adj_R2	n
None_Op	-1.76	-58.55	22.6	71.04	94.38	3
Op_Op	-3.41	-60.61	22.6	81.21	99.14	3
OpB_OpB	-7.44	-65.38	22.6	87.94	99.81	3
OpBV_OpBV	-9.32	-65.02	22.6	87.62	99.54	3

Figure 3.3.3 2005 Norfolk Robigus Green Leaf Area

GROUP	k	b	a+b	a+be**k	Adj_R2	n
None_Op	-1.49	-31.01	35.57	59.6	97.32	3
Op_Op	-4	-31.77	35.57	66.76	99.14	3
OpB_OpB	-9.22	-36.99	35.57	72.56	99.51	3
OpBV_OpBV	-6.13	-38.5	35.57	73.98	96.55	3

Figure 3.3.4 2006 Hampshire Consort Green Leaf Area

GROUP	k	b	a+b	a+be**k	Adj_R2	n
None_Op	-1.05	-83.15	14.16	68.08	93.45	2
Op_Op	-2.14	-71.6	14.16	77.37	88.73	2
OpB_OpB	-6.49	-73.85	14.16	87.9	99.38	2
OpBV_OpBV	-5.93	-74.32	14.16	88.27	97.28	2

Figure 3.3.5 2006 Herefordshire Consort Green Leaf Area

GROUP	k	b	a+b	a+be**k	Adj_R2	n
None_Op	-2.93	-77.01	6.94	79.83	98.65	2
Op_Op	-4.19	-85.51	6.94	91.15	99.41	2
OpB_OpB	-5.56	-82.31	6.94	88.93	98.19	2
OpBV_OpBV	-9.79	-82.06	6.94	89	99.42	2

Figure 3.3.6 2007 Hampshire Einstein Green Leaf Area

GROUP	k	k (se)	b	b (se)	a+b	a+be**k	a+be**k (se)	Adj_R2	n
None_Op	-1.58	0.4	-86.5	9.04	6.17	74.79	10.7	95.83	2
Op_Op	-3.14	0.26	-84.48	2.11	6.17	86.99	1.07	99.46	2
OpB_OpB	-5.05	1.3	-81.6	4.74	6.17	87.24	0.71	96.2	2
OpBV_OpBV	-8.3	1.05	-85.34	1.5	6.17	91.48	0.02	99.59	2

Figure 3.3.7 2007 Norfolk Consort Green Leaf Area

GROUP	k	k (se)	b	b (se)	a+b	a+be**k	a+be**k (se)	Adj_R2	n
None_Op	-1.5	0.17	-64.41	2.99	15	65.02	3.66	99.24	2
Op_Op	-2.56	0.4	-71.48	3.66	15	80.97	2.6	98.17	2
OpB_OpB	-3.93	0.26	-71.23	1.27	15	84.83	0.39	99.69	2
OpBV_OpBV	-7.7	0.64	-73.48	0.92	15	88.45	0.02	99.79	2

Figure 3.3.8 2007 Norfolk Robigus Green Leaf Area

GROUP	k	k (se)	b	b (se)	a+b	a+be**k	a+be**k (se)	Adj_R2	n
None_Op	-0.16	0.56	-184.81	582.74	22.5	49.09	997.03	86.97	2
Op_Op	-1.93	0.15	-66.54	1.88	22.5	79.42	1.87	99.57	2
OpB_OpB	-1.2	0.52	-75.65	15.06	22.5	75.42	20.86	92.18	2
OpBV_OpBV	-8.16	1.31	-65.13	1.48	22.5	87.61	0.02	99.31	2

Figure 3.3.9 2007 Borders Robigus Green Leaf Area

GROUP	k	k (se)	b	b (se)	a+b	a+be**k	a+be**k (se)	Adj_R2	n
None_Op	-4.99	1.27	-77.86	4.5	10.83	88.16	0.7	96.28	2
Op_Op	-7.48	0.54	-85.21	0.97	10.83	96	0.03	99.83	2
OpB_OpB	-5.94	0.88	-85.65	2.51	10.83	96.26	0.2	98.97	2
OpBV_OpBV	-14.27	5.16	-85.7	1.56	10.83	96.54	0	99.52	2

Grain Yield

Figure 3.4.1 2005 Norfolk Consort Grain Yield

GROUP	k	b	a+b	a+be**k	Adj_R2
None_Op	-1.2	-3.78	6.49	9.14	99.5
Op_Op	-1.35	-4.63	6.49	9.93	99.96
OpB_OpB	-2.5	-4.73	6.49	10.83	99.52
OpBV_OpBV	-3.23	-4.84	6.49	11.15	98.37

Figure 3.4.2 2005 Norfolk Einstein Grain Yield

GROUP	k	b	a+b	a+be**k	Adj_R2
None_Op	-2.06	-2.29	9.46	11.46	99.87
Op_Op	-2.39	-2.88	9.46	12.07	99.37
OpB_OpB	-6.57	-2.99	9.46	12.44	97.36
OpBV_OpBV	-6.58	-3.17	9.46	12.63	98.58

Figure 3.4.3 2005 Norfolk Robigus Grain Yield

GROUP	k	b	a+b	a+be**k	Adj_R2
None_Op	-2.01	-1.69	9.88	11.35	97.92
Op_Op	-2.4	-1.94	9.88	11.65	97.75
OpB_OpB	-5.16	-2.09	9.88	11.96	99.77
OpBV_OpBV	-6.09	-2.23	9.88	12.11	99.48

Figure 3.4.4 2006 Hampshire Consort Grain Yield

GROUP	k	b	a+b	a+be**k	Adj_R2
None_Op	-1.19	-2.29	7.5	9.09	98.99
Op_Op	-1.17	-3.25	7.5	9.74	98.54
OpB_OpB	-3.2	-2.82	7.5	10.2	99.2
OpBV_OpBV	-3.91	-2.99	7.5	10.43	96.66

Figure 3.4.5 2006 Herefordshire Consort Grain Yield

GROUP	k	b	a+b	a+be**k	Adj_R2
None_Op	-0.64	-3.79	6.59	8.38	98.38
Op_Op	-1.4	-3.69	6.59	9.38	99.33
OpB_OpB	-1.78	-3.75	6.59	9.71	98.51
OpBV_OpBV	-3.81	-3.34	6.59	9.86	94.05

Figure 3.4.6 2007 Morley Consort Grain Yield

GROUP	k	k (se)	b	b (se)	a+b	a+be**k	a+be**k (se)	Adj_R2	n
None_Op	-0.37	0.15	-4.52	1.36	5.34	6.72	2.29	98.88	2
Op_Op	-1.27	0.19	-3.19	0.21	5.34	7.63	0.28	98.86	2
OpB_OpB	-2.13	0.2	-3.05	0.1	5.34	8.03	0.09	99.32	2
OpBV_OpBV	-3.73	0.76	-3.01	0.16	5.34	8.27	0.06	97.21	2

Figure 3.4.7 2007 Borders Consort Grain Yield

GROUP	k	k (se)	b	b (se)	a+b	a+be**k	a+be**k (se)	Adj_R2	n
None_Op	-3.81	0.9	-2.19	0.13	5.88	8.02	0.04	96.64	2
Op_Op	-2.55	0.15	-2.88	0.06	5.88	8.53	0.04	99.72	2
OpB_OpB	-3.17	0.75	-2.85	0.19	5.88	8.61	0.1	95.99	2
OpBV_OpBV	-5.12	0.8	-2.73	0.08	5.88	8.6	0.01	98.94	2

Figure 3.4.8 2007 Hampshire Consort Grain Yield

GROUP	k	k (se)	b	b (se)	a+b	a+be**k	a+be**k (se)	Adj_R2	n
None_Op	-0.73	0.4	-2.82	0.87	4.81	6.27	1.39	93.02	2
Op_Op	-0.51	0.26	-5.59	1.91	4.81	7.03	3.17	96.93	2
OpB_OpB	-2.08	1.34	-2.73	0.63	4.81	7.2	0.58	74.07	2
OpBV_OpBV	-4.12	0.19	-3.64	0.04	4.81	8.38	0.01	99.86	2

Figure 3.4.9 2007 Herefordshire Consort Grain Yield

GROUP	k	k (se)	b	b (se)	a+b	a+be**k	a+be**k (se)	Adj_R2	n
None_Op	-0.36	0.26	-3.35	1.81	4.94	5.94	3.05	96.85	2
Op_Op	-0.25	0.04	-9.21	1.19	4.94	6.95	2.02	99.92	2
OpB_OpB	-2.76	0.42	-2.93	0.14	4.94	7.68	0.09	98.32	2
OpBV_OpBV	-3.66	0.61	-3.64	0.16	4.94	8.49	0.06	98.07	2

Grain Specific Weight

Figure 3.5.1 2005 Norfolk Consort Grain Specific Weight

GROUP	k	b	a+b	a+be**k	Adj_R2
None_Op	-1.24	-8.43	68.27	74.25	98.19
Op_Op	-2.17	-8.44	68.27	75.75	99.62
OpB_OpB	-3.57	-7.49	68.27	75.55	96.28
OpBV_OpBV	-5.7	-8.33	68.27	76.57	99.93

Figure 3.5.2 2005 Norfolk Einstein Grain Specific Weight

GROUP	k	b	a+b	a+be**k	Adj_R2
None_Op	-2.13	-4.55	72.62	76.63	97.95
Op_Op	-2.98	-4.86	72.62	77.23	99.85
OpB_OpB	-8.56	-4.59	72.62	77.21	99.62
OpBV_OpBV	-10.3	-5.01	72.62	77.63	99.98

Figure 3.5.3 2005 Norfolk Robigus Grain Specific Weight

GROUP	k	b	a+b	a+be**k	Adj_R2
None_Op	-4	-2.4	74.43	76.78	96.12
Op_Op	-4.64	-2.56	74.43	76.97	90.97
OpB_OpB	-7.82	-2.91	74.43	77.34	94.9
OpBV_OpBV	-10.3	-2.96	74.43	77.39	98.9

Appendix H. Additional cross-site analyses

Septoria tritici

Table 3.1.4 Cross-site analysis of % area of leaves 3, 2 and the flag leaf showing *S. tritici* symptoms at GS69-77 (mean of 4 sites from 2005 and 2006, except Einstein 3 sites only in 2005). (a) Effect of treatment group (mean of four Opus doses) and (b) Effect of Opus dose (mean of four treatment groups)

(a)

Variety	% *S. tritici* on leaves 3, 2 and the flag leaf per treatment group				
	Untreated	Opus 1-spray	Opus 2-spray	Opus + Bravo	Opus + Bravo + Vivid
Consort	18.2	10.1	6.4	3.9	3.3
Einstein	11.5	5.2	3.3	1.5	1.5
Robigus	7.8	4.7	3.4	1.8	1.6
	F prob. <0.001, SEM 0.514 (max), 2.297 (min) d.f. 2764				

(b)

Variety	% *S. tritici* on leaves 3,2 and the flag leaf per T2 (or total) Opus dose				
	0 (untreated)	0.25 (0.4)	0.5 (0.8)	1.0 (1.6)	2.0 (3.2)
Consort	18.2	9.6	6.8	4.5	2.9
Einstein	11.5	4.5	3.3	2.3	1.3
Robigus	7.8	3.6	3.3	2.4	2.0
	F prob. <0.001, SEM 0.514 (max), 2.297 (min) d.f. 2764				

Green Leaf Area

Table 3.3.3 Cross-site analysis showing % green leaf area remaining on leaves 3, 2 and the flag leaf at GS69-77 (mean of 4 sites from 2005 and 2006, except Einstein 3 sites only in 2005). (a) Effect of treatment group (mean of four Opus doses) and (b) Effect of Opus dose (mean of four treatment groups)

(a)

Variety	% GLA on leaves 3, 2 and the flag leaf per treatment group				
	Untreated	Opus 1-spray	Opus 2-spray	Opus + Bravo	Opus + Bravo + Vivid
Consort	66.0	79.8	84.7	89.4	90.5
Einstein	72.2	81.5	84.6	86.9	88.0
Robigus	78.1	86.1	88.0	90.1	91.2
	F prob. <0.001, SEM 0.832 (max), 3.326 (min) d.f. 5312				

(b)

Variety	% GLA on leaves 3, 2 and the flag leaf per T2 (or total) Opus dose				
	0 (untreated)	0.25 (0.4)	0.5 (0.8)	1.0 (1.6)	2.0 (3.2)
Consort	66.0	81.3	84.5	87.7	90.9
Einstein	72.2	82.2	85.0	86.1	87.7
Robigus	78.1	86.9	88.5	89.7	90.3
	F prob. <0.001, SEM 0.832 (max), 3.326 (min) d.f. 5312				

Table 3.3.4 Cross-site analysis showing % green leaf area remaining on leaves 3, 2 and the flag leaf at GS71-80 (mean of 4 sites from 2007). (a) Effect of treatment group (mean of four Opus doses) and (b) Effect of Opus dose (mean of four treatment groups)

(a)

Variety	% GLA on leaves 3, 2 and the flag leaf per treatment group				
	Untreated	Opus 1-spray	Opus 2-spray	Opus + Bravo	Opus + Bravo + Vivid
Consort	63.3	71.1	77.1	81.2	85.0
Einstein	66.2	85.0	90.9	92.6	94.2
Robigus	61.7	72.9	83.0	87.6	90.6
	F prob. <0.001, SEM 1.506 (max), 2.130 (min) d.f. 2142				

(b)

Variety	% GLA on leaves 3, 2 and the flag leaf per T2 (or total) Opus dose				
	0 (untreated)	0.25 (0.4)	0.5 (0.8)	1.0 (1.6)	2.0 (3.2)
Consort	63.3	68.6	74.5	82.1	89.1
Einstein	66.2	86.8	88.1	92.7	95.0
Robigus	61.7	75.0	80.2	88.1	90.8
	F prob. <0.001, SEM 1.506 (max), 2.130 (min) d.f. 2142				

Appendix H. Additional methods for fungicide mixture calculator

Adding or amending data

The data file FungicideMix.dat is a binary file that is not suitable for editing. In order to change the data, a separate file (FungicideMix.txt) is required. This is a plain text file that can be edited using Notepad or any text editor. The use of a word processor is not recommended. If the program finds FungicideMix.txt but not FungicideMix.dat in the same folder when it starts, it reads the data from the file and writes a new copy of FungicideMix.dat. As described below, the data are also contained in a Microsoft Access^{TM} database called FungicideMix.mdb. The data can also be changed in the database, and exported to FungicideMix.txt and hence FungicideMix.dat. Both options are described below.

The input file FungicideMix.txt

A short extract from FungicideMix.txt is shown in Figure 7.2.5. This is designed to be fairly simple to edit using Notepad or any other text editor. A feature of the program is that text at the end of a line after the expected values is ignored, making it possible to annotate the file. All text in the example other than the disease and chemical names is annotation. There are two parts to the data: diseases and chemicals.

The list of diseases is placed at the start of the file. The first line gives the number of diseases in the list. There are then two lines for each disease. The first contains 3 values:

- The disease number. In the example these are consecutive, but they need not be, provided each has a unique number.
- The maximum value to be shown on the y axis.
- The number of intervals to show on the y axis.

The second line simply contains the disease name; this line must not contain any other text.

The remainder of the file contains a group of lines for each chemical. The number of lines depends on the number of diseases for which there are coefficients. Each group begins with the name of a chemical, which must not contain any other text. If values for more than one year are included, the year should be added to the name in brackets. If two chemicals names are identical up to the brackets, the program will not mix them. The next line contains 2 values giving the general properties:

- The chemical type number. This is used to identify chemicals with the same mode of action; in the example shown, fenpropimorph and other morpholines are type 15. The numbers currently in use are those used in Wheat Disease Manager (WDM), but any consistent numbering could be used.
- The maximum dose (g/ha). This is normally derived from the concentration in the standard single-active product and its maximum application rate.

The next line contains a single value: the number of diseases for which there are coefficients. This is followed by the appropriate number of lines giving a disease number and the values of a, b and k for that disease.

```
6            number of diseases
 1             30           6
Brown rust
 2             30           6
Yellow rust
 3             10           5
Mildew
 4             30           6
Septoria nodorum
 5             30           6
Septoria tritici/eradicant
 6             30           6
Septoria tritici/protectant
Fenpropimorph(2006)
 15            750         type & max dose
 1                         Ndiseases then a, b, k for each
 3             4.67         2.59         -0.65
Chlorothalonil(2006)
 70            1000        type & max dose
 2                         Ndiseases then a, b, k for each
 4             15.37        6.5          -1.59
 5             16.99        12.13        -16
Tebuconazole(2006)
 2             250         type & max dose
 4                         Ndiseases then a, b, k for each
 1             3.42         25.7         -7.7
 2             12.16        11.07        -2.3
 4             7.31         14.56        -4.1
 5             5.18         23.94        -2.35
```

Fig. 7.2.5 Extract from the start of FungicideMix.txt

The database FungicideMix.mdb

Although FungicideMix.txt is easy to edit, during development it was found simpler when creating the file for the first time to enter the data into a database and use a macro to export it correctly. This made it easier to ensure data integrity and maintain a consistent format. The database is available for future use if required. Its structure is slightly more complex than is needed for the present purpose, because it is derived from the more comprehensive active ingredients database used by WDM. The database contains 5 tables, as follows.

This **Active** table contains the simple data for each chemical in the text file. The fields are

- ActiveID – a unique number for each chemical; the primary key for this table, used as a foreign key by the activity table.
- Name – the name of the chemical as used in the text file.
- MaxDose – the maximum dose (g/ha) as used in the text file.
- TypeID – the chemical type number as used in the text file.
- Product – the name of a product containing the active ingredient; optional and purely cosmetic.

The **Activity** table contains all the coefficients. The fields are

- ActivityID – an automatic unique number for each row in the table; the primary key, not used by any other table.
- ActiveID – the number of the active ingredient that a row refers to.
- DiseaseID – the number of the disease that a row refers to.
- Year – the year of trials data to which the coefficients were fitted.
- a, b, k – the three coefficients for this active-disease combination.

Data integrity requires that the ActiveID and DiseaseID should be valid keys in the relevant tables, but it is not necessary to have a row for every combination.

The **Disease** table contains all the information used in the disease section of the text file. The fields are

- DiseaseID – the disease number as used in the text file; the primary key for this table, used as a foreign key by the activity table.
- Name – the disease name as used in the text file.
- ScaleMax – the maximum for the y axis scale as used in the text file.

- ScaleSteps – the number of steps on the y axis scale as used in the text file.

The **Type** table uses the TypeID as its primary key and contains a name for each chemical type. It has no function in the program, but is used by some of the queries to provide information that is useful when checking the contents of the database.

The **VersionInfo** table is provided as a place to record changes to the database. It is good practice to update it whenever a change is made to the structure or contents.

The database contains the following three queries

- **ActivesAndTypes** – produces a list of actives and their type names to simplify checking of the type number assignments.
- **ActivesForOutput** – a list of active IDs, names, years for which there are coefficients, maximum dose and Type ID; used by the ExportText module, so do not change it.
- **ActivitiesForActiveIDandYear** – this returns the coefficients for one active against each disease based on one year; used by the ExportText module, so do not change it.
- **Activity_Query** – returns a table of all the actives, types and coefficients using names for types and diseases; intended for use when checking the contents.

The **EditActivity** form can be used to edit the coefficients for all the existing active-disease combinations in the database using the *Go to active* combo box and the navigation buttons to move around. It is not possible to add an active-disease combination using the form.

The database contains two reports showing the actives and coefficients in a form suitable for printing.

- **Active** – groups the data by active ingredient.
- **Disease** – groups the data by disease.

The ExportText macro provided a convenient way to run the code in the ExportText module, which contains the PrintTextFile() function that is used to create FungicideMix.txt from the contents of the database.

Editing the coefficients for an existing active-disease combination is most easily accomplished using the EditActivity form. Adding new data requires a basic understanding of the database structure. The details of an active, an active type or a disease can be added or amended by using the appropriate table. To add coefficients for an active and disease that are already in the database, add a new record to the Activity table with the correct ActiveID and DiseaseID, then fill in the coefficients. Referential integrity should prevent the deletion of data from any of the tables if it is in use by one of the others.