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# Appropriate Doses Network: up-to-date information on fungicide performance for wheat growers

by

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## ABSTRACT

Advances in fungicide chemistry play a key role in maximising economic returns from wheat production. With grain values stronger than for some time, but high crop establishment and nitrogen costs, it is crucial that the investment made in establishing and growing green crop canopy is protected through effective disease management. The development of fungicide resistance threatens disease control, making it more important that the industry uses new fungicide active substances and modes of action efficiently. The project reported here assessed the performance of a range of established and newly introduced fungicides against the major economic diseases of UK wheat. Dose-response curves were quantified to help establish the doses required to obtain effective control, even under high disease pressure. Each of the fungicides tested was applied as a single spray to the upper leaves, at quarter, half, full and double the label recommended dose, and untreated plots were included for comparison. Double dose treatments were applied for experimental purposes and must not be applied to farm crops. The conclusions from this work were widely reported during the life of the project, at HGCA events, Cereals 2005, 2006 and 2007, and in the farming press, so the practical messages may no longer seem ‘new’. This report sets out the dose-response curves for all the diseases and products tested. In summary, the main conclusions were:

*Septoria tritici*: The decline in the performance of triazole fungicides seen over recent decades appears to have stabilised. Epoxiconazole and prothioconazole both continue to provide good control, provided the dose used is sufficiently robust for the disease susceptibility of the variety and disease pressure. The addition of chlorothalonil or boscalid is recommended. The addition of strobilurins to good triazoles adds little to septoria control, but is justified for rust control (see below).

*Stagonospora* (*Septoria*) *nodorum* (glume blotch): This disease remains a substantial risk in the south west. Products based on prothioconazole or epoxiconazole gave good glume blotch control, as did pyraclostrobin.

Brown rust: 2007 was a particular severe brown rust season across much of southern and eastern England, due to high spring temperatures and a breakdown of disease resistance in some major wheat varieties. Strobilurins and triazoles have maintained their effectiveness against brown rust. The most effective control was given by Fandango, Tracker and Vivid. Yield responses in the trials (as in farm crops) were related to control of rust and septoria, and the largest yield responses were given by Opus + Comet, Prosaro, Tracker and Fandango.

Yellow rust: Fungicides or fungicide mixtures containing epoxiconazole, prothioconazole or tebuconazole all gave excellent control, usually even at low doses. The strobilurins azoxystrobin and pyraclostrobin were also effective. Control by prothioconazole appeared to be improved by the addition of fluoxastrobin (as Fandango).

Powdery mildew: A range of new active substances have provided a substantial improvement in mildew control. Metrafenone (Flexity), proquinazid, (Talius) and the more recently introduced cyflufenamid (Cyflamid), gave excellent control even at low doses. Yield responses were modest (as mildew is less damaging to yield than septoria or rusts), but economic.

# 1.0 **SUMMARY**

The project assessed the performance of a range of established and newly introduced fungicides against the major economic diseases of the UK wheat crop. Dose-response curves were quantified to establish the doses required to obtain effective control, even under high disease pressure.

This report covers work conducted over three harvest years at sites selected to target the main foliar diseases of winter wheat – *Septoria tritici*, *Stagonospora (Septoria) nodorum*, yellow rust, brown rust and powdery mildew.

A randomised block design incorporating between 34 and 42 treatments with three replicates was used for all experiments. At sites targeting rusts or mildew, guard plots of a variety resistant to the target disease were drilled alternately with treatment plots wherever possible.

Fungicide treatments listed in the table below were applied as single sprays. The target stage for fungicide application was determined by pathogen development. At the *S. tritici* sites, the target timing was at the emergence of eventual leaf 2. This was usually at GS 33, but may have occurred at GS 32 in some crops. This growth stage was also the timing for the yellow rust and mildew sites, but at these sites, the timing was adjusted earlier if early epidemic development required. Brown rust and *S. nodorum* are characterised by rapid development late in the season, so the target timing for these sites was at GS 37-39 rather than GS 33 unless there was a risk of severe disease development at GS 33.

Each fungicide product was applied at quarter, half, full and double the label recommended dose. Double dose treatments were applied for specific experimental purposes and must not be applied by farmers to farm crops. Crop that received double dose treatments was disposed of safely at harvest.

**Active ingredients and products tested**

| | Active ingredient | Product |
|---|---|---|
| *Standards* | | |
| | Epoxiconazole | Opus |
| | Chlorothalonil | Bravo |
| | Tebuconazole | Folicur |
| *Test actives* | | |
| | Pyraclostrobin | Vivid/Comet |
| | Prochloraz | Poraz |
| | Prothioconazole | Proline |
| | Prothioconazole + fluoxastrobin | Fandango |
| | Prothioconazole + tebuconazole | Prosaro |
| | Dimoxystrobin + epoxiconazole | Swing Gold |
| | Epoxiconazole + boscalid | Tracker |
| | Trifloxystrobin | Swift |
| | Pyraclostrobin + epoxiconazole | Vivid + Opus |
| | Azoxystrobin | Amistar |
| | Fenpropidin | Tern |
| | Fenpropimorph | Corbel |
| | Cyprodinil | Unix |
| | Spiroxamine | Neon |
| | Quinoxyfen | Fortress |
| | Metrafenone | Flexity |
| | Cyflufenamid | Cyflamid |
| | Proquinazid | Talius |
| | Untreated | |

The main conclusions from the project in relation to each disease were:

***Stagonospora (Septoria) nodorum***

- Products based on epoxiconazole or prothioconazole gave good control of glume blotch.
- Chlorothalonil and prochloraz did not give effective control of glume blotch when applied to leaves.
- Pyraclostrobin continues to give reasonable control of glume blotch, even at low doses.
- Some large yield responses were recorded, up to 4 tonnes/ha, but it was not possible to determine how much of this was due to glume blotch control and how much was due to the control of *S. tritici.*
- Yield increases were reflected in increases in specific weight.

***Septoria tritici***

- The decline in activity of strobilurin fungicides against *S. tritici* appears to have stabilised and there is a suggestion that pyraclostrobin (Vivid or Comet) gave slightly better disease control in 2006 and 2007 than in 2005.
- However, there was no evidence that the addition of a strobilurin product to an effective azole fungicide enhanced *Septoria* control (Fandango v Proline or Opus + Comet v Opus).
- Tebuconazole (Folicur) was consistently less effective in controlling *S. tritici* than epoxiconazole (Opus) or prothioconazole (Proline).
- The activity of prochloraz (Poraz) against *S. tritici* remains weak and at the moment, there seems little, if any, benefit from its slightly different target site.
- Increases in specific weight were generally in line with yield increases.

**Yellow Rust**

- Fungicides or fungicide mixtures containing the azoles epoxiconazole, prothioconazole and tebuconazole all gave good control of yellow rust, usually even at low doses.
- The strobilurins azoxystrobin and pyraclostrobin were also effective, except when *S. tritici* compromised disease control.
- The control of yellow rust by prothioconazole (Proline) appeared to be improved by the addition of fluoxastrobin (as Fandango)
- Spiroxamine (Torch Extra) had some activity against yellow rust, but was inconsistent.
- Levels of yellow rust at the three sites were not high and yield responses from the control of the disease in the absence of significant *Septoria* were modest, but often achieved by low doses.
- Where *Septoria* infection was more severe, as in 2006, the shape of the dose-response curves for yield for the azole fungicides was different. These curves did not level off after quarter dose and full doses were needed to give maximum yield responses.
- Increases in specific weight were generally small.

**Brown Rust**

- The most effective control of brown rust was given by Fandango, Tracker and Vivid.
- The activity of Fandango was largely due to the strobilurin component of the fungicide mixture.
- Prothioconazole (Proline) consistently gave poorer control of brown rust than other azole products (Opus and Folicur)
- The inclusion of boscalid in Tracker improved brown rust control compared with Opus alone.
- Data for spiroxamine (Torch Extra) was limited to one year and no firm conclusions can be drawn concerning its activity against brown rust.
- Yield responses were generally modest except in 2007. Even in 2007, yield responses were not as great as might be expected considering the brown rust severity. However, treatments were applied when the crop was already at the beginning of ear emergence, and this was probably too late to achieve effective control due to the early development of the brown rust epidemic.
- Fandango, Tracker, Prosaro and Comet plus Opus gave the greatest yield responses.

**Mildew**

- The new generation of mildewicides - metrafenone (Flexity) and proquinazid (Talius) and more recently cyflufenamid (Cyflamid) gave very good control of mildew, often at quarter or half doses.
- Other recent introductions such as quinoxyfen (Fortress) and spiroxamine (Neon, Torch Extra) were not quite as effective.
- Fenpropimorph (Corbel) and Cyprodinil (Unix) generally gave poor control of mildew.
- Of the azole fungicides, prothioconazole gave slightly better mildew control than epoxiconazole.
- As usual, yield responses and any increase in specific weight from mildew control were small.
- Prothioconazole (Proline) consistently gave the greatest yield increase despite its poorer mildew control, probably due to the control of low levels of *Septoria*.

## 2.0 INTRODUCTION

With recent rises in grain prices and advances in the yield potential of wheat varieties it is important to ensure that disease control is highly effective to maximise economic returns. Advances in fungicide chemistry continue to play a crucial role and despite considerable rationalisation in the agrochemical industry, the flow of novel active ingredients being introduced continues. New products command premium prices, so it is important that growers have access to independent data on their performance, in order to weigh benefits against costs. Fungicides can also remain on the market for many years and some of the established materials offer useful disease control at a lower price. However, the performance of pesticides is not static. Over time, less sensitive pathogen strains can be selected, resulting in shifts in dose-response curves, causing changes in the dose required to obtain effective control. Although there is a degree of cross-resistance between fungicides in a given mode of action group, it has become apparent that, in some cases, not all fungicides within a group are affected equally by insensitivity. Analysis of data from the appropriate dose experiments since 1994 have shown a decline in activity of the azole fungicides against *S. tritici* and, for example, that tebuconazole has been particularly affected by this decline.

This report presents dose-response curves from all the appropriate dose experiments on winter wheat during the harvest years 2005, 2006 and 2007, showing the activity of a range of commercially important fungicides against the major economic diseases in the UK.

For those not already familiar with the interpretation of dose-response curves, an explanation is given in the Addendum.

# 3.0 MATERIALS AND METHODS

## 3.1 Experimental sites, cultivars and target diseases

This report covers work conducted over three harvest years (2005 to 2007) at sites selected to target the main foliar diseases of winter wheat – *Septoria tritici*, *Stagonospora (Septoria) nodorum*, yellow rust, brown rust and powdery mildew. The location of sites and cultivars used are listed in Table 3.1.

**Table 3.1 Site numbers, locations, harvest years, cultivars and target diseases**

| Site number | Location | Harvest year | Cultivar | Target disease |
|---|---|---|---|---|
| 1 | Pelynt, Looe, Cornwall | 2005 | Savannah | *S. nodorum/S. tritici* |
| 2 | Terrington, King's Lynn, Norfolk | 2005 | Brigadier | Yellow rust |
| 3 | Morley, Wymondham, Norfolk | 2005 | Consort | *S. tritici* |
| 4 | Morley, Wymondham, Norfolk | 2005 | Shamrock | Brown rust |
| 5 | Balgonie Glenrothes Fife | 2005 | Consort | *S. tritici* |
| 6 | Balgonie Glenrothes Fife | 2005 | Claire | Powdery mildew |
| 7 | Oak Park, Carlow | 2005 | Savannah | *S. tritici* |
| 8 | Pelynt, Looe, Cornwall | 2006 | Savannah | *S. nodorum/S. tritici* |
| 9 | Terrington, King's Lynn, Norfolk | 2006 | Brigadier | Yellow rust |
| 10 | Morley, Wymondham, Norfolk | 2006 | Consort | *S. tritici* |
| 11 | Edworth, Bedfordshire | 2006 | Alchemy | Brown rust |
| 12 | Skeddoway, Fife | 2006 | Consort | *S. tritici* |
| 13 | Skeddoway, Fife | 2006 | Claire | Powdery mildew |
| 14 | Kildalton, Kilkenny | 2006 | Savannah | *S. tritici* |
| 15 | Pelynt, Looe, Cornwall | 2007 | Cordiale | *S. nodorum/S. tritici* |
| 16 | Terrington, King's Lynn, Norfolk | 2007 | Robigus | Yellow rust |
| 17 | Morley, Wymondham, Norfolk | 2007 | Ambrosia | *S. tritici* |
| 18 | Edworth, Bedfordshire | 2007 | Alchemy | Brown rust |
| 19 | Thornton, Fife | 2007 | Consort | *S. tritici* |
| 20 | Thornton, Fife | 2007 | Claire | Powdery mildew |
| 21 | Carlow, Ireland | 2007 | Consort | *S. tritici* |

### 3.2 Site selection and establishment

First wheat sites with at least a one-year break from cereals (excluding oats) were chosen. Soil was sampled for pH and nutrient analysis and plots were drilled using a suitable plot drill (e.g. Øyjord) at a seed rate appropriate for the locality and soil type. Plot size was variable to fit in with local farm tramlines, but was in the range of 20 - 60m². All inputs other than fungicides were applied to ensure that the crop remained free, as far as possible, from nutritional deficiencies, or severe pest or weed infestations. At yellow rust sites, pots of rust-infected plants were planted out in a regular grid pattern in the spring to maximise the chance of disease development.

### 3.3 Experiment Design

A randomised block design incorporating between 34 and 42 treatments with three replicates was used for all experiments. At sites targeting rusts or mildew, guard plots of a variety resistant to the target disease were drilled alternately with treatment plots wherever possible.

### 3.4 Fungicide treatments

Fungicide treatments were applied as single sprays. The target stage for fungicide application was determined by crop and epidemic development. At the *S. tritici* sites, the target timing was at the emergence of eventual leaf 2. This was usually at GS 33, but may have occurred at GS 32 in some crops. Crop development was checked regularly from the beginning of GS 31 to ensure that the emergence of this leaf was identified correctly. This growth stage was also the timing for the yellow rust and mildew sites, but at these sites, the timing was adjusted earlier if early epidemic development required. Brown rust and *S. nodorum* are characterised by rapid development late in the season, so the target timing for these sites was at GS 37-39 rather than GS 33, unless there was a risk of severe disease development at GS 33. Sprays were applied in 200-300 litres water/ha using hand-held pressurised plot spraying equipment fitted with flat fan nozzles, selected to produce a medium spray quality at 200-300 kPa pressure. Each fungicide product was applied at quarter, half, full and double the label recommended dose. Double dose treatments were applied for specific experimental purposes (to ensure accurate dose-response curve fitting) and must not be applied by farmers to farm crops . Crop that received double dose treatments was disposed of safely at harvest.

Details of fungicide treatments at each site in each year are given in Tables 3.2 – 3.12.

**Table 3.2 Treatments for *S. nodorum/S. tritici* Experiment 2005 (Site 1)**

| Treatment code | Active ingredient | Product | Dose product/ha |
|---|---|---|---|
| *Standards* | | | |
| 1 | Epoxiconazole | Opus | 2.00 litre |
| 2 | Epoxiconazole | Opus | 1.00 litre |
| 3 | Epoxiconazole | Opus | 0.50 litre |
| 4 | Epoxiconazole | Opus | 0.25 litre |
| 5 | Chlorothalonil | Bravo | 4.00 litre |
| 6 | Chlorothalonil | Bravo | 2.00 litre |
| 7 | Chlorothalonil | Bravo | 1.00 litre |
| 8 | Chlorothalonil | Bravo | 0.50 litre |
| 9 | Tebuconazole | Folicur | 2.00 litre |
| 10 | Tebuconazole | Folicur | 1.00 litre |
| 11 | Tebuconazole | Folicur | 0.50 litre |
| 12 | Tebuconazole | Folicur | 0.25 litre |
| *Test actives* | | | |
| 13 | Pyraclostrobin | Vivid/Comet | 2.00 litre |
| 14 | Pyraclostrobin | Vivid/Comet | 1.00 litre |
| 15 | Pyraclostrobin | Vivid/Comet | 0.50 litre |
| 16 | Pyraclostrobin | Vivid/Comet | 0.25 litre |
| 17 | Trifloxystrobin | Swift | 1.00 litre |
| 18 | Trifloxystrobin | Swift | 0.50 litre |
| 19 | Trifloxystrobin | Swift | 0.25 litre |
| 20 | Trifloxystrobin | Swift | 0.125 litre |
| 21 | Prothioconazole | Proline | 1.60 litre |
| 22 | Prothioconazole | Proline | 0.80 litre |
| 23 | Prothioconazole | Proline | 0.40 litre |
| 24 | Prothioconazole | Proline | 0.20 litre |
| 25 | Prothioconazole + fluoxastrobin | Fandango | 3.00 litre |
| 26 | Prothioconazole + fluoxastrobin | Fandango | 1.50 litre |
| 27 | Prothioconazole + fluoxastrobin | Fandango | 0.75 litre |
| 28 | Prothioconazole + fluoxastrobin | Fandango | 0.375 litre |
| 29 | Prothioconazole + tebuconazole | Prosaro | 2.40 litre |
| 30 | Prothioconazole + tebuconazole | Prosaro | 1.20 litre |
| 31 | Prothioconazole + tebuconazole | Prosaro | 0.60 litre |
| 32 | Prothioconazole + tebuconazole | Prosaro | 0.30 litre |
| 33 | Dimoxystrobin + epoxiconazole | Swing Gold | 3.00 litre |
| 34 | Dimoxystrobin + epoxiconazole | Swing Gold | 1.50 litre |
| 35 | Dimoxystrobin + epoxiconazole | Swing Gold | 0.75 litre |
| 36 | Dimoxystrobin + epoxiconazole | Swing Gold | 0.375 litre |
| 37 | Epoxiconazole + boscalid | Tracker | 3.00 litre |
| 38 | Epoxiconazole + boscalid | Tracker | 1.50 litre |
| 39 | Epoxiconazole + boscalid | Tracker | 0.75 litre |
| 40 | Epoxiconazole + boscalid | Tracker | 0.375 litre |
| 41 | Untreated | | |
| 42 | Untreated | | |

**Table 3.3 Treatments for *S. nodorum/S. tritici* Experiment 2006 (Site 8)**

| Treatment code | Active ingredient | Product | Dose product/ha |
|---|---|---|---|
| *Standards* | | | |
| 1 | Epoxiconazole | Opus | 2.00 litre |
| 2 | Epoxiconazole | Opus | 1.00 litre |
| 3 | Epoxiconazole | Opus | 0.50 litre |
| 4 | Epoxiconazole | Opus | 0.25 litre |
| 5 | Chlorothalonil | Bravo | 4.00 litre |
| 6 | Chlorothalonil | Bravo | 2.00 litre |
| 7 | Chlorothalonil | Bravo | 1.00 litre |
| 8 | Chlorothalonil | Bravo | 0.50 litre |
| 9 | Tebuconazole | Folicur | 2.00 litre |
| 10 | Tebuconazole | Folicur | 1.00 litre |
| 11 | Tebuconazole | Folicur | 0.50 litre |
| 12 | Tebuconazole | Folicur | 0.25 litre |
| *Test actives* | | | |
| 13 | Pyraclostrobin | Vivid/Comet | 2.00 litre |
| 14 | Pyraclostrobin | Vivid/Comet | 1.00 litre |
| 15 | Pyraclostrobin | Vivid/Comet | 0.50 litre |
| 16 | Pyraclostrobin | Vivid/Comet | 0.25 litre |
| 17 | Prochloraz | Poraz | 1.80 litre |
| 18 | Prochloraz | Poraz | 0.90 litre |
| 19 | Prochloraz | Poraz | 0.45 litre |
| 20 | Prochloraz | Poraz | 0.225 litre |
| 21 | Prothioconazole | Proline | 1.60 litre |
| 22 | Prothioconazole | Proline | 0.80 litre |
| 23 | Prothioconazole | Proline | 0.40 litre |
| 24 | Prothioconazole | Proline | 0.20 litre |
| 25 | Prothioconazole + fluoxastrobin | Fandango | 3.00 litre |
| 26 | Prothioconazole + fluoxastrobin | Fandango | 1.50 litre |
| 27 | Prothioconazole + fluoxastrobin | Fandango | 0.75 litre |
| 28 | Prothioconazole + fluoxastrobin | Fandango | 0.375 litre |
| 29 | Prothioconazole + tebuconazole | Prosaro | 2.40 litre |
| 30 | Prothioconazole + tebuconazole | Prosaro | 1.20 litre |
| 31 | Prothioconazole + tebuconazole | Prosaro | 0.60 litre |
| 32 | Prothioconazole + tebuconazole | Prosaro | 0.30 litre |
| 33 | Dimoxystrobin + epoxiconazole | Swing Gold | 3.00 litre |
| 34 | Dimoxystrobin + epoxiconazole | Swing Gold | 1.50 litre |
| 35 | Dimoxystrobin + epoxiconazole | Swing Gold | 0.75 litre |
| 36 | Dimoxystrobin + epoxiconazole | Swing Gold | 0.375 litre |
| 37 | Epoxiconazole + boscalid | Tracker | 3.00 litre |
| 38 | Epoxiconazole + boscalid | Tracker | 1.50 litre |
| 39 | Epoxiconazole + boscalid | Tracker | 0.75 litre |
| 40 | Epoxiconazole + boscalid | Tracker | 0.375 litre |
| 41 | Untreated | | |
| 42 | Untreated | | |

**Table 3.4 Treatments for *S. nodorum/S. tritici* Experiment 2007 (Site 15)**

| Treatment code | Active ingredient | Product | Dose product/ha |
|---|---|---|---|
| *Standards* | | | |
| 1 | Epoxiconazole | Opus | 2.00 litre |
| 2 | Epoxiconazole | Opus | 1.00 litre |
| 3 | Epoxiconazole | Opus | 0.50 litre |
| 4 | Epoxiconazole | Opus | 0.25 litre |
| 5 | Chlorothalonil | Bravo | 4.00 litre |
| 6 | Chlorothalonil | Bravo | 2.00 litre |
| 7 | Chlorothalonil | Bravo | 1.00 litre |
| 8 | Chlorothalonil | Bravo | 0.50 litre |
| 9 | Tebuconazole | Folicur | 2.00 litre |
| 10 | Tebuconazole | Folicur | 1.00 litre |
| 11 | Tebuconazole | Folicur | 0.50 litre |
| 12 | Tebuconazole | Folicur | 0.25 litre |
| *Test actives* | | | |
| 13 | Pyraclostrobin | Comet 200 | 2.50 litre |
| 14 | Pyraclostrobin | Comet 200 | 1.25 litre |
| 15 | Pyraclostrobin | Comet 200 | 0.625 litre |
| 16 | Pyraclostrobin | Comet 200 | 0.3125 litre |
| 17 | Prochloraz | Poraz | 1.80 litre |
| 18 | Prochloraz | Poraz | 0.90 litre |
| 19 | Prochloraz | Poraz | 0.45 litre |
| 20 | Prochloraz | Poraz | 0.225 litre |
| 21 | Prothioconazole | Proline | 1.60 litre |
| 22 | Prothioconazole | Proline | 0.80 litre |
| 23 | Prothioconazole | Proline | 0.40 litre |
| 24 | Prothioconazole | Proline | 0.20 litre |
| 25 | Prothioconazole + fluoxastrobin | Fandango | 3.00 litre |
| 26 | Prothioconazole + fluoxastrobin | Fandango | 1.50 litre |
| 27 | Prothioconazole + fluoxastrobin | Fandango | 0.75 litre |
| 28 | Prothioconazole + fluoxastrobin | Fandango | 0.375 litre |
| 29 | Prothioconazole + tebuconazole | Prosaro | 2.40 litre |
| 30 | Prothioconazole + tebuconazole | Prosaro | 1.20 litre |
| 31 | Prothioconazole + tebuconazole | Prosaro | 0.60 litre |
| 32 | Prothioconazole + tebuconazole | Prosaro | 0.30 litre |
| 33 | Dimoxystrobin + epoxiconazole | Swing Gold | 3.00 litre |
| 34 | Dimoxystrobin + epoxiconazole | Swing Gold | 1.50 litre |
| 35 | Dimoxystrobin + epoxiconazole | Swing Gold | 0.75 litre |
| 36 | Dimoxystrobin + epoxiconazole | Swing Gold | 0.375 litre |
| 37 | Epoxiconazole + boscalid | Tracker | 3.00 litre |
| 38 | Epoxiconazole + boscalid | Tracker | 1.50 litre |
| 39 | Epoxiconazole + boscalid | Tracker | 0.75 litre |
| 40 | Epoxiconazole + boscalid | Tracker | 0.375 litre |
| 41 | Untreated | | |
| 42 | Untreated | | |

**Table 3.5 Treatments for *S. tritici* Experiments 2005 (Sites 3, 5, 7)**

| Treatment code | Active ingredient | Product | Dose product/ha |
|---|---|---|---|
| *Standards* | | | |
| 1 | Epoxiconazole | Opus | 2.00 litre |
| 2 | Epoxiconazole | Opus | 1.00 litre |
| 3 | Epoxiconazole | Opus | 0.50 litre |
| 4 | Epoxiconazole | Opus | 0.25 litre |
| 5 | Chlorothalonil | Bravo | 4.00 litre |
| 6 | Chlorothalonil | Bravo | 2.00 litre |
| 7 | Chlorothalonil | Bravo | 1.00 litre |
| 8 | Chlorothalonil | Bravo | 0.50 litre |
| 9 | Tebuconazole | Folicur | 2.00 litre |
| 10 | Tebuconazole | Folicur | 1.00 litre |
| 11 | Tebuconazole | Folicur | 0.50 litre |
| 12 | Tebuconazole | Folicur | 0.25 litre |
| *Test actives* | | | |
| 13 | Pyraclostrobin | Vivid/Comet | 2.00 litre |
| 14 | Pyraclostrobin | Vivid/Comet | 1.00 litre |
| 15 | Pyraclostrobin | Vivid/Comet | 0.50 litre |
| 16 | Pyraclostrobin | Vivid/Comet | 0.25 litre |
| 17 | Trifloxystrobin | Swift | 1.00 litre |
| 18 | Trifloxystrobin | Swift | 0.50 litre |
| 19 | Trifloxystrobin | Swift | 0.25 litre |
| 20 | Trifloxystrobin | Swift | 0.125 litre |
| 21 | Prothioconazole | Proline | 1.60 litre |
| 22 | Prothioconazole | Proline | 0.80 litre |
| 23 | Prothioconazole | Proline | 0.40 litre |
| 24 | Prothioconazole | Proline | 0.20 litre |
| 25 | Prothioconazole + fluoxastrobin | Fandango | 3.00 litre |
| 26 | Prothioconazole + fluoxastrobin | Fandango | 1.50 litre |
| 27 | Prothioconazole + fluoxastrobin | Fandango | 0.75 litre |
| 28 | Prothioconazole + fluoxastrobin | Fandango | 0.375 litre |
| 29 | Prothioconazole + tebuconazole | Prosaro | 2.40 litre |
| 30 | Prothioconazole + tebuconazole | Prosaro | 1.20 litre |
| 31 | Prothioconazole + tebuconazole | Prosaro | 0.60 litre |
| 32 | Prothioconazole + tebuconazole | Prosaro | 0.30 litre |
| 33 | Pyraclostrobin + epoxiconazole | Vivid + Opus | 2.00 litre + 0.50 litre |
| 34 | Pyraclostrobin + epoxiconazole | Vivid + Opus | 1.00 litre + 0.50 litre |
| 35 | Pyraclostrobin + epoxiconazole | Vivid + Opus | 0.50 litre + 0.50 litre |
| 36 | Pyraclostrobin + epoxiconazole | Vivid + Opus | 0.25 litre + 0.50 litre |
| 37 | Epoxiconazole + boscalid | Tracker | 3.00 litre |
| 38 | Epoxiconazole + boscalid | Tracker | 1.50 litre |
| 39 | Epoxiconazole + boscalid | Tracker | 0.75 litre |
| 40 | Epoxiconazole + boscalid | Tracker | 0.375 litre |
| 41 | Untreated | | |
| 42 | Untreated | | |

**Table 3.6 Treatments for *S. tritici* Experiments 2006 (Sites 10, 12, & 14)**

| Treatment code | Active ingredient | Product | Dose product/ha |
|---|---|---|---|
| *Standards* | | | |
| 1 | Epoxiconazole | Opus | 2.00 litre |
| 2 | Epoxiconazole | Opus | 1.00 litre |
| 3 | Epoxiconazole | Opus | 0.50 litre |
| 4 | Epoxiconazole | Opus | 0.25 litre |
| 5 | Chlorothalonil | Bravo | 4.00 litre |
| 6 | Chlorothalonil | Bravo | 2.00 litre |
| 7 | Chlorothalonil | Bravo | 1.00 litre |
| 8 | Chlorothalonil | Bravo | 0.50 litre |
| 9 | Tebuconazole | Folicur | 2.00 litre |
| 10 | Tebuconazole | Folicur | 1.00 litre |
| 11 | Tebuconazole | Folicur | 0.50 litre |
| 12 | Tebuconazole | Folicur | 0.25 litre |
| *Test actives* | | | |
| 13 | Pyraclostrobin | Vivid/Comet | 2.00 litre |
| 14 | Pyraclostrobin | Vivid/Comet | 1.00 litre |
| 15 | Pyraclostrobin | Vivid/Comet | 0.50 litre |
| 16 | Pyraclostrobin | Vivid/Comet | 0.25 litre |
| 17 | Prochloraz | Poraz | 1.80 litre |
| 18 | Prochloraz | Poraz | 0.90 litre |
| 19 | Prochloraz | Poraz | 0.45 litre |
| 20 | Prochloraz | Poraz | 0.225 litre |
| 21 | Prothioconazole | Proline | 1.60 litre |
| 22 | Prothioconazole | Proline | 0.80 litre |
| 23 | Prothioconazole | Proline | 0.40 litre |
| 24 | Prothioconazole | Proline | 0.20 litre |
| 25 | Prothioconazole + fluoxastrobin | Fandango | 3.00 litre |
| 26 | Prothioconazole + fluoxastrobin | Fandango | 1.50 litre |
| 27 | Prothioconazole + fluoxastrobin | Fandango | 0.75 litre |
| 28 | Prothioconazole + fluoxastrobin | Fandango | 0.375 litre |
| 29 | Prothioconazole + tebuconazole | Prosaro | 2.40 litre |
| 30 | Prothioconazole + tebuconazole | Prosaro | 1.20 litre |
| 31 | Prothioconazole + tebuconazole | Prosaro | 0.60 litre |
| 32 | Prothioconazole + tebuconazole | Prosaro | 0.30 litre |
| 33 | Pyraclostrobin + epoxiconazole | Vivid + Opus | 2.00 litre + 0.50 litre |
| 34 | Pyraclostrobin + epoxiconazole | Vivid + Opus | 1.00 litre + 0.50 litre |
| 35 | Pyraclostrobin + epoxiconazole | Vivid + Opus | 0.50 litre + 0.50 litre |
| 36 | Pyraclostrobin + epoxiconazole | Vivid + Opus | 0.25 litre + 0.50 litre |
| 37 | Epoxiconazole + boscalid | Tracker | 3.00 litre |
| 38 | Epoxiconazole + boscalid | Tracker | 1.50 litre |
| 39 | Epoxiconazole + boscalid | Tracker | 0.75 litre |
| 40 | Epoxiconazole + boscalid | Tracker | 0.375 litre |
| 41 | Untreated | | |
| 42 | Untreated | | |

**Table 3.7 Treatments for *S. tritici* Experiments 2007 (Sites 17, 19 & 21)**

| Treatment code | Active ingredient | Product | Dose product/ha |
|---|---|---|---|
| *Standards* | | | |
| 1 | Epoxiconazole | Opus | 2.00 litre |
| 2 | Epoxiconazole | Opus | 1.00 litre |
| 3 | Epoxiconazole | Opus | 0.50 litre |
| 4 | Epoxiconazole | Opus | 0.25 litre |
| 5 | Chlorothalonil | Bravo | 4.00 litre |
| 6 | Chlorothalonil | Bravo | 2.00 litre |
| 7 | Chlorothalonil | Bravo | 1.00 litre |
| 8 | Chlorothalonil | Bravo | 0.50 litre |
| 9 | Tebuconazole | Folicur | 2.00 litre |
| 10 | Tebuconazole | Folicur | 1.00 litre |
| 11 | Tebuconazole | Folicur | 0.50 litre |
| 12 | Tebuconazole | Folicur | 0.25 litre |
| *Test actives* | | | |
| 13 | Pyraclostrobin | Comet 200 | 2.50 litre |
| 14 | Pyraclostrobin | Comet 200 | 1.25 litre |
| 15 | Pyraclostrobin | Comet 200 | 0.625 litre |
| 16 | Pyraclostrobin | Comet 200 | 0.3125 litre |
| 17 | Prochloraz | Poraz | 1.80 litre |
| 18 | Prochloraz | Poraz | 0.90 litre |
| 19 | Prochloraz | Poraz | 0.45 litre |
| 20 | Prochloraz | Poraz | 0.225 litre |
| 21 | Prothioconazole | Proline | 1.60 litre |
| 22 | Prothioconazole | Proline | 0.80 litre |
| 23 | Prothioconazole | Proline | 0.40 litre |
| 24 | Prothioconazole | Proline | 0.20 litre |
| 25 | Prothioconazole + fluoxastrobin | Fandango | 3.00 litre |
| 26 | Prothioconazole + fluoxastrobin | Fandango | 1.50 litre |
| 27 | Prothioconazole + fluoxastrobin | Fandango | 0.75 litre |
| 28 | Prothioconazole + fluoxastrobin | Fandango | 0.375 litre |
| 29 | Prothioconazole + tebuconazole | Prosaro | 2.40 litre |
| 30 | Prothioconazole + tebuconazole | Prosaro | 1.20 litre |
| 31 | Prothioconazole + tebuconazole | Prosaro | 0.60 litre |
| 32 | Prothioconazole + tebuconazole | Prosaro | 0.30 litre |
| 33 | Pyraclostrobin + epoxiconazole | Comet 200 + Opus | 2.50 litre + 0.50 litre |
| 34 | Pyraclostrobin + epoxiconazole | Comet 200 + Opus | 1.25 litre + 0.50 litre |
| 35 | Pyraclostrobin + epoxiconazole | Comet 200 + Opus | 0.625 litre 0.50 litre |
| 36 | Pyraclostrobin + epoxiconazole | Comet 200 + Opus | 0.3125 litre 0.50 litre |
| 37 | Epoxiconazole + boscalid | Tracker | 3.00 litre |
| 38 | Epoxiconazole + boscalid | Tracker | 1.50 litre |
| 39 | Epoxiconazole + boscalid | Tracker | 0.75 litre |
| 40 | Epoxiconazole + boscalid | Tracker | 0.375 litre |
| 41 | Untreated | | |
| 42 | Untreated | | |

**Table 3.8 Treatments for Rust Experiments 2005 (Sites 2 & 4)**

| Treatment code | Active ingredient | Product | Dose product/ha |
|---|---|---|---|
| *Standards* | | | |
| 1 | Epoxiconazole | Opus | 2.00 litre |
| 2 | Epoxiconazole | Opus | 1.00 litre |
| 3 | Epoxiconazole | Opus | 0.50 litre |
| 4 | Epoxiconazole | Opus | 0.25 litre |
| 5 | Chlorothalonil | Bravo | 4.00 litre |
| 6 | Chlorothalonil | Bravo | 2.00 litre |
| 7 | Chlorothalonil | Bravo | 1.00 litre |
| 8 | Chlorothalonil | Bravo | 0.50 litre |
| 9 | Tebuconazole | Folicur | 2.00 litre |
| 10 | Tebuconazole | Folicur | 1.00 litre |
| 11 | Tebuconazole | Folicur | 0.50 litre |
| 12 | Tebuconazole | Folicur | 0.25 litre |
| *Test actives* | | | |
| 13 | Azoxystrobin | Amistar | 2.00 litre |
| 14 | Azoxystrobin | Amistar | 1.00 litre |
| 15 | Azoxystrobin | Amistar | 0.50 litre |
| 16 | Azoxystrobin | Amistar | 0.25 litre |
| 17 | Pyraclostrobin | Vivid/Comet | 2.00 litre |
| 18 | Pyraclostrobin | Vivid/Comet | 1.00 litre |
| 19 | Pyraclostrobin | Vivid/Comet | 0.50 litre |
| 20 | Pyraclostrobin | Vivid/Comet | 0.25 litre |
| 21 | Prothioconazole | Proline | 1.60 litre |
| 22 | Prothioconazole | Proline | 0.80 litre |
| 23 | Prothioconazole | Proline | 0.40 litre |
| 24 | Prothioconazole | Proline | 0.20 litre |
| 25 | Prothioconazole + fluoxastrobin | Fandango | 3.00 litre |
| 26 | Prothioconazole + fluoxastrobin | Fandango | 1.50 litre |
| 27 | Prothioconazole + fluoxastrobin | Fandango | 0.75 litre |
| 28 | Prothioconazole + fluoxastrobin | Fandango | 0.375 litre |
| 29 | Prothioconazole + tebuconazole | Prosaro | 2.40 litre |
| 30 | Prothioconazole + tebuconazole | Prosaro | 1.20 litre |
| 31 | Prothioconazole + tebuconazole | Prosaro | 0.60 litre |
| 32 | Prothioconazole + tebuconazole | Prosaro | 0.30 litre |
| 33 | Epoxiconazole + boscalid | Tracker | 3.00 litre |
| 34 | Epoxiconazole + boscalid | Tracker | 1.50 litre |
| 35 | Epoxiconazole + boscalid | Tracker | 0.75 litre |
| 36 | Epoxiconazole + boscalid | Tracker | 0.375 litre |
| 37 | Untreated | | |
| 38 | Untreated | | |

**Table 3.9 Treatments for Rust Experiments 2006 (Sites 9 & 11)**

| Treatment code | Active ingredient | Product | Dose product/ha |
|---|---|---|---|
| *Standards* | | | |
| 1 | Epoxiconazole | Opus | 2.00 litre |
| 2 | Epoxiconazole | Opus | 1.00 litre |
| 3 | Epoxiconazole | Opus | 0.50 litre |
| 4 | Epoxiconazole | Opus | 0.25 litre |
| 5 | Chlorothalonil | Bravo | 4.00 litre |
| 6 | Chlorothalonil | Bravo | 2.00 litre |
| 7 | Chlorothalonil | Bravo | 1.00 litre |
| 8 | Chlorothalonil | Bravo | 0.50 litre |
| 9 | Tebuconazole | Folicur | 2.00 litre |
| 10 | Tebuconazole | Folicur | 1.00 litre |
| 11 | Tebuconazole | Folicur | 0.50 litre |
| 12 | Tebuconazole | Folicur | 0.25 litre |
| *Test actives* | | | |
| 13 | Azoxystrobin | Amistar | 2.00 litre |
| 14 | Azoxystrobin | Amistar | 1.00 litre |
| 15 | Azoxystrobin | Amistar | 0.50 litre |
| 16 | Azoxystrobin | Amistar | 0.25 litre |
| 17 | Pyraclostrobin | Vivid/Comet | 2.00 litre |
| 18 | Pyraclostrobin | Vivid/Comet | 1.00 litre |
| 19 | Pyraclostrobin | Vivid/Comet | 0.50 litre |
| 20 | Pyraclostrobin | Vivid/Comet | 0.25 litre |
| 21 | Prothioconazole | Proline | 1.60 litre |
| 22 | Prothioconazole | Proline | 0.80 litre |
| 23 | Prothioconazole | Proline | 0.40 litre |
| 24 | Prothioconazole | Proline | 0.20 litre |
| 25 | Prothioconazole + fluoxastrobin | Fandango | 3.00 litre |
| 26 | Prothioconazole + fluoxastrobin | Fandango | 1.50 litre |
| 27 | Prothioconazole + fluoxastrobin | Fandango | 0.75 litre |
| 28 | Prothioconazole + fluoxastrobin | Fandango | 0.375 litre |
| 29 | Prothioconazole + tebuconazole | Prosaro | 2.40 litre |
| 30 | Prothioconazole + tebuconazole | Prosaro | 1.20 litre |
| 31 | Prothioconazole + tebuconazole | Prosaro | 0.60 litre |
| 32 | Prothioconazole + tebuconazole | Prosaro | 0.30 litre |
| 33 | Epoxiconazole + boscalid | Tracker | 3.00 litre |
| 34 | Epoxiconazole + boscalid | Tracker | 1.50 litre |
| 35 | Epoxiconazole + boscalid | Tracker | 0.75 litre |
| 36 | Epoxiconazole + boscalid | Tracker | 0.375 litre |
| 37 | Spiroxamine | Torch Extra | 1.80 litre |
| 38 | Spiroxamine | Torch Extra | 0.90 litre |
| 39 | Spiroxamine | Torch Extra | 0.45 litre |
| 40 | Spiroxamine | Torch Extra | 0.225 litre |
| 41 | Untreated | | |
| 42 | Untreated | | |

**Table 3.10 Treatments for Rust Experiments 2007 (Sites 16 & 18)**

| Treatment code | Active ingredient | Product | Dose product/ha |
|---|---|---|---|
| *Standards* | | | |
| 1 | Epoxiconazole | Opus | 2.00 litre |
| 2 | Epoxiconazole | Opus | 1.00 litre |
| 3 | Epoxiconazole | Opus | 0.50 litre |
| 4 | Epoxiconazole | Opus | 0.25 litre |
| 5 | Chlorothalonil | Bravo | 4.00 litre |
| 6 | Chlorothalonil | Bravo | 2.00 litre |
| 7 | Chlorothalonil | Bravo | 1.00 litre |
| 8 | Chlorothalonil | Bravo | 0.50 litre |
| 9 | Tebuconazole | Folicur | 2.00 litre |
| 10 | Tebuconazole | Folicur | 1.00 litre |
| 11 | Tebuconazole | Folicur | 0.50 litre |
| 12 | Tebuconazole | Folicur | 0.25 litre |
| *Test actives* | | | |
| 13 | Azoxystrobin | Amistar | 2.00 litre |
| 14 | Azoxystrobin | Amistar | 1.00 litre |
| 15 | Azoxystrobin | Amistar | 0.50 litre |
| 16 | Azoxystrobin | Amistar | 0.25 litre |
| 17 | Pyraclostrobin | Comet 200 | 2.50 litre |
| 18 | Pyraclostrobin | Comet 200 | 1.25 litre |
| 19 | Pyraclostrobin | Comet 200 | 0.625 litre |
| 20 | Pyraclostrobin | Comet 200 | 0.3125 litre |
| 21 | Prothioconazole | Proline | 1.60 litre |
| 22 | Prothioconazole | Proline | 0.80 litre |
| 23 | Prothioconazole | Proline | 0.40 litre |
| 24 | Prothioconazole | Proline | 0.20 litre |
| 25 | Prothioconazole + fluoxastrobin | Fandango | 3.00 litre |
| 26 | Prothioconazole + fluoxastrobin | Fandango | 1.50 litre |
| 27 | Prothioconazole + fluoxastrobin | Fandango | 0.75 litre |
| 28 | Prothioconazole + fluoxastrobin | Fandango | 0.375 litre |
| 29 | Prothioconazole + tebuconazole | Prosaro | 2.40 litre |
| 30 | Prothioconazole + tebuconazole | Prosaro | 1.20 litre |
| 31 | Prothioconazole + tebuconazole | Prosaro | 0.60 litre |
| 32 | Prothioconazole + tebuconazole | Prosaro | 0.30 litre |
| 33 | Epoxiconazole + boscalid | Tracker | 3.00 litre |
| 34 | Epoxiconazole + boscalid | Tracker | 1.50 litre |
| 35 | Epoxiconazole + boscalid | Tracker | 0.75 litre |
| 36 | Epoxiconazole + boscalid | Tracker | 0.375 litre |
| 37 | Spiroxamine | Torch Extra | 1.80 litre |
| 38 | Spiroxamine | Torch Extra | 0.90 litre |
| 39 | Spiroxamine | Torch Extra | 0.45 litre |
| 40 | Spiroxamine | Torch Extra | 0.225 litre |
| 41 | Untreated | | |
| 42 | Untreated | | |

**Table 3.11 Treatments for Mildew Experiment 2005 (Site 6)**

| Treatment code | Active ingredient | Product | Dose product/ha |
|---|---|---|---|
| *Standards* | | | |
| 1 | Epoxiconazole | Opus | 2.00 litre |
| 2 | Epoxiconazole | Opus | 1.00 litre |
| 3 | Epoxiconazole | Opus | 0.50 litre |
| 4 | Epoxiconazole | Opus | 0.25 litre |
| 5 | Fenpropidin | Tern | 2.00 litre |
| 6 | Fenpropidin | Tern | 1.00 litre |
| 7 | Fenpropidin | Tern | 0.50 litre |
| 8 | Fenpropidin | Tern | 0.25 litre |
| 9 | Fenpropimorph | Corbel | 2.00 litre |
| 10 | Fenpropimorph | Corbel | 1.00 litre |
| 11 | Fenpropimorph | Corbel | 0.50 litre |
| 12 | Fenpropimorph | Corbel | 0.25 litre |
| *Test actives* | | | |
| 13 | Cyprodinil | Unix | 2.00 kg |
| 14 | Cyprodinil | Unix | 1.00 kg |
| 15 | Cyprodinil | Unix | 0.50 kg |
| 16 | Cyprodinil | Unix | 0.25 kg |
| 17 | Spiroxamine | Neon | 3.00 litre |
| 18 | Spiroxamine | Neon | 1.50 litre |
| 19 | Spiroxamine | Neon | 0.75 litre |
| 20 | Spiroxamine | Neon | 0.375 litre |
| 21 | Quinoxyfen | Fortress | 0.60 litre |
| 22 | Quinoxyfen | Fortress | 0.30 litre |
| 23 | Quinoxyfen | Fortress | 0.15 litre |
| 24 | Quinoxyfen | Fortress | 0.075 litre |
| 25 | Prothioconazole | Proline | 1.60 litre |
| 26 | Prothioconazole | Proline | 0.80 litre |
| 27 | Prothioconazole | Proline | 0.40 litre |
| 28 | Prothioconazole | Proline | 0.20 litre |
| 29 | Metrafenone | Flexity | 1.00 litre |
| 30 | Metrafenone | Flexity | 0.50 litre |
| 31 | Metrafenone | Flexity | 0.25 litre |
| 32 | Metrafenone | Flexity | 0.125 litre |
| 33 | Cyflufenamid | Cyflamid | 1.00 litre |
| 34 | Cyflufenamid | Cyflamid | 0.50 litre |
| 35 | Cyflufenamid | Cyflamid | 0.25 litre |
| 36 | Cyflufenamid | Cyflamid | 0.125 litre |
| 37 | Proquinazid | Talius | 0.50 litre |
| 38 | Proquinazid | Talius | 0.25 litre |
| 39 | Proquinazid | Talius | 0.125 litre |
| 40 | Proquinazid | Talius | 0.0625 litre |
| 41 | Untreated | --- | --- |
| 42 | Untreated | --- | --- |

**Table 3.11 Treatments for Mildew Experiment 2006 & 2007 (Sites 13 & 20)**

| Treatment code | Active ingredient | Product | Dose product/ha |
|---|---|---|---|
| *Standards* | | | |
| 1 | Epoxiconazole | Opus | 2.00 litre |
| 2 | Epoxiconazole | Opus | 1.00 litre |
| 3 | Epoxiconazole | Opus | 0.50 litre |
| 4 | Epoxiconazole | Opus | 0.25 litre |
| 5 | Fenpropidin | Tern | 2.00 litre |
| 6 | Fenpropidin | Tern | 1.00 litre |
| 7 | Fenpropidin | Tern | 0.50 litre |
| 8 | Fenpropidin | Tern | 0.25 litre |
| 9 | Fenpropimorph | Corbel | 2.00 litre |
| 10 | Fenpropimorph | Corbel | 1.00 litre |
| 11 | Fenpropimorph | Corbel | 0.50 litre |
| 12 | Fenpropimorph | Corbel | 0.25 litre |
| *Test actives* | | | |
| 13 | Cyprodinil | Unix | 2.00 kg |
| 14 | Cyprodinil | Unix | 1.00 kg |
| 15 | Cyprodinil | Unix | 0.50 kg |
| 16 | Cyprodinil | Unix | 0.25 kg |
| 17 | Spiroxamine | Torch Extra | 1.80 litres |
| 18 | Spiroxamine | Torch Extra | 0.90 litre |
| 19 | Spiroxamine | Torch Extra | 0.45 litre |
| 20 | Spiroxamine | Torch Extra | 0.225 litre |
| 21 | Quinoxyfen | Fortress | 0.60 litre |
| 22 | Quinoxyfen | Fortress | 0.30 litre |
| 23 | Quinoxyfen | Fortress | 0.15 litre |
| 24 | Quinoxyfen | Fortress | 0.075 litre |
| 25 | Prothioconazole | Proline | 1.60 litre |
| 26 | Prothioconazole | Proline | 0.80 litre |
| 27 | Prothioconazole | Proline | 0.40 litre |
| 28 | Prothioconazole | Proline | 0.20 litre |
| 29 | Metrafenone | Flexity | 1.00 litre |
| 30 | Metrafenone | Flexity | 0.50 litre |
| 31 | Metrafenone | Flexity | 0.25 litre |
| 32 | Metrafenone | Flexity | 0.125 litre |
| 33 | Cyflufenamid | Cyflamid | 1.00 litre |
| 34 | Cyflufenamid | Cyflamid | 0.50 litre |
| 35 | Cyflufenamid | Cyflamid | 0.25 litre |
| 36 | Cyflufenamid | Cyflamid | 0.125 litre |
| 37 | Proquinazid | Talius | 0.50 litre |
| 38 | Proquinazid | Talius | 0.25 litre |
| 39 | Proquinazid | Talius | 0.125 litre |
| 40 | Proquinazid | Talius | 0.0625 litre |
| 41 | Untreated | --- | --- |
| 42 | Untreated | --- | --- |

## 3.5 Assessments and records

### 3.5.1 Assessments of leaf disease and green leaf area

Levels of foliar disease and green leaf area were assessed as described below on 25-50 shoots sampled from across the experiment area immediately prior to fungicide application.

Approximately three weeks and six weeks after treatments were applied, all plots were assessed, by randomly sampling 10 shoots per plot and estimating the average percentage leaf area affected by disease symptoms (including any necrosis or chlorosis attributable to disease) on each leaf layer. The first assessment was aimed at quantifying disease on leaves 3 and 4, giving an indication of eradicant activity of fungicides. The second assessment recorded treatment effects on leaves 1 and 2 giving a measure of the protectant properties of the fungicides. The precise timing of assessments was according to the judgement of site managers.

### 3.5.2 Assessments of ear diseases

Diseases were assessed on a random sample of 10 ears per plot at GS 85 if more than 5% ear area or more than five grain sites per ear were affected in untreated plots.

### 3.5.3 Stem-base disease

Stem-base diseases (eyespot, sharp eyespot and *Fusarium spp.*) were assessed on 25 stems per plot in untreated plots at GS 75. If over 25% of stems had moderate or severe lesions, or if over 10% of stems had severe lesions, then all plots were assessed.

### 3.5.4 Lodging

If plots were affected by lodging, the percentage plot area affected was recorded prior to harvest.

### 3.5.5 Yield

All plots were harvested using a plot combine harvester. Grain samples were taken for moisture determination and grain quality assessments. Yields were calculated at 85% dry matter.

### 3.5.6 Grain quality

Specific weight of grain was measured for each plot and adjusted to 85% dry matter.

### 3.5.7 Agronomic records

Details of site, soil type and all agrochemical inputs were recorded.

## 3.6 Data handling

Disease, green leaf area, yield and grain quality data were collected manually or directly onto portable computers. All data were transferred to Microsoft Excel worksheets after collection.

## 3.7 Statistical analysis

### 3.7.1 Individual season and site assessments

Each season, each assessment (site, variate, date, leaf layer) was summarised by analysis of variance and the validity of the analysis was checked by examination of residuals.

An over-assessment analysis of data from a previous Appropriate Fungicide Dose project has shown that, whilst no transformation is needed for yield or specific weights, a logit transformation of % disease and % green leaf area provides a more valid analysis. Thus disease and green leaf area were analysed on a logit scale and back-transformed for presentation.

A small number of extreme outliers were removed from the data after consultation as to the cause.

In some cases plots of residuals against plot number showed a linear trend in the residuals within some of the blocks. These trends were removed by using covariates on plot number within each block.

For each disease assessment, dose-response curves were plotted for each fungicide. Exponential curves of the form $y=a+be^{kx}$ , where y = % disease and x = proportion of the recommended dose, were fitted. Exponential curves were also fitted to the green leaf areas and harvest variables. All curves were constrained to pass through the mean of the untreated (dose = 0) plots.

Variates that did not contribute useful information were excluded from further analysis. These were defined to be variates for which there was no significant effect of treatment, disease variates for which there was an average of less than 5% disease on untreated plots, and green leaf areas for which there was more than an average of 90% green leaf area on the untreated plots. In addition, assessments where more than one disease was recorded on a particular date were examined to check whether they were reliable. Any assessments felt to be unsafe were excluded from over-assessment means.

Over-assessment means were calculated for each site and disease, together with corresponding green leaf area means. Means for all transformed variables were calculated on the logit scale and then back-transformed for presentation. For *Septoria tritici*, means were calculated separately for protectant fungicide activity (leaves just emerged, or still to emerge at time of treatment, together with ear disease), and eradicant fungicide activity (the first two non-protectant leaves down the stem). For other diseases the eradicant and protectant categories were combined.

Each season, over-site means were calculated for each disease. These were constructed from valid assessments and giving equal weight to each site, rather than each assessment.
At each stage exponential curves were fitted to the means.

<u>3.7.2 Over-season means</u>

In a previous project, incomplete tables means for fungicides and doses by site were analysed using the method of fitting constants, which was has been widely used in the analysis of variety trials. More recently, residual maximum likelihood (REML) has been developed for the analysis of this type of data (Patterson 1997) and is now available in several general purpose statistical computer packages, including GenStat. The REML method has the advantage of including information on product differences that may be available in the site means, and of calculating the appropriate weight to give this information in the combined means. REML means are always between the unadjusted and the ‘fitcon’ means of the data. If the variability between sites is large relative to the variation within sites, as is usually the case with multi-site and season experiments, REML means will be close to the ‘fitcon’ means. Conversely if the variability between sites was small relative to the variation within sites, REML means would be close to the unadjusted means.

The REML method is more flexible than the fitting constants method, but this flexibility does means that the most appropriate form of the method for the data produced in this project needed to be investigated. REML analysis is sensitive to the proportion of the data matrix that is missing. For the UK data, although it is theoretically possible to include all the data from individual assessment dates and leaf layers at each site, the resulting data matrix is very sparse and investigation has shown that the method often does not converge to give a solution. Several versions of REML analysis have been examined. For the UK data, the average percent disease over assessments, calculated from the first two leaves in each of the eradicant and protectant categories at each site, provides a suitable measure of disease for combining over experiments using the REML method. The form of REML used for calculating over site and season means was a fixed effect with levels representing each fungicide and dose combination plus untreated, and a random effect with a level for each site and season. Corresponding green leaf areas, yields and specific weights were summarised by REML in the same way. Exponential curves were fitted to the REML adjusted means to provide over site and season summaries.

# 4.0 RESULTS

## 4.1 *Stagonospora (Septoria) nodorum* experiments

### 4.1.1 Disease control.

All currently available commercial cultivars that are susceptible to *S. nodorum* are also susceptible to *Septoria tritici*. Since both diseases are favoured by similar weather conditions, mixed infections frequently occur. It is rarely possible to differentiate in the field between the foliar symptoms caused by the two fungi and activity of fungicides against *S. nodorum* can therefore best be assessed by the ear symptoms known as glume blotch.

The control of glume blotch given by the different fungicides at various doses (zero, quarter, half, full and double the label recommended doses) at Site 1 in 2005 and at Site 8 in 2006 is shown in Figures 4.1 and 4.2. It is important to bear in mind that fungicides in this experiment were applied to leaves before ear emergence. Control of glume blotch therefore is an indirect effect of fungicide activity on foliar infection by *S. nodorum*

In 2005, most fungicides gave reasonable control of *S. nodorum*, although trifloxystrobin (Swift) and chlorothalonil (Bravo) were weak at low doses and dimoxystrobin + epoxiconazole (Swing Gold) did not improve control as dose increased above quarter dose (Figure 4.1). Fungicides based on prothioconazole (Proline, Prosaro and Fandango) were most effective; products containing epoxiconazole (Opus, Swing Gold and Tracker) were slightly less effective.

In 2006, although the severity of glume blotch at zero dose was greater than in 2005, most fungicides continued to give reasonable control of the disease; exceptions were chlorothalonil (Bravo) and prochloraz (Poraz) (Figure 4.2). Products based on epoxiconazole and prothioconazole all performed well, and mixtures were generally better than straight products. Pyraclostrobin continued to give useful control of glume blotch.

Levels of glume blotch in 2007 were very low and dose-response curves could not be produced. This may have been due to the change of cultivar from Savannah to Cordiale.

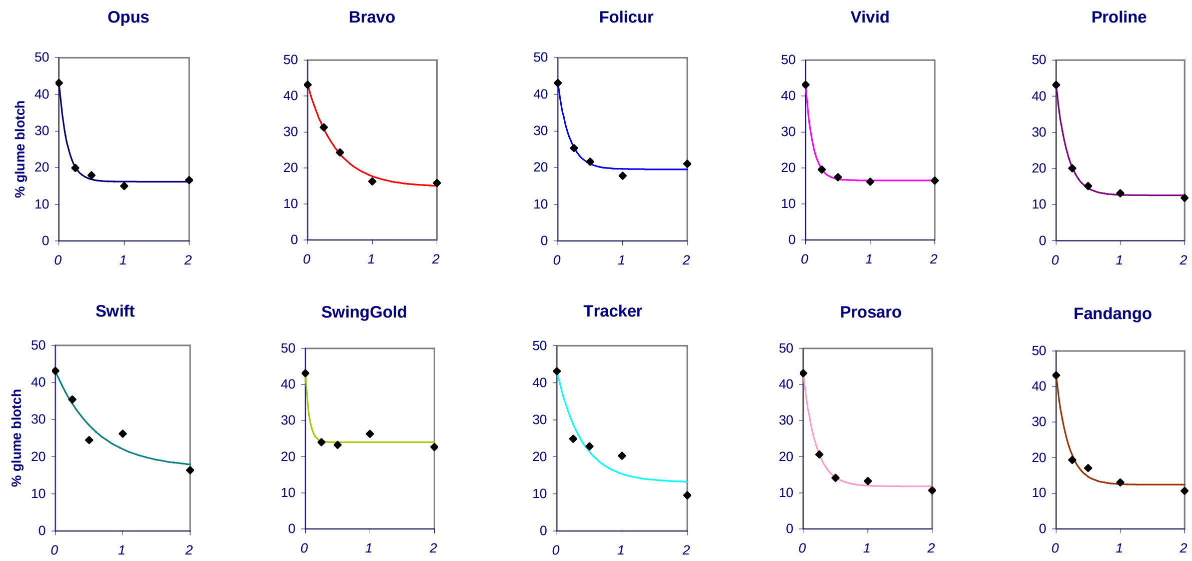


Figure 4.1 Fungicide dose-response curves for glume blotch (% ear area affected) at Site 1 in 2005. In this and all subsequent dose response figures, the dots represent mean values and the lines represent exponential curves fitted to means.

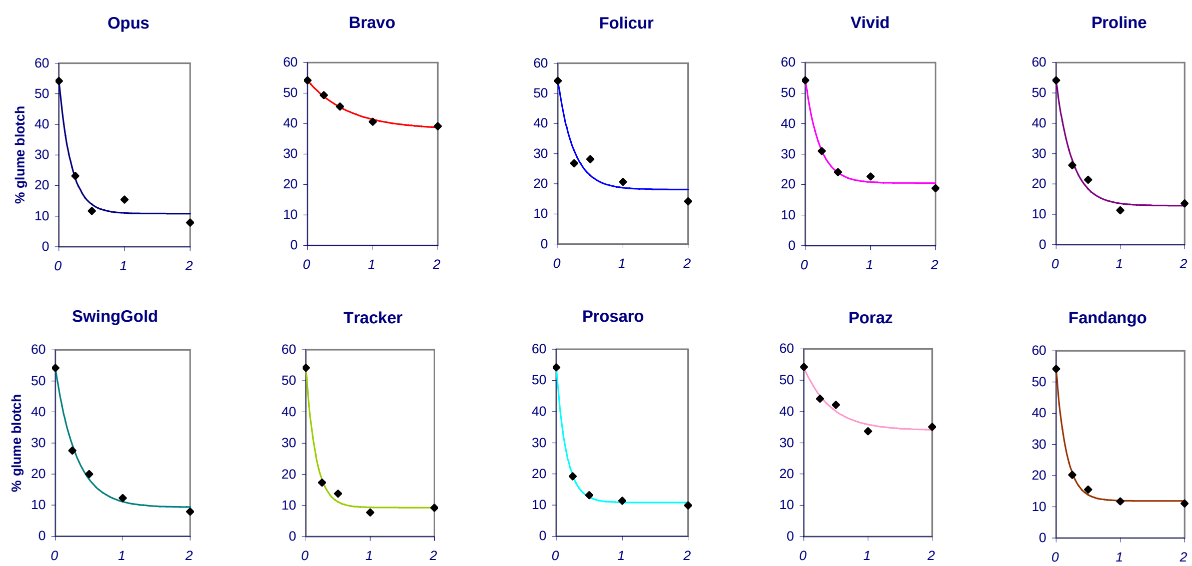


Figure 4.2 Fungicide dose-response curves for glume blotch (% ear area affected) at Site 8 in 2006

4.1.2 Yield

Yield responses at the *S. nodorum* site in 2005 and 2006 reflect control of both *S. tritici* and *S. nodorum*. The combined effects of both diseases caused substantial yield loss in 2005 (Figure 4.3). Most of the azole containing fungicides, with the exception of Folicur and Swing Gold, were very effective at increasing yield. The yield response from full dose Proline was 3.8 tonnes/ha; Prosaro gave a slightly greater increase (4.0 tonnes/ha) and Fandango a slightly smaller increase (3.6 tonnes/ha) at full dose. The yield increase given by full dose Opus was 3.1 tonnes/ha; Tracker gave a slightly lower yield response (2.9 tonnes/ha). The poor performance of strobilurin fungicides (Vivid, Swift) reflects, in part, the resistance situation regarding strobilurins and *S. tritici*. Vivid, which gave better control of glume blotch, gave a yield response of 1.3 tonnes/ha while Swift gave a 0.9 tonne/ha response at full dose. The response from full dose Bravo was 1.8 tonnes/ha.

The poorer performance of chlorothalonil (Bravo) in 2006 (Figure 4.4) compared with 2005, was probably due to sprays being delayed by wet weather until 28 May when the flag leaf was fully emerged in 2006. In 2005, sprays were applied on 9 May, when the flag leaf was just starting to emerge. Both Proline and Fandango increased yield by 2.8 tonnes/ha at full dose and Prosaro gave an increase of 3.1 tonnes/ha. Opus and Tracker increased yield by 2.9 tonnes/ha at full dose and Swing Gold was more effective than in 2005, giving an increase of 2.5 tonnes/ha at full dose. Of the other azoles, Folicur increased yield by 1.8 tonnes/ha at full dose and Poraz gave a 0.8 tonne/ha response. The increase given by the straight strobilurin product (Vivid) was 0.9 tonne/ha at full dose.

In 2007 the *S. tritici* epidemic, although late, was so severe that *S. nodorum* was probably unable to compete and the yield data almost completely reflected *S. tritici* control. However, as already mentioned, the cultivar was changed in 2007 from Savannah to Cordiale. Although both have a similar resistance rating for glume blotch, Cordiale may be less susceptible. Full doses of Proline, Fandango and Prosaro increased yield by 1.4, 1.3 and 1.7 tonnes/ha respectively (Figure 4.5). Opus and Tracker gave increases of 1.9 and 1.7 tonnes/ha respectively at full dose and Swing Gold increased yield by 1.2 tonnes/ha. Folicur gave a 0.6 tonne/ha response and Poraz a 0.5 tonne/ha yield increase at full dose. The response from a full dose of pyraclostrobin (Comet 200) was also 0.5 tonnes/ha. Bravo, which was much more effective in 2007, increased yield by 1.5 tonnes/ha at full dose.

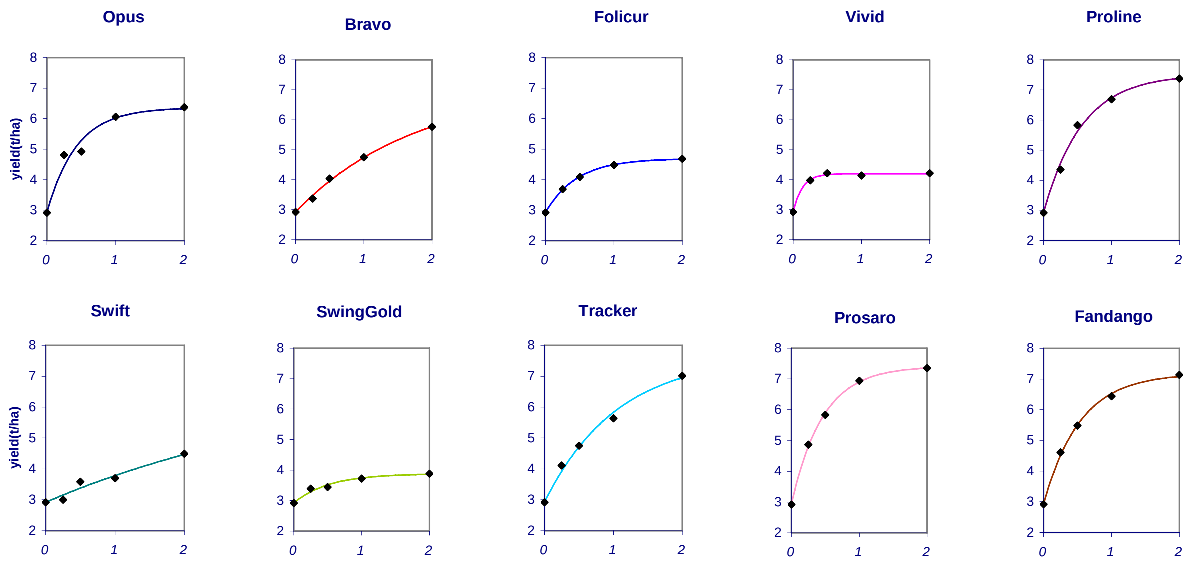


Figure 4.3 Fungicide dose-response curves for yield at Site 1in 2005

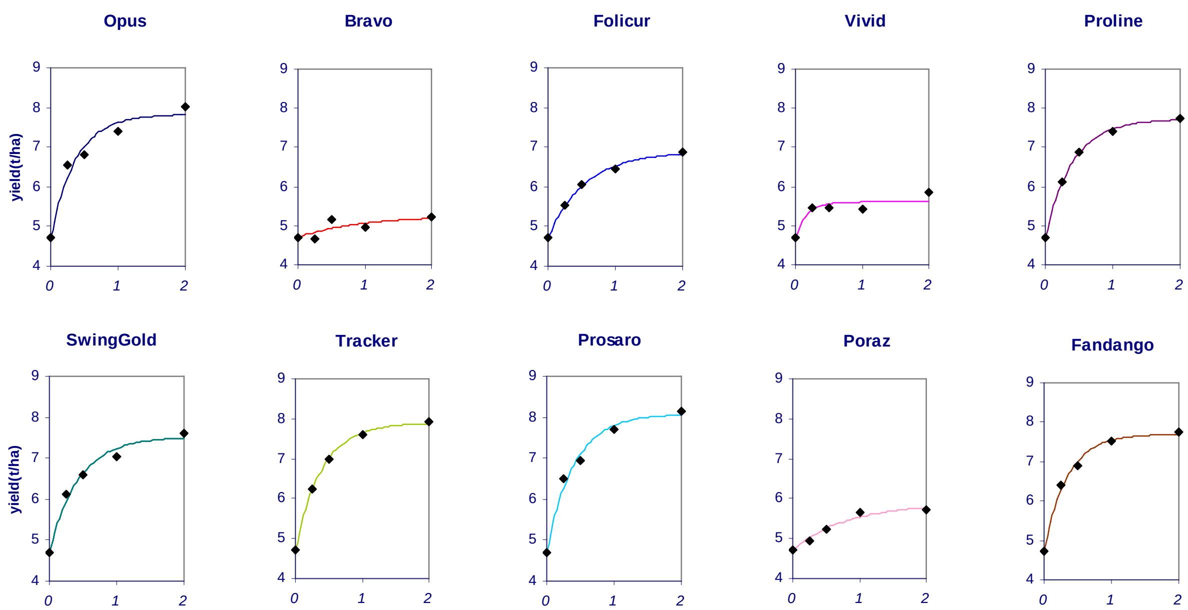


Figure 4.4 Fungicide dose-response curves for yield at Site 8 in 2006

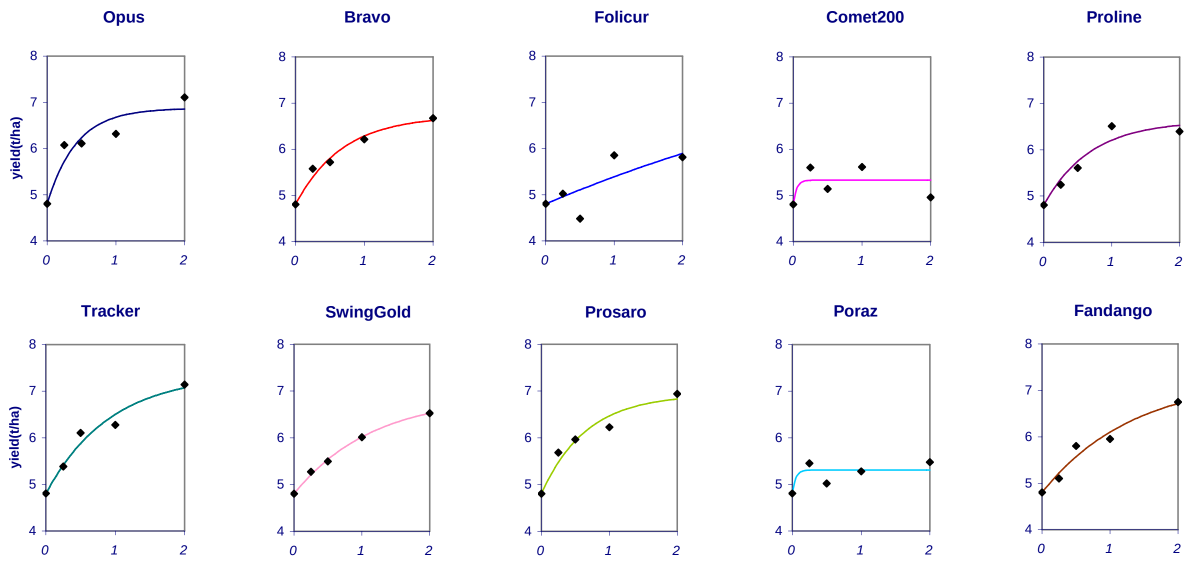


Figure 4.5 Fungicide dose-response curves for yield at Site 15 in 2007

### 4.1.3 Specific weight

Dose-response curves for specific weight were broadly similar to those obtained for yield. In 2005, prothioconazole based products gave the greatest increases in specific weight at full dose – Proline 6.5, Prosaro 6.4 and Fandango 5.8 kg/hl (Figure 4.6). Increases from epoxiconazole based products were slightly smaller - Opus 5.5, Tracker 4.1 and Swing Gold 2.0 kg/hl at full doses. Full dose Folicur gave an increase of 2.7 kg/hl while the strobilurins were lower – Vivid 2.5 and Swift 1.6 kg/hl. Bravo increased specific weight by 2.8 kg/hl.

Increases in specific weight in 2006 were generally larger with full doses of Proline, Prosaro and Fandango giving 9.6, 10.1 and 10.5 kg/hl, while Opus, Tracker and Swing Gold gave increases of 9.0, 10.3 and 9.6 kg/hl respectively (Figure 4.7). Full dose Folicur increased specific weight by 6.4 kg/hl and Poraz by 2.8 kg/ha. Vivid had a flat dose-response curve above quarter dose, giving an increase in specific weight of 3.5 kg/hl while Bravo gave an increase of 1.1 kg/hl at full dose.

Smaller increases in specific weight were recorded in 2007 (Figure 4.8). Full doses of Proline, Prosaro and Fandango gave increases of 3.3, 3.9 and 3.8 kg/ha while Opus, Tracker and Swing Gold increased specific weight by 4.4, 4.2 and 2.6 kg/hl respectively. Full doses of Folicur and Poraz were similar at 1.7 and 1.6 kg/hl and Bravo increased specific weight by 3.2 kg/hl.

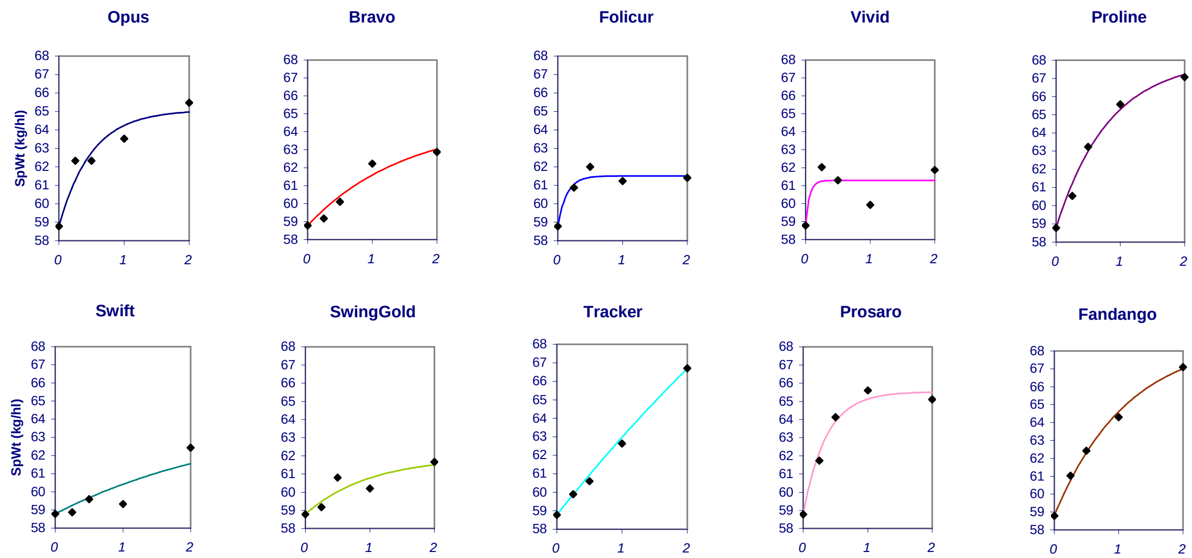


Figure 4.6 Fungicide dose-response curves for specific weight at Site 1 in 2005

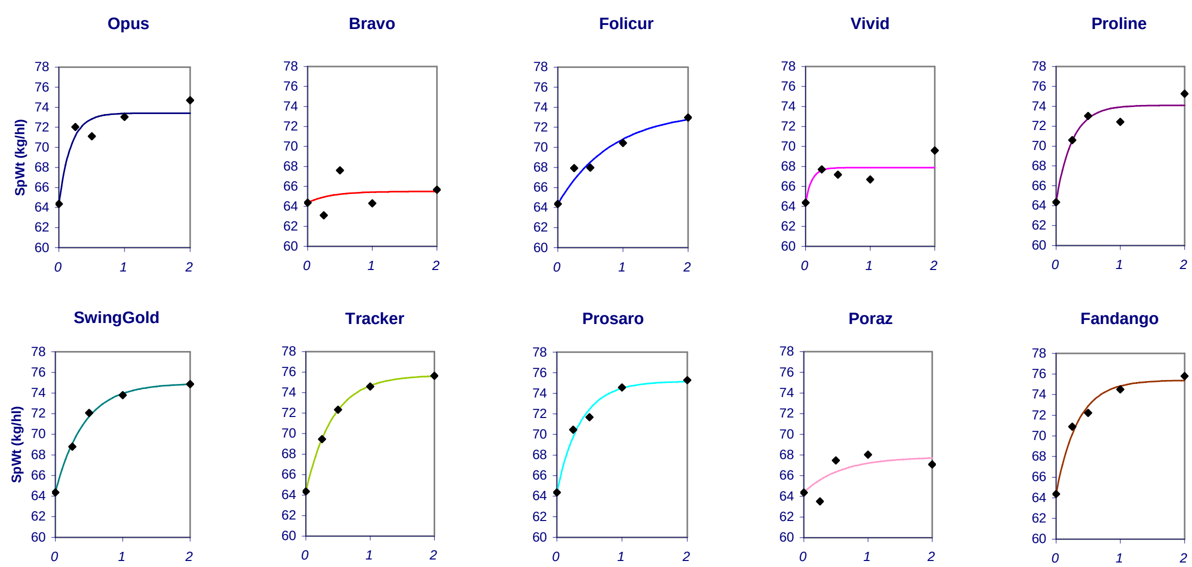


Figure 4.7 Fungicide dose-response curves for specific weight at Site 8 in 2006

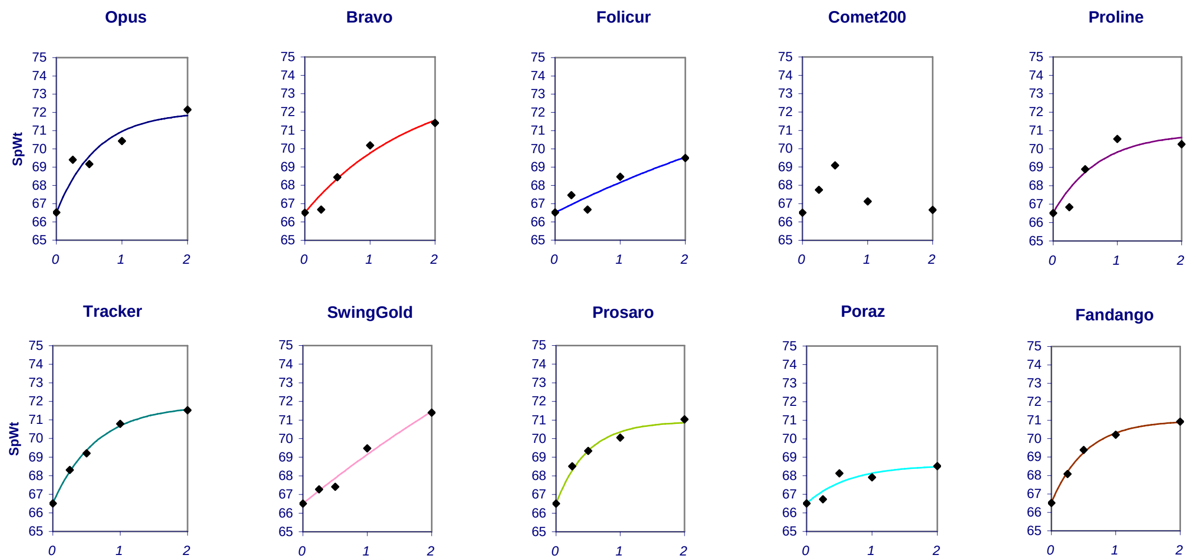


Figure 4.8 Fungicide dose-response curves for specific weight at Site 15 in 2007

## 4.2 *Septoria tritici* experiments

4.2.1 Disease control.

High levels of *S. tritici* were encountered in 2005. Fandango, Opus, Proline, Prosaro, Tracker and half dose Opus + Vivid all gave good disease control on the upper leaves where activity was mainly protectant (Figure 4.10). Folicur and Bravo were less effective and the straight strobilurin fungicides, Vivid and Swift, gave poor control. All products were less effective on lower leaves where some eradicant activity was required (Figure 4.9)

In 2006, data for the Scottish site was variable and that site was excluded from the mean data presented in Figures 4.11 and 4.12. Again, Fandango, Opus, Proline, Prosaro, Tracker and half dose Opus + Vivid gave broadly similar levels of control, although Tracker was noticeably less effective than Opus in protectant activity at the Irish site (Site 14). The straight strobilurin product, Vivid, was slightly more effective in 2006. Poraz, which was introduced into the experiments for the first time in 2006 because of its slightly different active site from other azole fungicides, was slightly poorer in eradicant activity compared with other azoles, with the exception of Folicur.

Data on eradicant activity was only obtained from the Scottish site in 2007, and although disease levels were low, differences in activity were demonstrated, with Folicur and Poraz less effective at low doses than Opus, Proline and Prosaro (Figure 4.13). This was also the case for protectant activity when meaned across the three sites (Figure 4.14). As in 2006, there was an indication that pyraclostrobin (Comet 200) was giving some useful control of *S. tritici*.

Cross-site analysis over the three years (Figures 4.15 and 4.16) shows that Opus, Proline and Prosaro gave reliable protectant and eradicant control. The addition of a strobilurin partner to Proline (as Fandango) did not appear to offer any advantage, nor did the addition of pyraclostrobin to half dose Opus. Although all products performed better as protectants than eradicants, this was particularly obvious with low doses of Poraz, with Tracker and with Bravo.

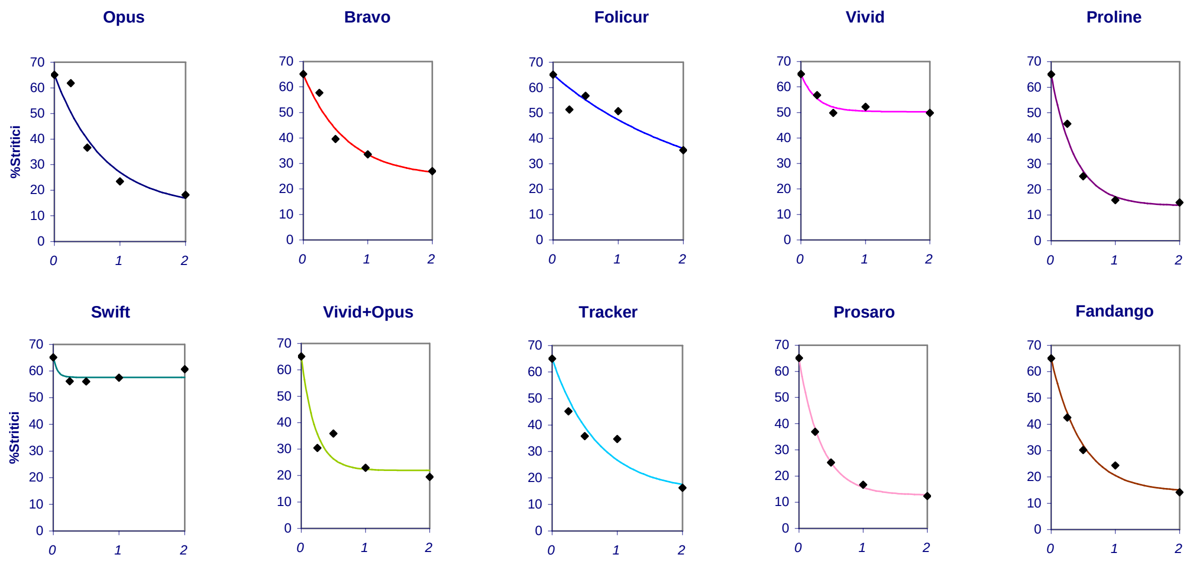


Figure 4.9 Fungicide dose-response curves for eradicant activity against *S. tritici* meaned across sites 3, 5 and 7 in 2005

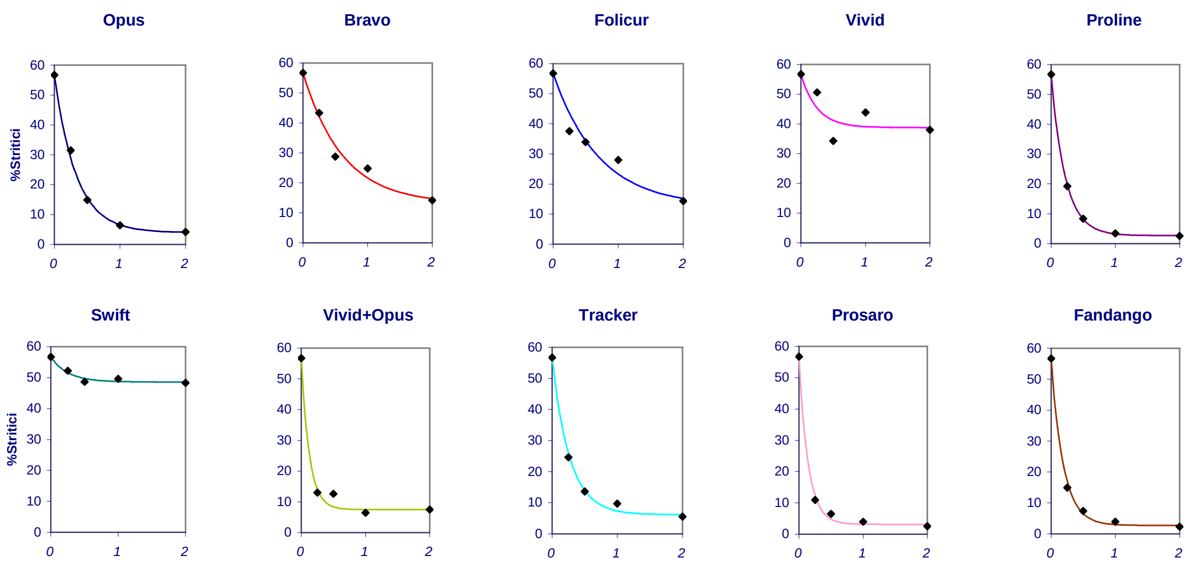


Figure 4.10 Fungicide dose-response curves for protectant activity against *S. tritici* meaned across sites 3, 5 and 7 in 2005

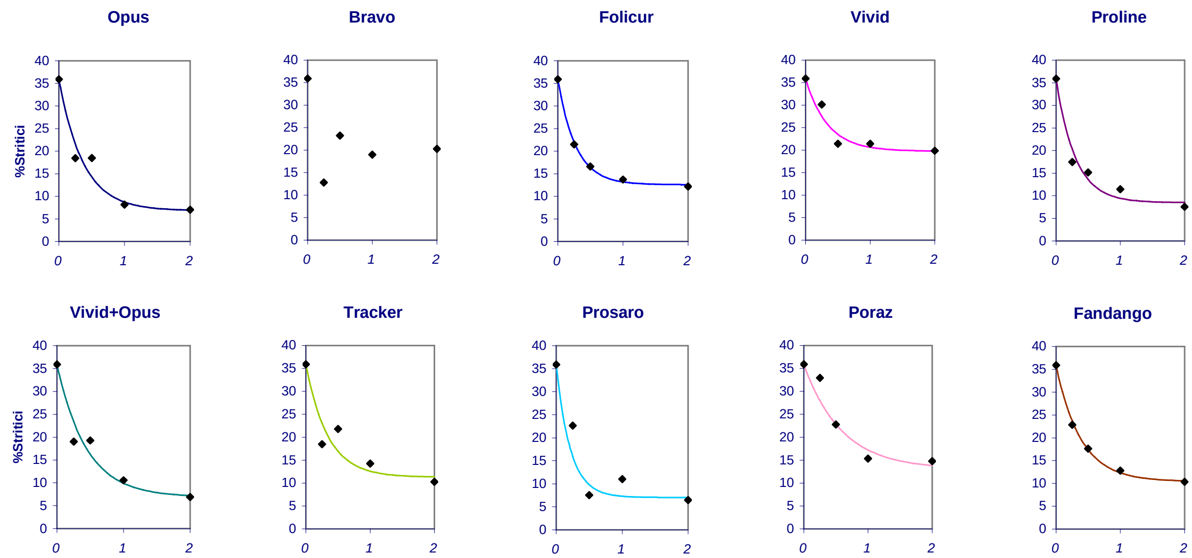


Figure 4.11 Fungicide dose-response curves for eradicant activity against *S. tritici* meaned across sites 10 and 14 in 2006.

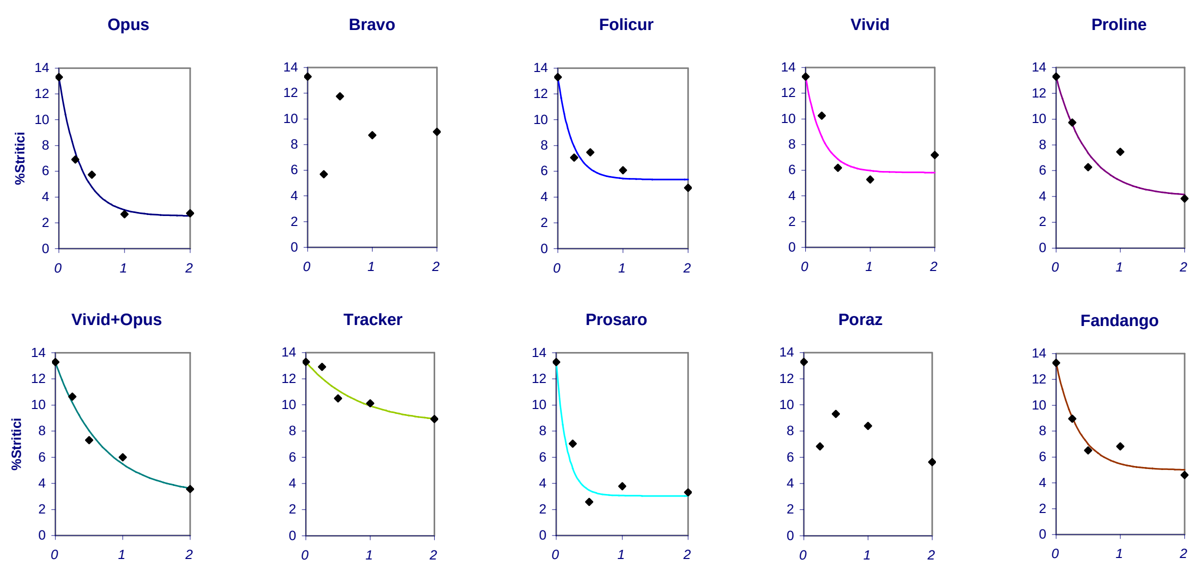


Figure 4.12 Fungicide dose-response curves for protectant activity against *S. tritici* for site 14 in 2006.

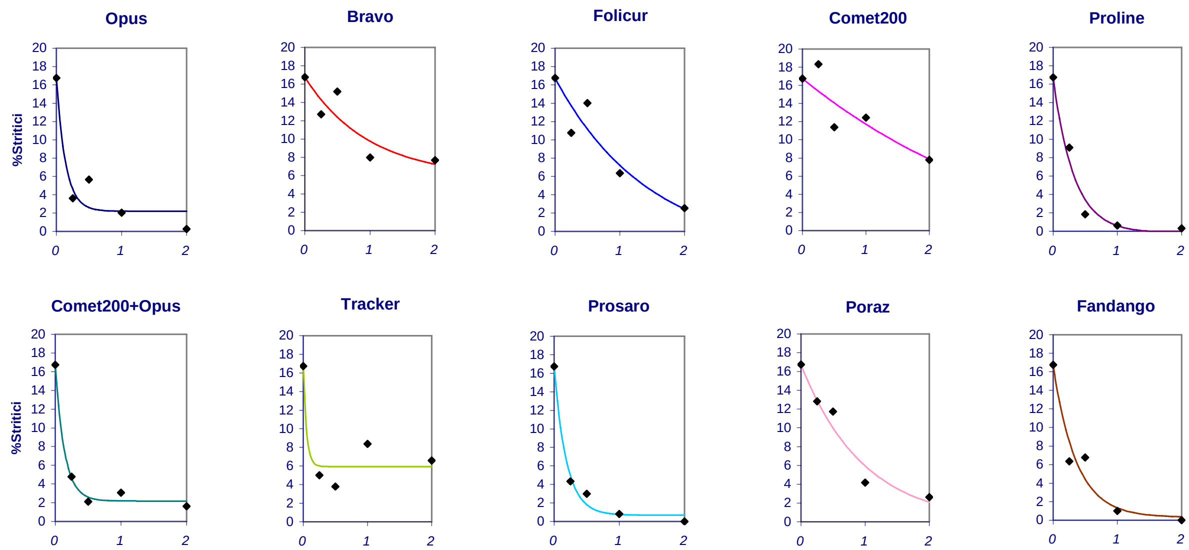


Figure 4.13 Fungicide dose-response curves for eradicant activity against *S. tritici* for site19 in 2007.

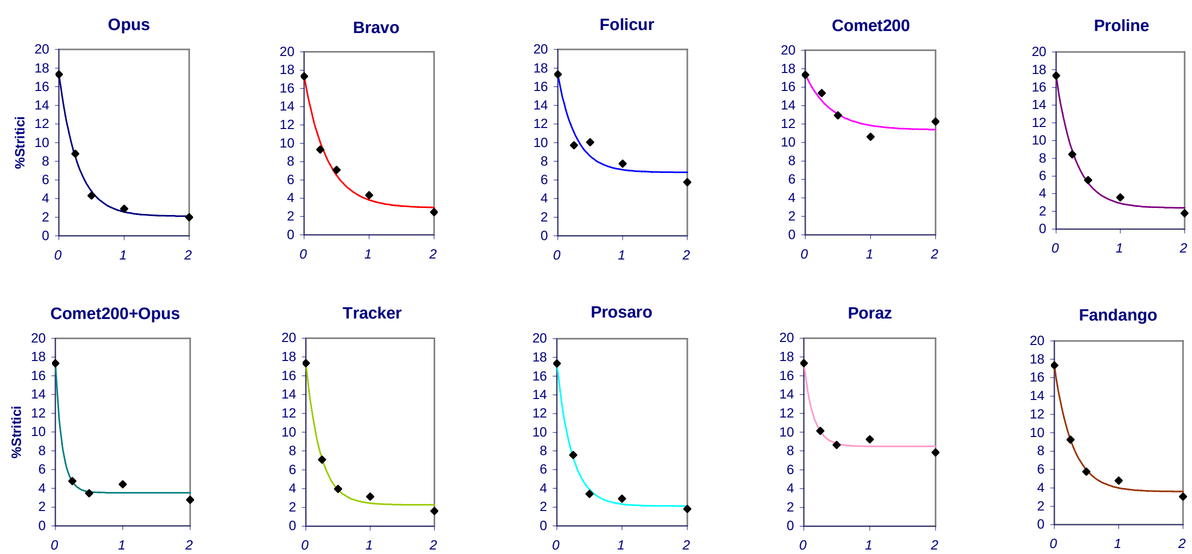


Figure 4.14 Fungicide dose-response curves for protectant activity against *S. tritici* meaned across sites 17, 19 and 21 in 2007.

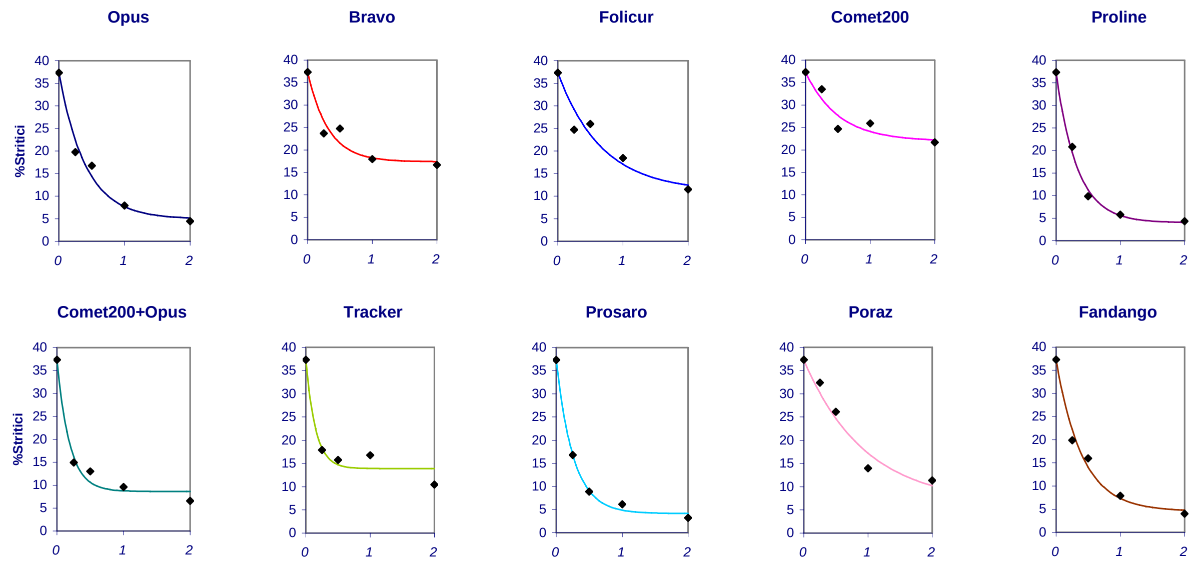


Figure 4.15 Fungicide dose-response curves for eradicant activity against *S. tritici* meaned across sites 3, 5, 7, 10, 12, 14, 17, 19 and 21; 2005 - 2007.

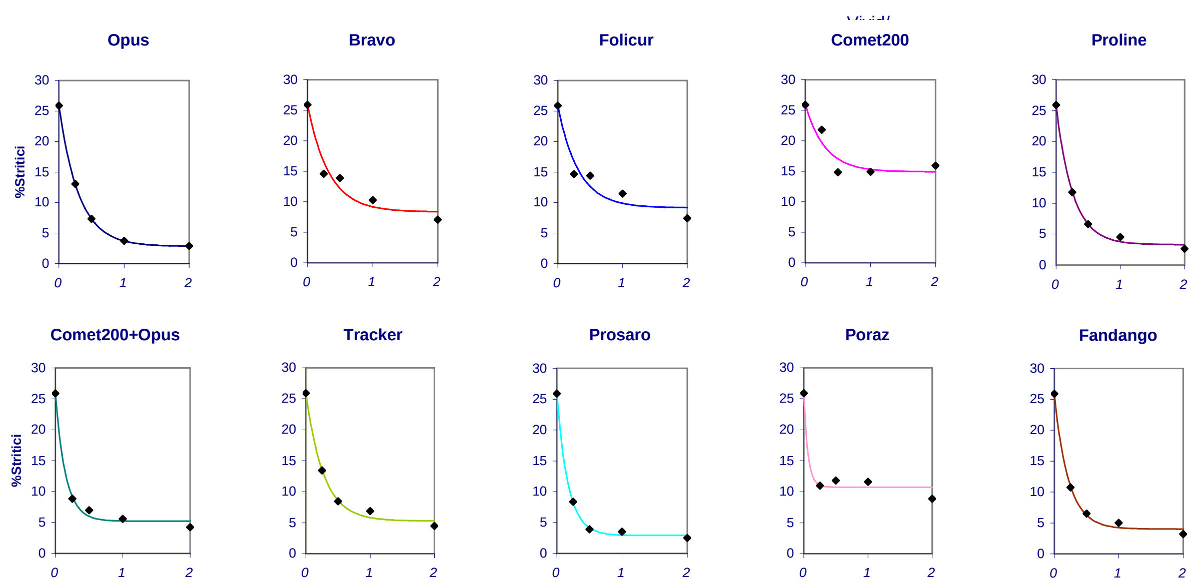


Figure 4.16 Fungicide dose-response curves for protectant activity against *S. tritici* meaned across sites 3, 5, 7, 10, 12, 14, 17, 19 and 21; 2005 - 2007.

4.2.2 Yield

Yield responses were large in 2005, with full dose applications of the more effective products giving responses of around two tonnes/ha (Figure 4.17). Proline, Prosaro and Fandango all gave similar yield responses at full dose (2.2, 2.4 and 2.3 tonnes/ha respectively) while Tracker and Opus were slightly lower (2.1 and1.9 tonnes/ha). The yield given by full dose Folicur was 0.9 tonne/ha lower than Opus. The straight strobilurin fungicides Vivid and Swift increased yield by 0.6 tonne/ha at full doses.

In 2006 (Figure 4.18) Yield responses to fungicides were smaller. Opus gave a one tonne/ha response at full dose while Proline and Fandango gave slightly less (0.6 and 0.75 tonne/ha respectively) and Prosaro slightly more (1.1 tonnes/ha). The response from full dose Folicur was again low (0.3 tonne/ha) and the full dose strobilurin gave half a tonne/ha when used alone. When added to half dose Opus, the yield benefit from the full dose strobilurin was worth 0.2 tonne/ha.

Full dose Opus increased yield by 1.2 tonnes/ha in 2007 (Figure 4.19). Full dose applications of Proline, Prosaro and Fandango all gave a response of 1.1 tonnes/ha. Both Folicur and Poraz were lower at 0.5 tonne/ha. Comet 200 increased yield by just 0.2 tonne/ha at full dose. When added to half dose Opus, a full dose of the strobilurin had very little effect, raising yield by 0.1 tonne/ha over half dose Opus alone.

When yield data across all the *S. tritici* sites is meaned over the three years (Figure 4.20) the response from full dose Opus was 1.4 tonnes/ha. Adding boscalid to Opus (as Tracker) resulted in an additional yield benefit of 0.1 tonne/ha at full dose while adding a full dose of strobilurin to half dose Opus raised yield by 0.3 tonne/ha. The strobilurin pyraclostrobin alone gave a yield response of 0.4 tonne/ha at full dose. Full dose Proline gave a yield response of 1.3 tonnes/ha. Adding a strobilurin (as Fandango) increased this by 0.1 tonne/ha at full dose, and adding tebuconazole (as Prosaro) boosted yield by 0.2 tonne/ha at the label recommended dose. The responses from full doses of Folicur and Poraz were 0.6 and 0.8 tonne/ha respectively. A full dose of the protectant fungicide Bravo gave an average yield response of 0.9 tonne/ha.

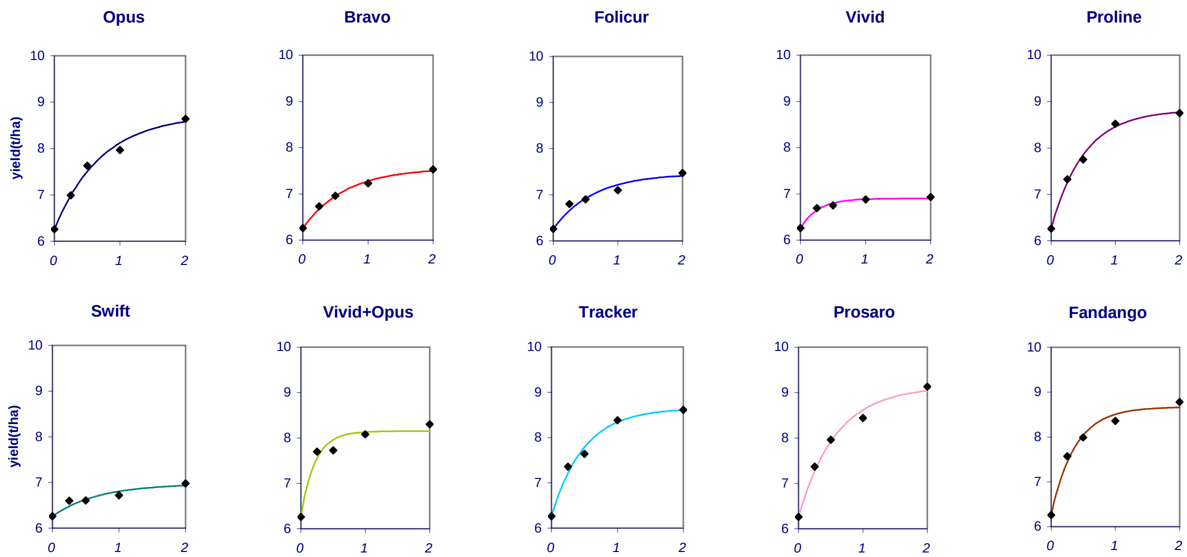


Figure 4.17 Fungicide dose-response curves for yield meaned across sites 3, 5 and 7 in 2005.

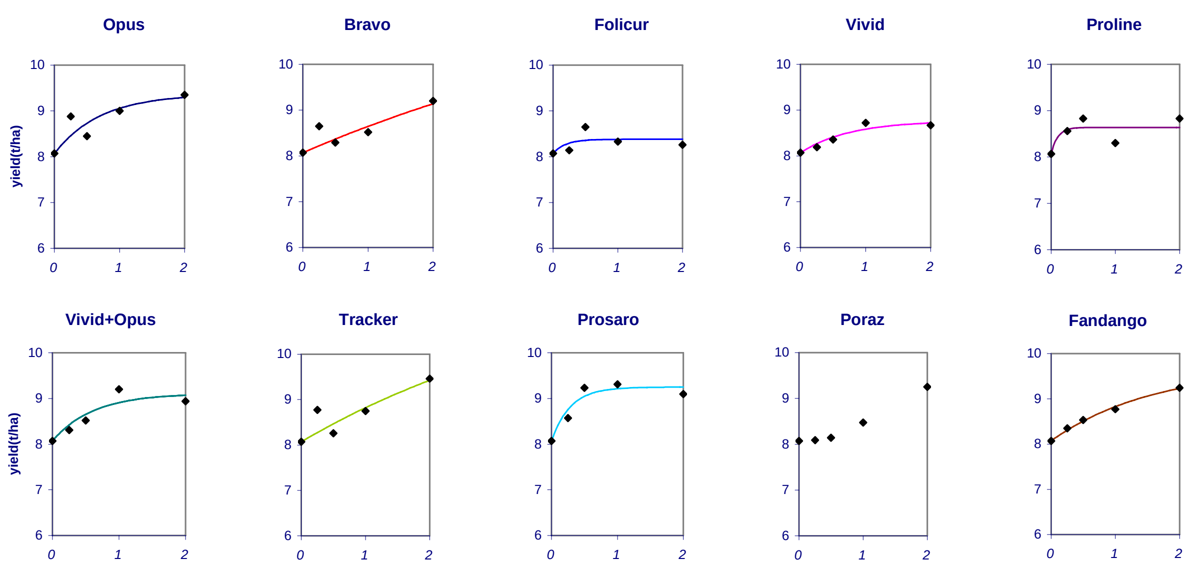


Figure 4.18 Fungicide dose-response curves for yield meaned across sites 10 and 14 in 2006.

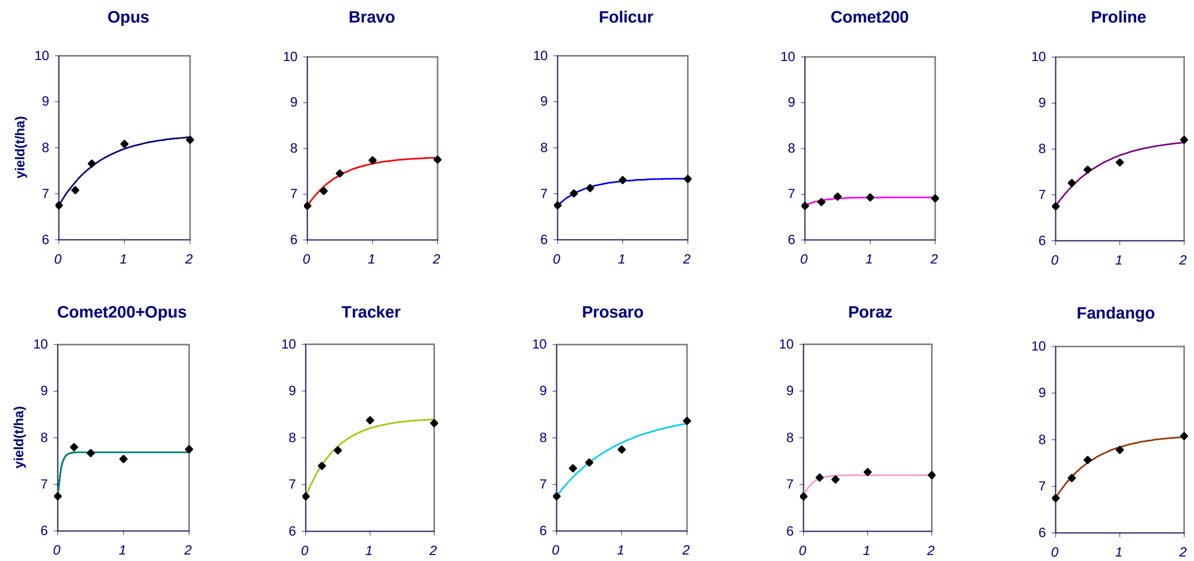


Figure 4.19 Fungicide dose-response curves for yield meaned across sites 17, 19 and 21 in 2007.

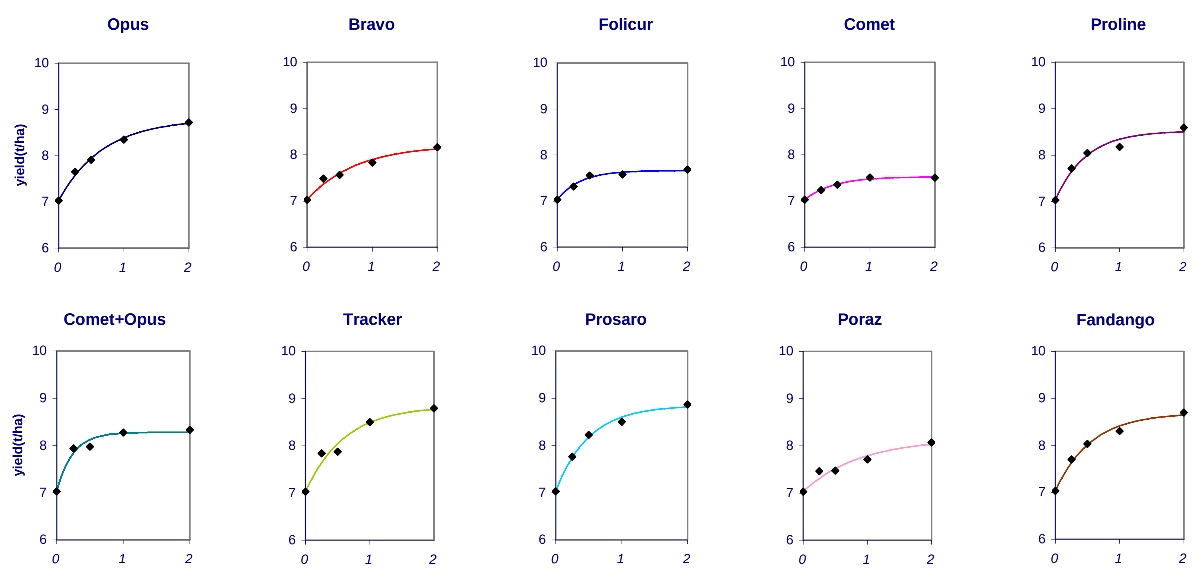


Figure 4.20 Fungicide dose-response curves for yield meaned across sites 3, 5, 7, 10, 12, 14, 17, 19 and 21; 2005 – 2007.

### 4.2.3 Specific weight

The shapes of the dose-response curves for specific weight of grain in 2005 are almost identical to those for yield (Figure 4.21). The products most effective at increasing specific weights were Prosaro, Tracker, Proline and Fandango (increases of 4.5, 4.3, 4.1 and 4.0 kg/hl respectively at label recommended doses). Full dose Opus increased specific weight by 3.6 kg/hl; the mixture of half dose Opus and full dose Vivid gave an increase of 3.4 kg/ha, 1.0 kg/ha greater than half dose Opus alone. The straight strobilurins gave small increases in specific weight of 0.4 (Vivid) and 0.6 kg/hl (Swift) while Folicur and Bravo both gave increases of 1.1 kg/hl.

In 2006, when yield effects were small, specific weight data were variable and dose-response curves could not be fitted for most products (Figure 4.22). Where curves could be fitted, full dose Opus increased specific weight by 1.9 kg/hl and Prosaro by 1.5 kg/hl. The mixture of full dose Vivid plus half dose Opus gave an increase of 1.1 kg/hl, 0.4 kg/ha less than half dose Opus alone.

Moderate increases in specific weight were recorded in 2007 (Figure 4.23). At full doses, Tracker gave the greatest increase (3.8 kg/hl) followed by Opus and Proline (3.0 kg/hl). Prosaro and Fandango gave increases of 2.9 and 2.6 kg/hl respectively. Other azole fungicides, Poraz and Folicur gave smaller increases in specific weight (1.4 and 1.2 kg/hl) while Bravo increased specific weight by 2.2 kg/hl at full dose.

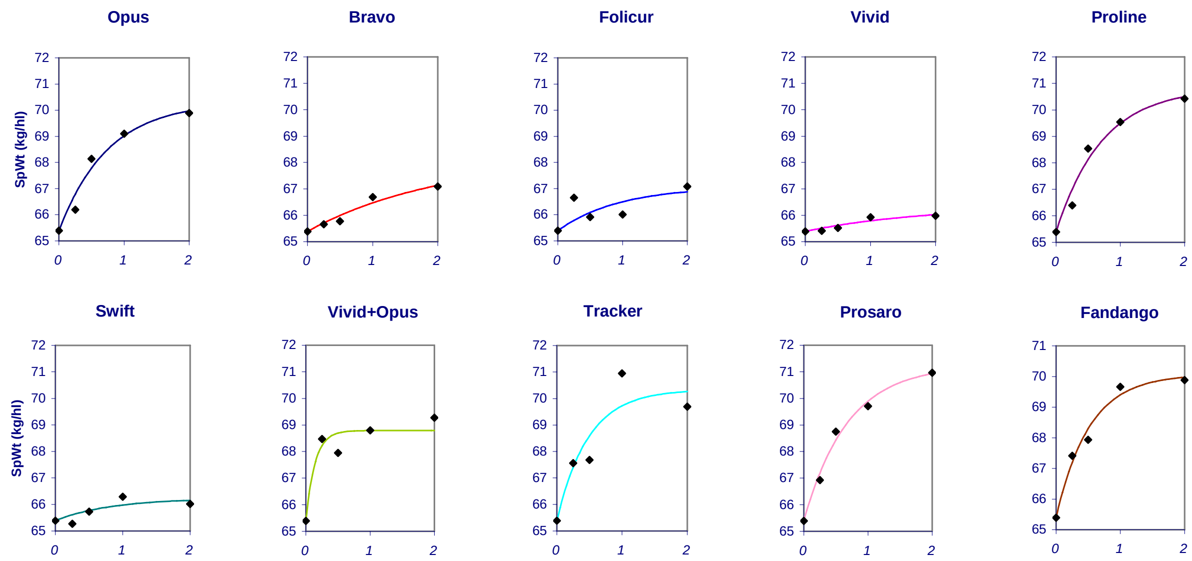


Figure 4.21 Fungicide dose-response curves for specific weight meaned across sites 3 and 7 in 2005.

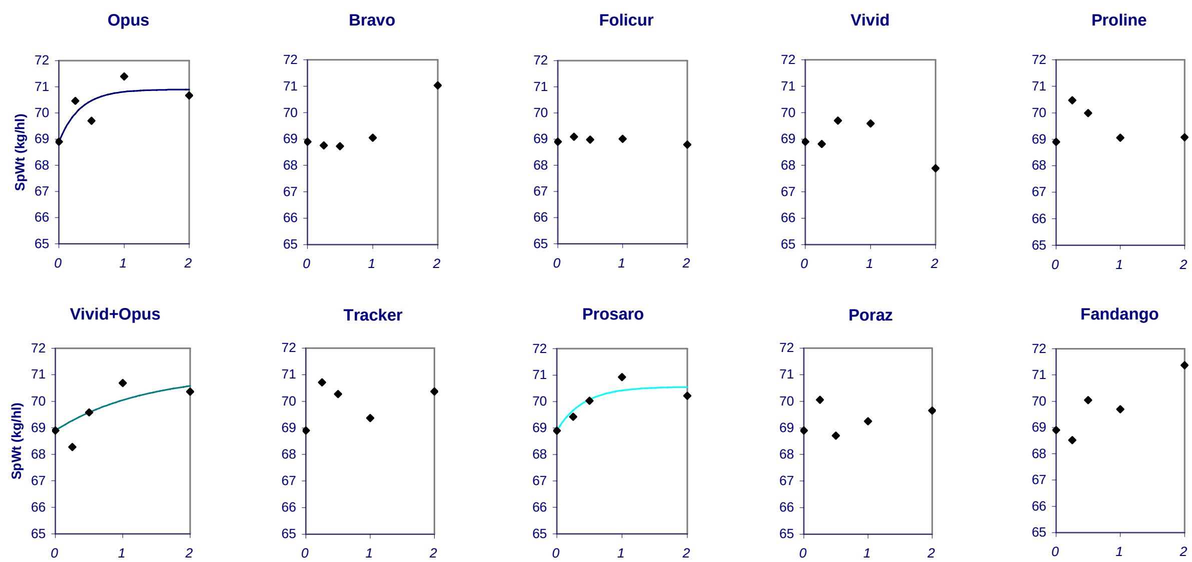


Figure 4.22 Fungicide dose-response curves for specific weight meaned across sites 10 and 14 in 2006.

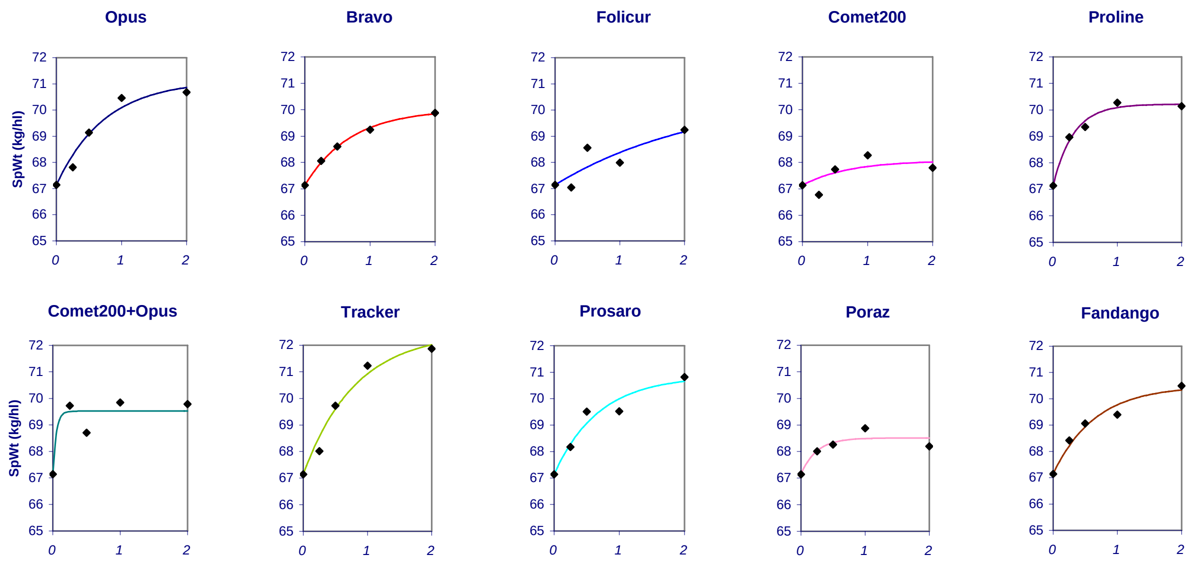


Figure 4.23 Fungicide dose-response curves for specific weight meaned across sites 17, 19 and 21 in 2007.

## 4.3 Yellow rust experiments

### 4.3.1 Disease control.

With the exception of Bravo (which does not control rusts) all products gave effective protection against yellow rust on the flag leaf, even at a quarter or half dose in 2005 (Figure 4.24)

The data from 2006 were rather atypical and proved impossible to fit for several products. Higher doses of fungicides were required in 2006 to control the disease (Figure 4.25). Non-azole products alone did not appear to control the disease. These effects may be due to *Septoria* symptoms masking yellow rust control.

High levels of yellow rust developed in 2007 (Figure 4.26). Tracker, Folicur and Prosaro all gave effective control at a quarter dose. The two strobilurin products (Amistar and Comet 200) gave good control at full dose, but were less effective at lower doses. The addition of fluoxastrobin to prothioconazole (as Fandango) improved the control of yellow rust. Torch Extra appeared to have some activity against yellow rust, but data were variable.

When data were averaged over the three years (Figure 4.27) Prosaro and Tracker gave very good control of yellow rust, even at quarter dose. The inclusion of boscalid in Tracker appeared to improve the control given by epoxiconazole alone (Opus), even though dose for dose, Tracker contains 20% less epoxiconazole than Opus.

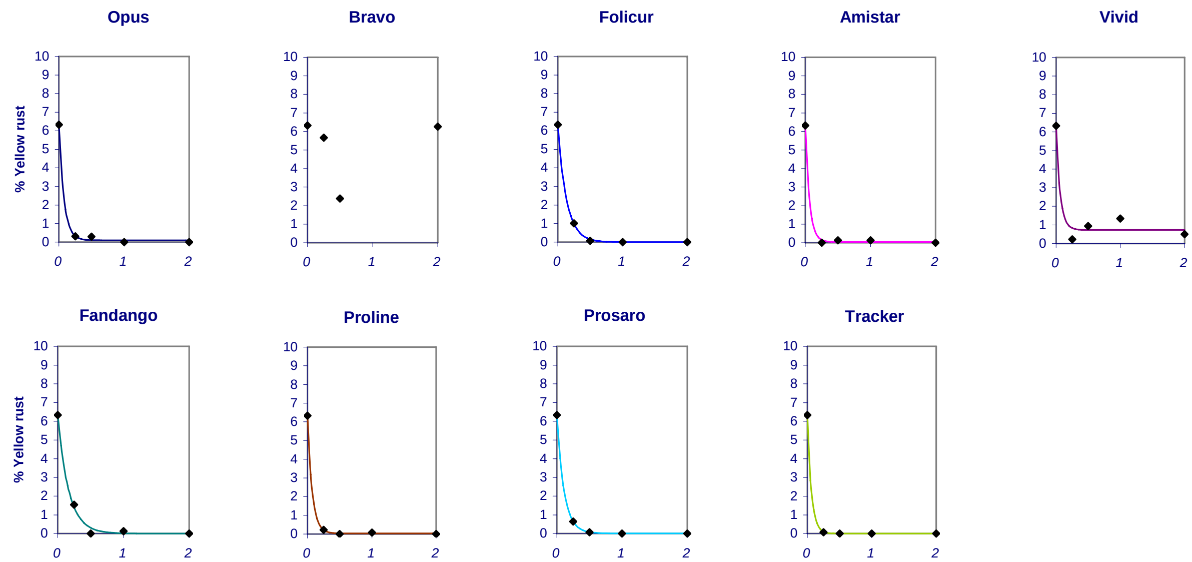


Figure 4.24 Fungicide dose-response curves for yellow rust control at site 2 in 2005

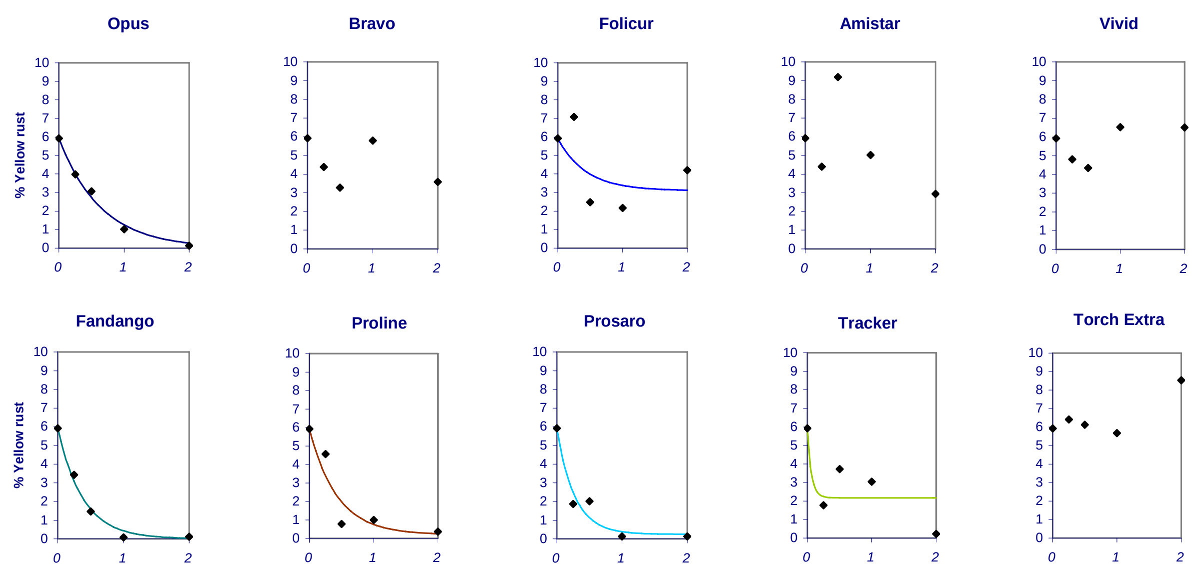


Figure 4.25 Fungicide dose-response curves for yellow rust control at site 9 in 2006

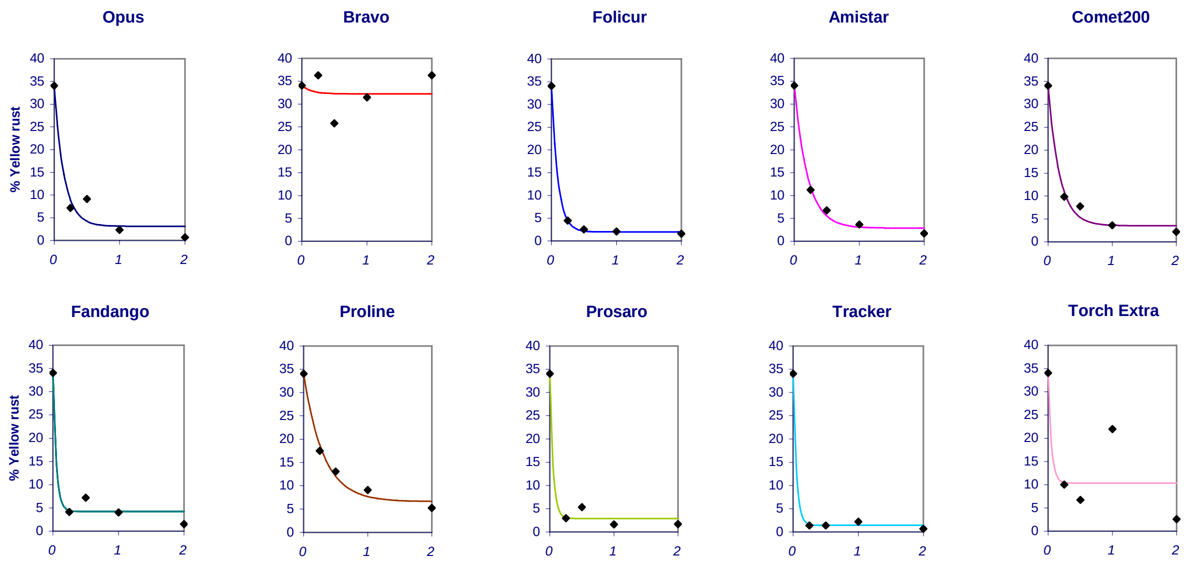


Figure 4.26 Fungicide dose-response curves for yellow rust control at site 16 in 2007

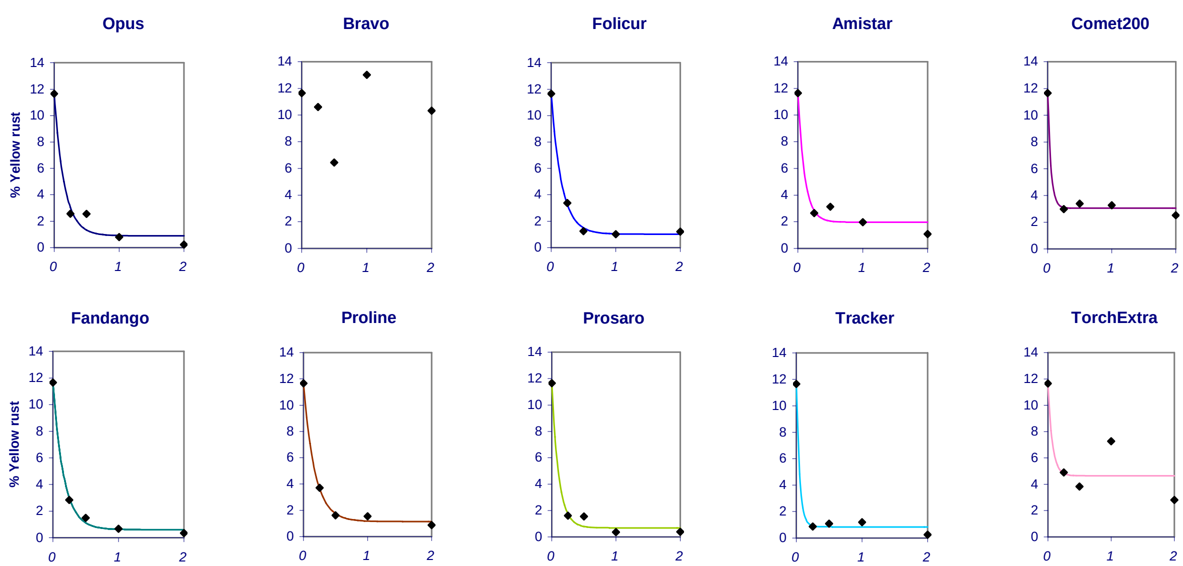


Figure 4.27 Fungicide dose-response curves for yellow rust control meaned across sites 2, 9 and 16; 2005 – 2007.

4.3.2 Yield.

Yield data for 2005 and 2006 reflect the fungicides' activity against *S. tritici* as well as yellow rust. In 2007, when the cultivar was changed from Brigadier to Robigus, yields mainly reflect yellow rust activity.

In 2005, yield responses were modest and dresponse curves were fairly flat after half dose (Figure 4.28). Full dose Tracker increased yield by 1.3 tonnes/ha; Folicur gave a 1.1 tonne/ha increase at full dose; Opus and Proline increased yield by 1.0 tonne/ha and Amistar did so by 0.9 tonne/ha. Vivid, Prosaro and Fandango all increased yield by 0.8 tonne/ha while full dose Bravo added just 0.6 tonne/ha.

Yield responses were greater in 2006 (Figure 4.29) due to the control of significant *Septoria* infection by some products. Proline, Prosaro and Fandango increased yield by 3.9, 3.4 and 2.4 tonnes/ha respectively at full dose. Opus and Tracker gave responses of 3.0 and 2.9 tonnes/ha at full dose. Vivid increased yield by 1.1 tonnes/ha and Folicur by 0.8 tonne/ha.

Smaller yield responses in 2007 give a better indication of yellow rust activity of the fungicides. Tracker increased yield by 1.3 tonnes/ha at full dose and full dose applications of Opus and Comet 200 both gave responses of 1.1 tonnes/ha (Figure 4.30). Proline, Prosaro and Fandango gave increases of 0.4, 1.0 and 0.7 tonne/ha respectively when applied at full dose. The yield increase from full dose Amistar was 0.8 tonne/ha and that of Folicur, 0.6 tonne/ha. Torch Extra had a slight positive effect on yield (0.1 tonne/ha at full dose).
Proline and Tracker gave the greatest average yield response of 1.9 tonnes/ ha at full dose over the three years (Figure 4.31) while Opus and Prosaro gave increases of 1.7 tonne/ha. The average increase from full dose Fandango was 1.3 tonnes/ha and that of Comet, 1.0 tonne/ha. Full dose Folicur averaged a 0.8 tonne/ha increase and Amistar, 0.6 tonne/ha.

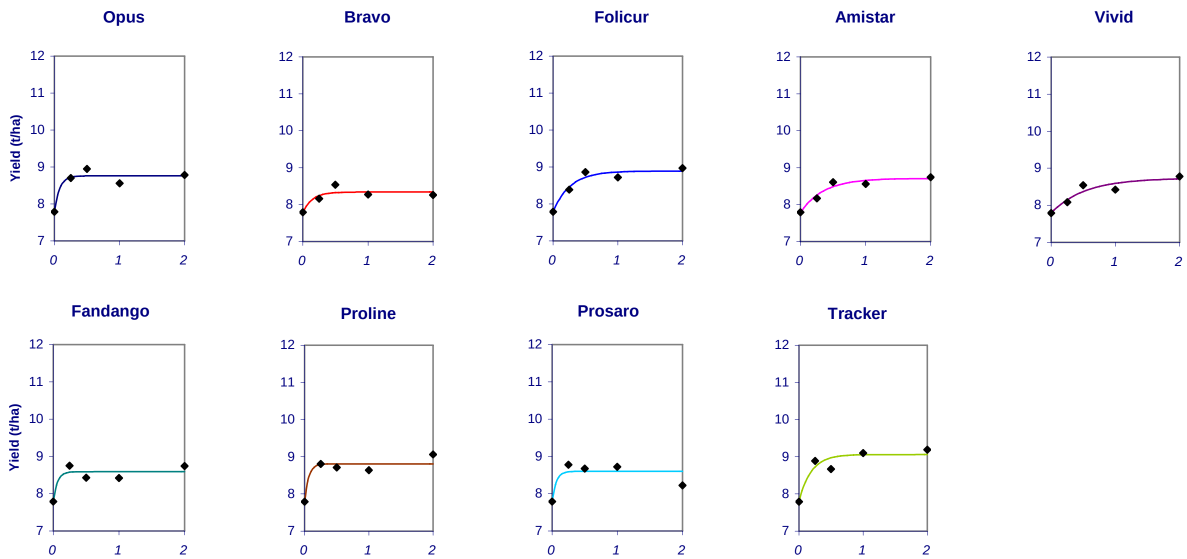


Figure 4.28 Fungicide dose-response curves for yield at site 2 in 2005.

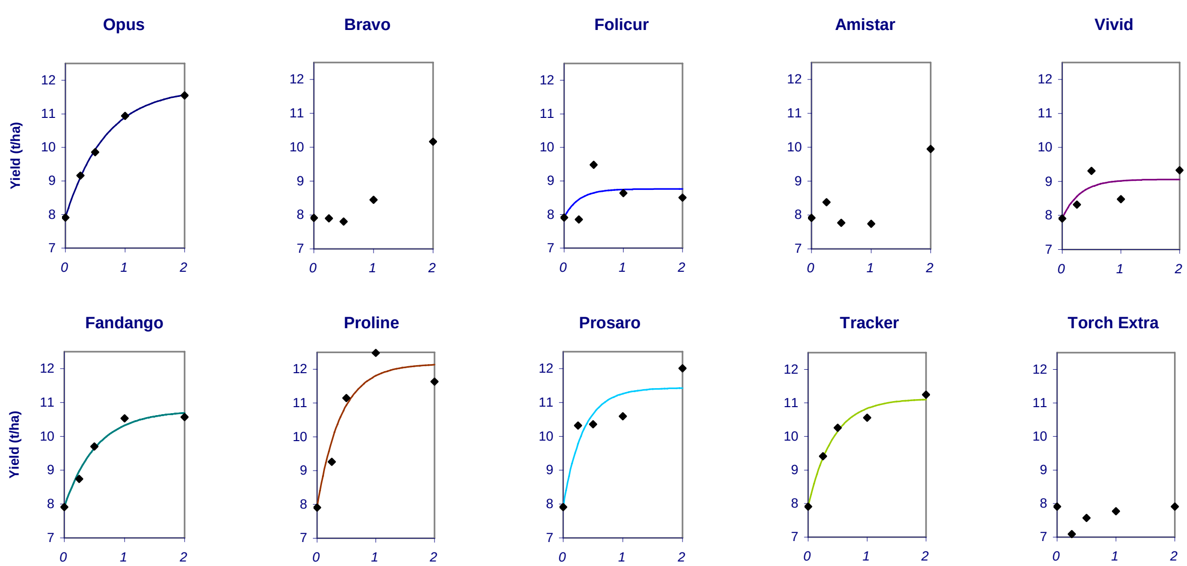


Figure 4.29 Fungicide dose-response curves for yield at site 9 in 2006.

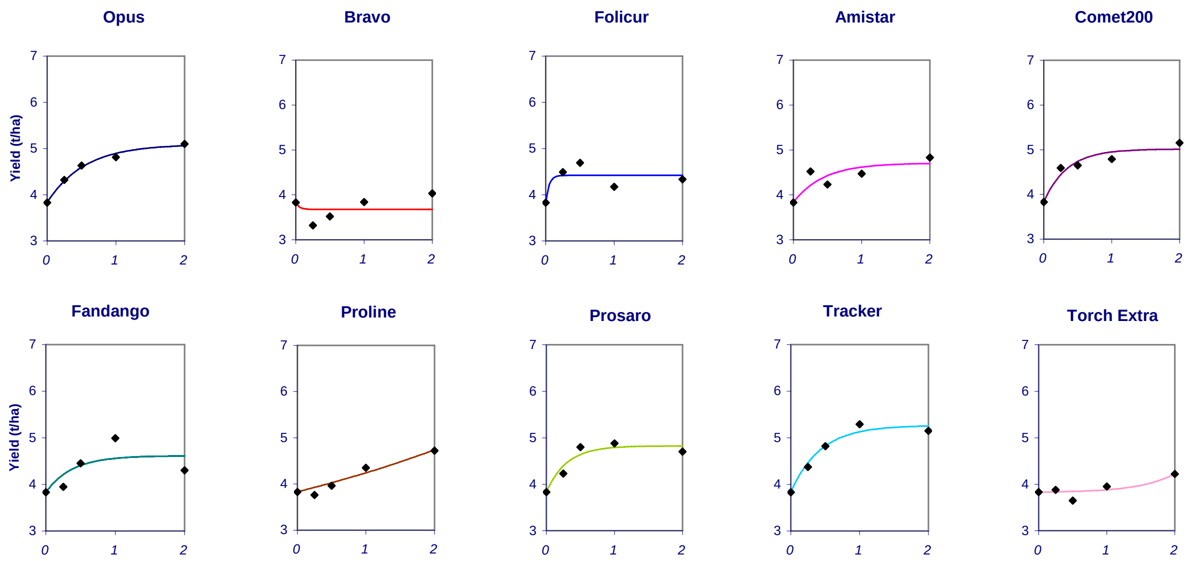


Figure 4.30 Fungicide dose-response curves for yield at site 16 in 2007.

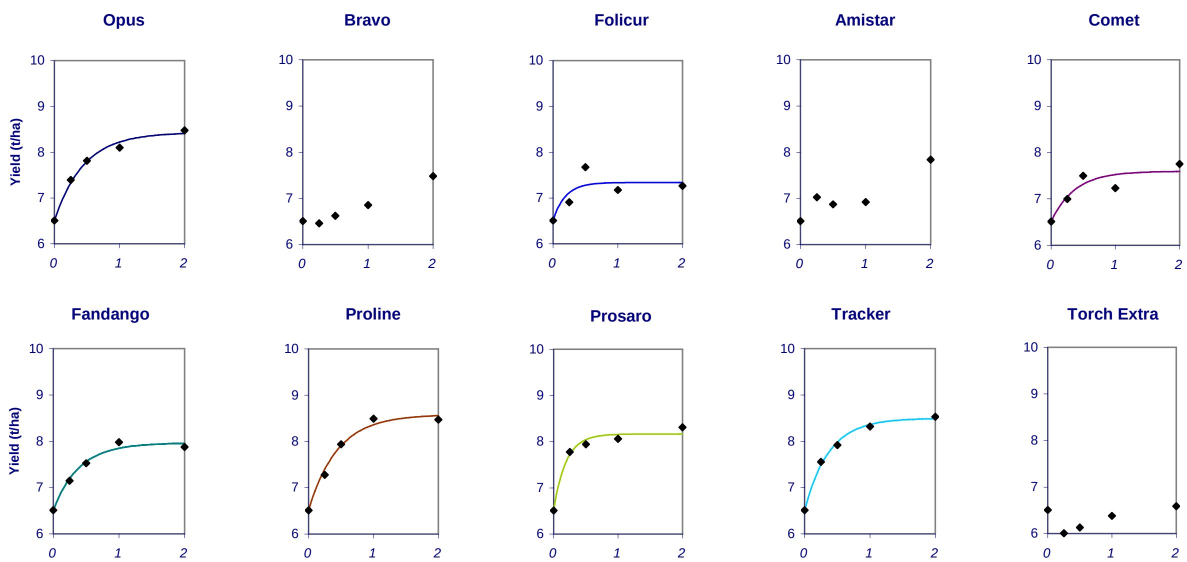


Figure 4.31 Fungicide dose-response curves for yield meaned across sites 2, 9, 16; 2005 - 2007.

### 4.3.3 Specific weight.

Any effects of fungicides on specific weights at yellow rust sites in 2005 and 2006 were either small (less than 1.0 kg/hl at full dose) or so variable that dose-response curves could not be fitted (Figures 4.32 and 4.33).

Moderate effects on specific weight were recorded in 2007 (Figure 4.37). Amistar and Tracker increased specific weight by 4.7 kg/hl at full dose and full doses of Opus and Fandango gave increases of 3.8 kg/hl. The increase in specific weight from full dose Folicur was 3.6 kg/hl, from Comet 3.5 kg/hl and from Prosaro, 3.4 kg/hl. A full dose of Torch Extra led to an increase in specific weight of 2.2kg/hl, and Bravo gave an increase of 1.7 kg/hl.

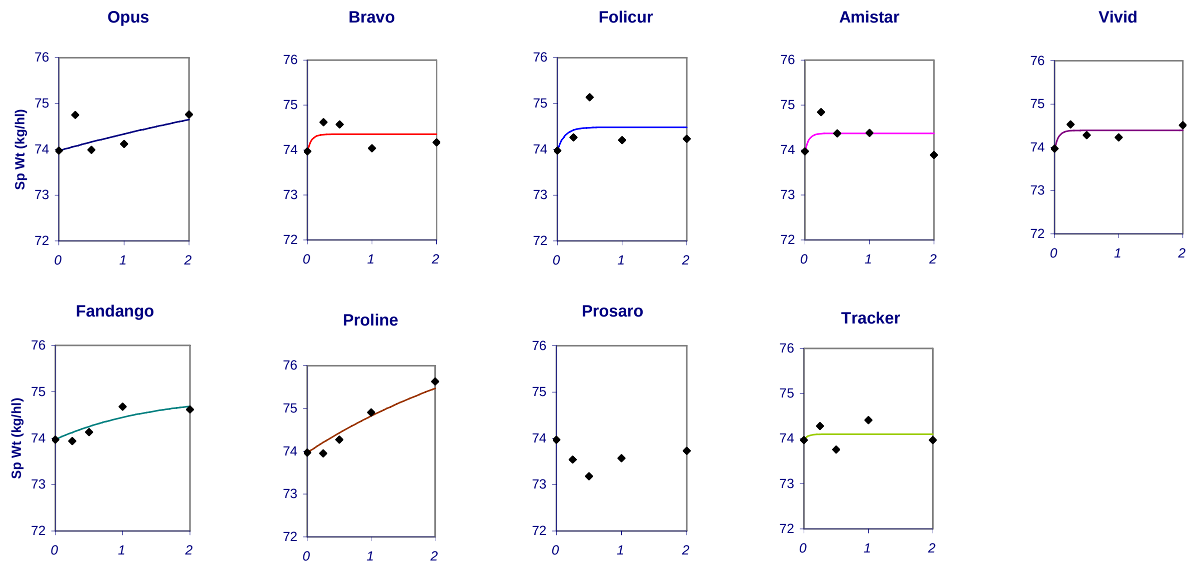


Figure 4.32 Fungicide dose-response curves for specific weight at site 2 in 2005.

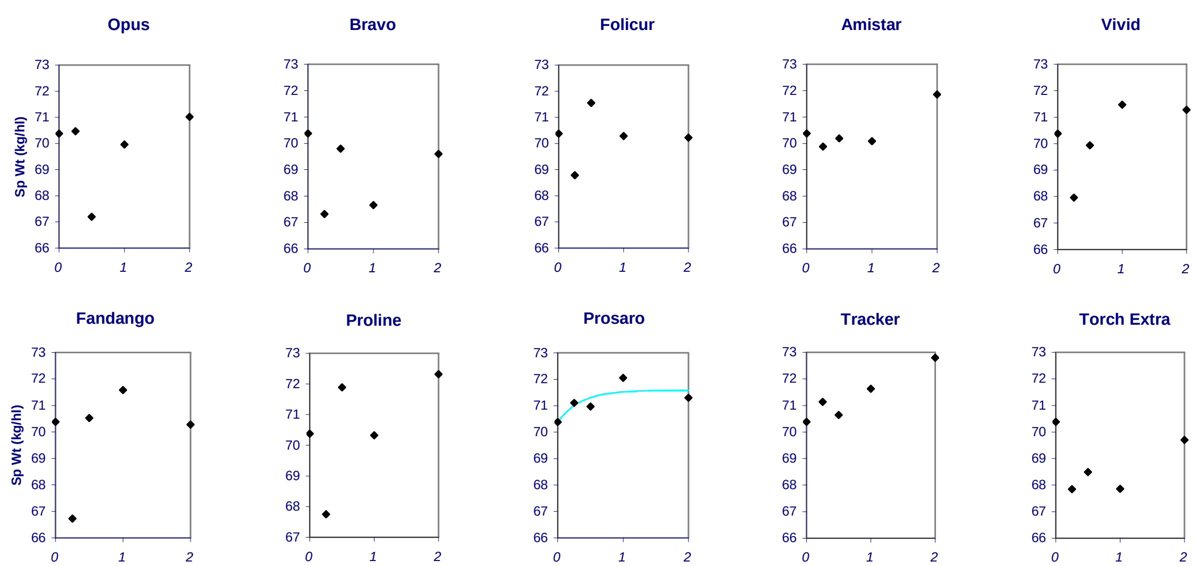


Figure 4.33 Fungicide dose-response curves for specific weight at site 9 in 2006.

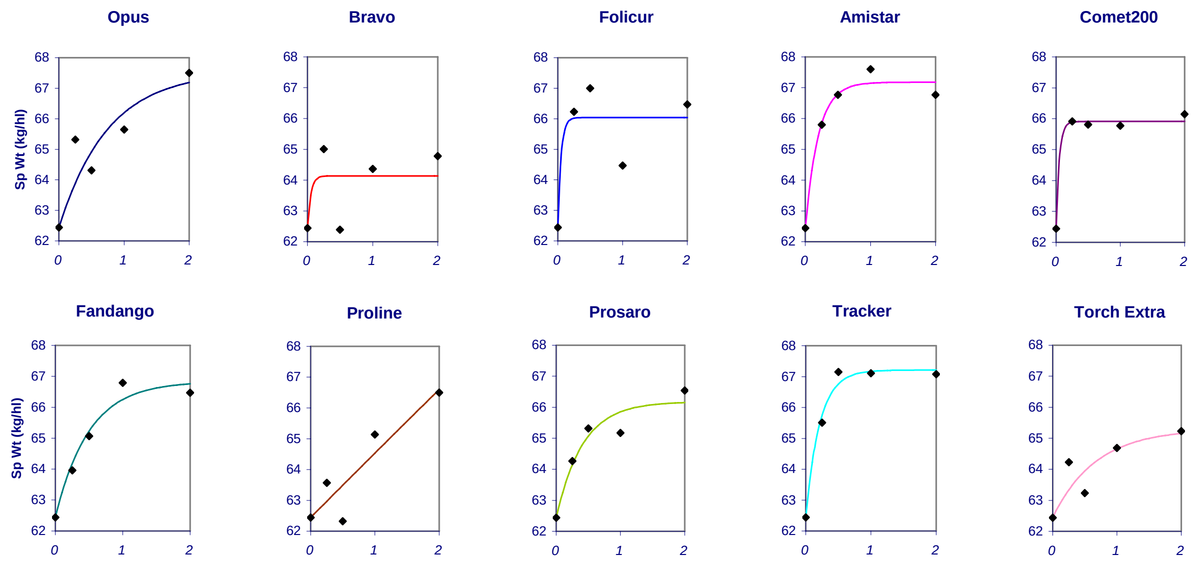


Figure 4.34 Fungicide dose-response curves for specific weight at site 16 in 2007.

## 4.4 Brown rust experiments

### 4.4.1 Disease control.

Moderate levels of brown rust developed in 2005 (Figure 4.35). Tracker and Vivid gave very good control at a quarter dose. Bravo, on the other hand was ineffective at a quarter dose. Proline was also weak on brown rust at lower doses. Opus, Folicur, Amistar, Fandango and Prosaro all gave good control at full doses.

Levels of brown rust were lower in 2006, but Fandango, Folicur and Vivid were particularly effective at a quarter dose (Figure 4.36). Amistar, Opus and Tracker gave good control, but Proline was again noticeably weaker against brown rust. The level of brown rust control given by Prosaro was intermediate between Folicur and Proline. The fungicide dose-response curve for brown rust could not be fitted to the data for Torch Extra, but there was some indication that higher doses gave control.

Although 2007 was an epic year for brown rust, the experimental site was also affected by *S. tritici* and this made assessment of brown rust difficult. Data for green leaf area are therefore presented in Figure 4.37. Treatments for *S. tritici* sites rather than rust sites were applied in error. It is clear that the main disease was brown rust since Bravo had very little effect on green leaf area and strobilurin fungicides were effective. Both Comet and the mixture of Comet plus Opus gave high levels of green leaf area at low doses. Tebuconazole based fungicides (Folicur and Prosaro) gave reasonable increases in green leaf area. Proline was weak compared with Opus, giving very little increase in green leaf area. Again, if *S. tritici* was a significant problem, this would not be expected.

Mean brown rust data across the two sites in 2005 and 2006 (Figure 4.38) showed Tracker, Comet and Fandango to be effective at low doses. Amistar, Folicur and Opus also gave good control, followed by Prosaro. Proline was weaker, even at full dose. It was not possible to fit the dose-response curve for Bravo.

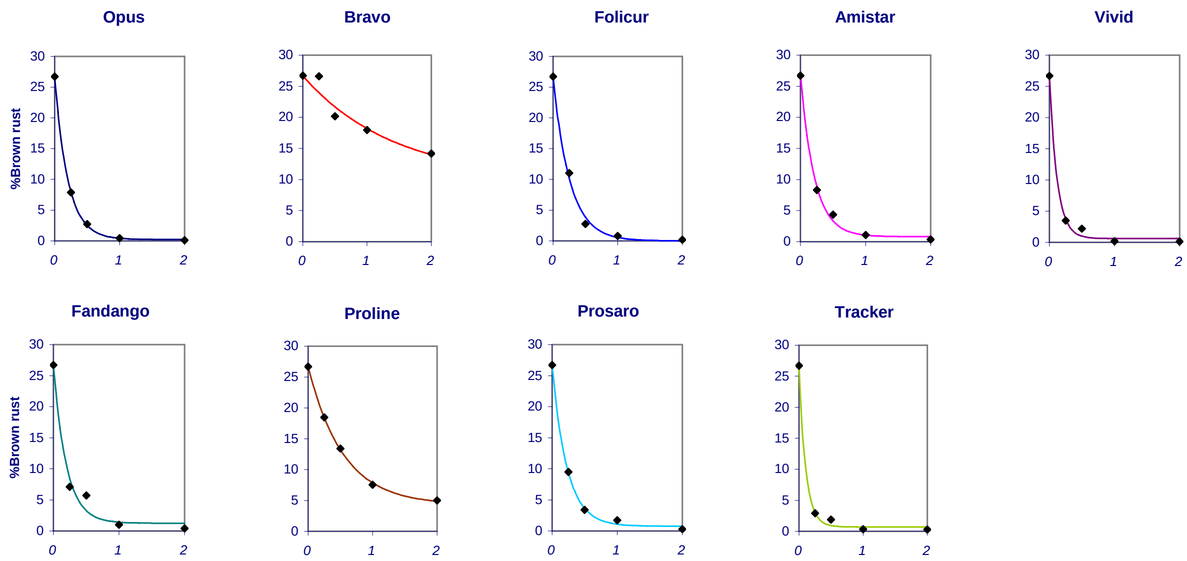


Figure 4.35 Fungicide dose-response curves for brown rust (%leaf area affected) for site 4 in 2005.

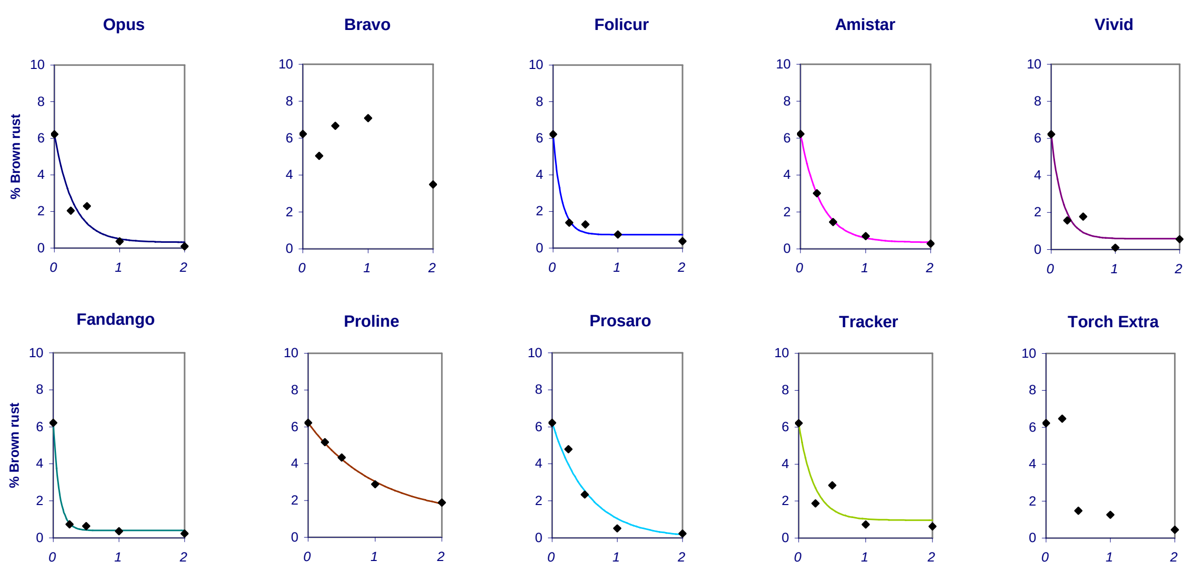


Figure 4.36 Fungicide dose-response curves for brown rust (%leaf area affected) for site 11 in 2006.

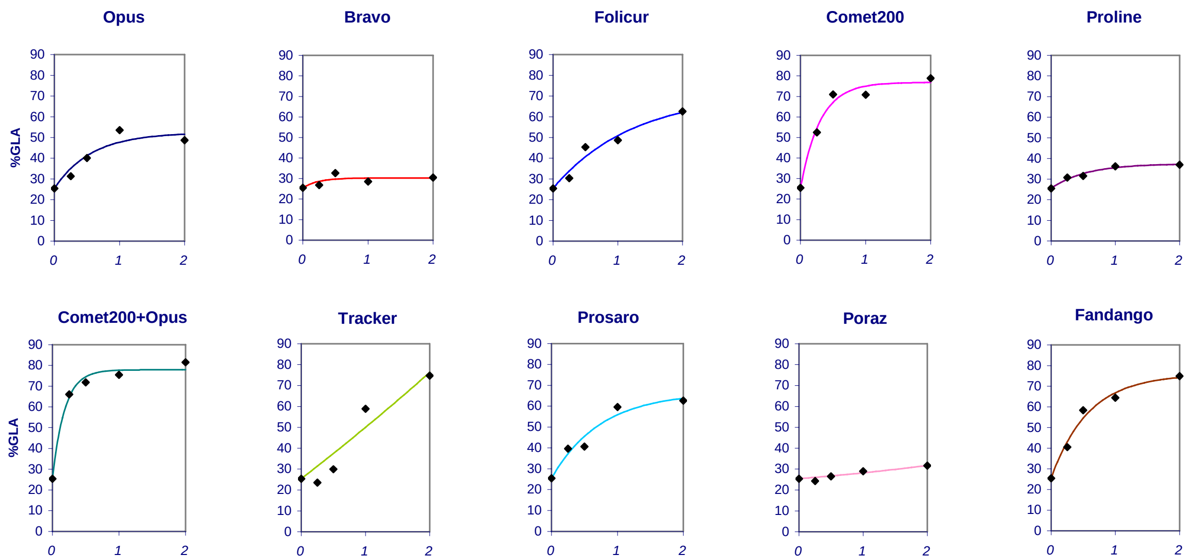


Figure 4.37 Fungicide dose-response curves for green leaf area (%leaf area) for site 18 in 2007.

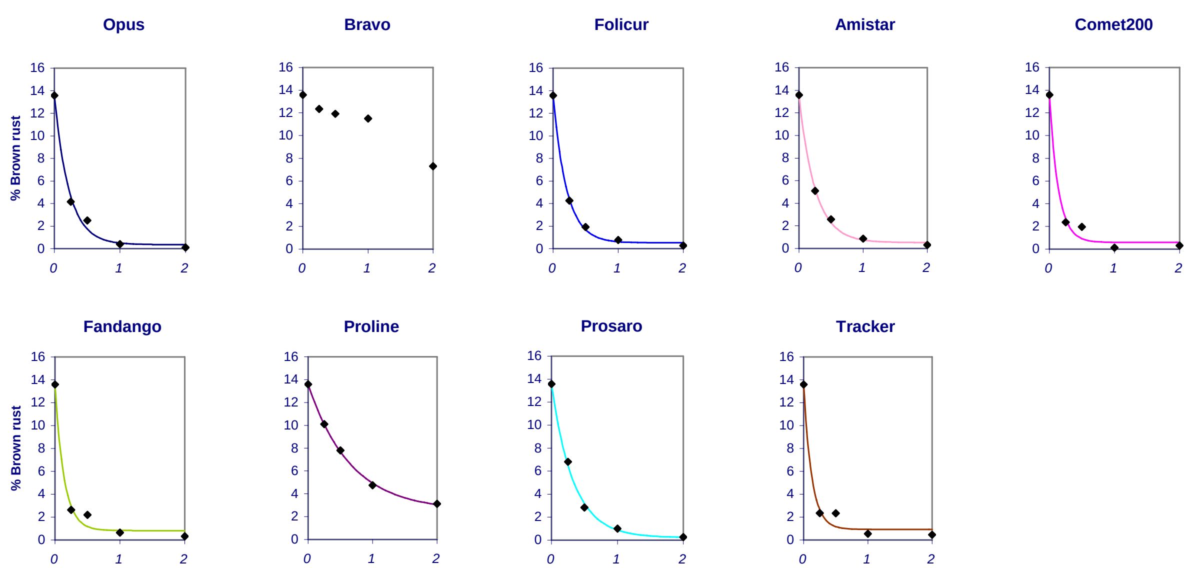


Figure 4.38 Fungicide dose-response curves for brown rust (%leaf area affected) meaned across sites 4 and 11; 2005 - 2006.

4.4.2 Yield.

With the exception of Bravo, which had little effect on yield, full doses of all products gave yield increases of just over one tonne/ha in 2005 (Figure 4.39). The greatest increases (1.4 tonnes/ha) were given by Fandango, Prosaro and Tracker. Opus and Vivid gave responses of 1.3 tonnes/ha at full dose while full doses of Amistar and Folicur both returned yield increases of 1.2 tonnes/ha.

Yield effects in 2006 were smaller (Figure 4.40). In many cases, the dose-response curve for yield flattened out after a quarter dose. At full doses, Proline and Tracker increased yield by 0.8 tonne/ha; Fandango and Prosaro by 0.7 tonne/ha and Opus and Amistar by 0.6 tonne/ha. Folicur gave a yield response of 0.5 tonne/ha at full dose, and Vivid gave 0.4 tonne/ha. The yield increase from full doses of Bravo and Torch Extra was 0.3 tonne/ha.

Yield increases were also modest in 2007 (Figure 4.41). Treatments containing strobilurin fungicides gave the greatest yields. The mixture of Comet plus Opus (full dose Comet plus half dose Opus) gave a yield increase of 2.3 tonnes/ha, this was 1.7 tonnes/ha greater than the increase given by half dose Opus alone. A full dose of Comet alone gave an increase of 1.6 tonnes/ha and Fandango gave 1.5 tonnes/ha at full dose. A full dose of Prosaro increased yield by 1.1 tonnes/ha. Tracker gave a yield response of 0.9 tonne/ha and Opus 0.8 tonne/ha at full dose. Folicur and Proline both increased yield by 0.7 tonne/ha at full dose.

When yield data were averaged over the two brown rust sites in 2005 and 2006 (Figure 4.42), full doses of Fandango and Tracker gave yield increases of 1.1 tonnes/ha; Proline and Prosaro gave 1.0 tonne/ha; Amistar, Folicur and Opus gave 0.9 tonne/ha and Vivid gave 0.8 tonne/ha. The average yield increase from a full dose of Bravo was 0.3 tonne/ha.

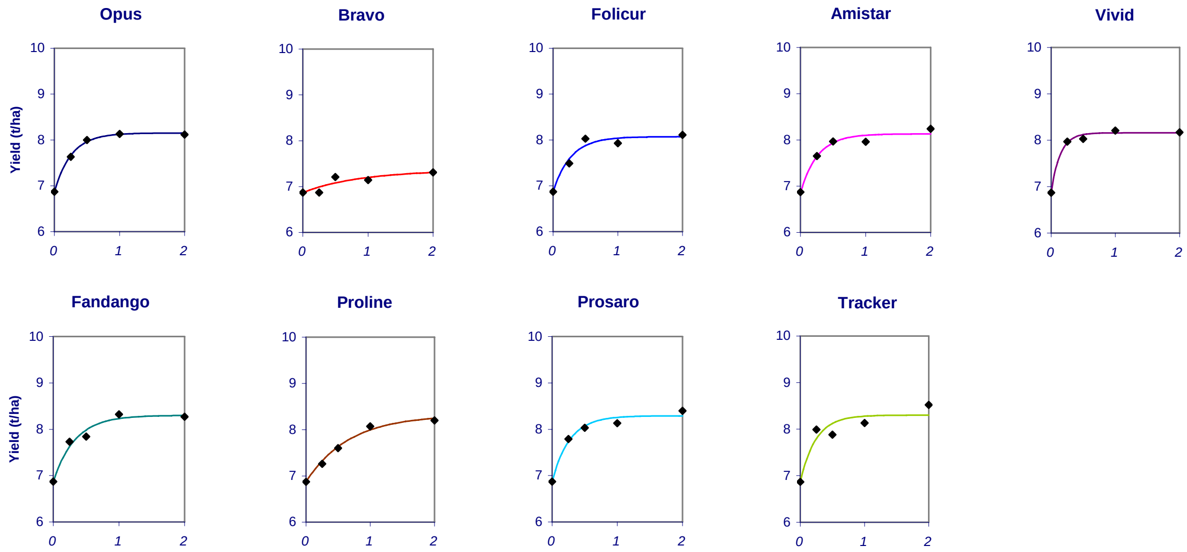


Figure 4.39 Fungicide dose-response curves for yield for site 4 in 2005.

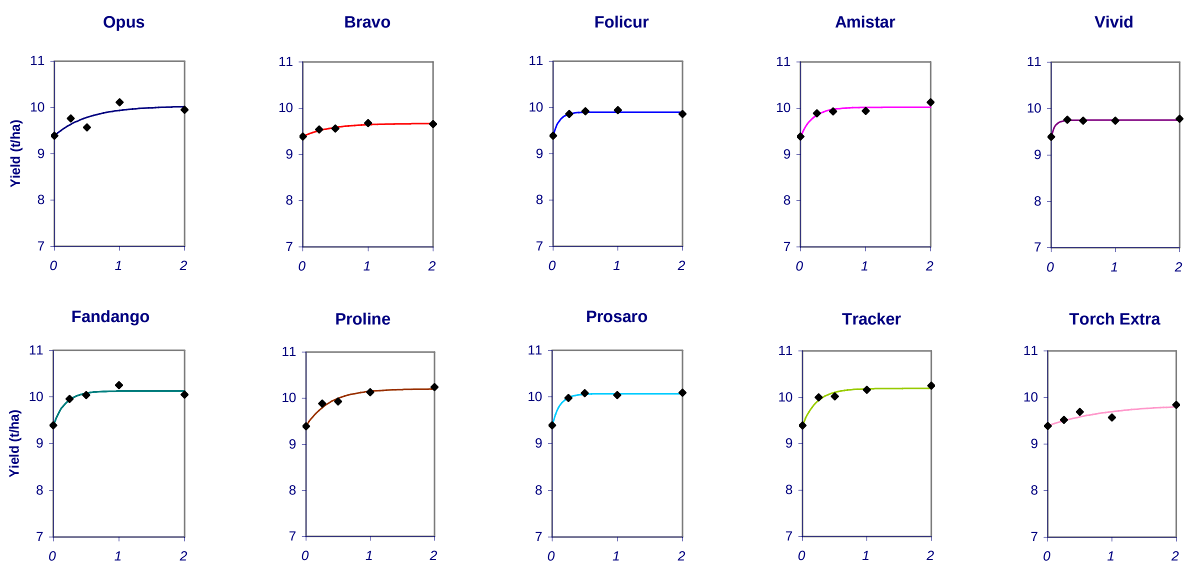


Figure 4.40 Fungicide dose-response curves for yield for site 11 in 2006.

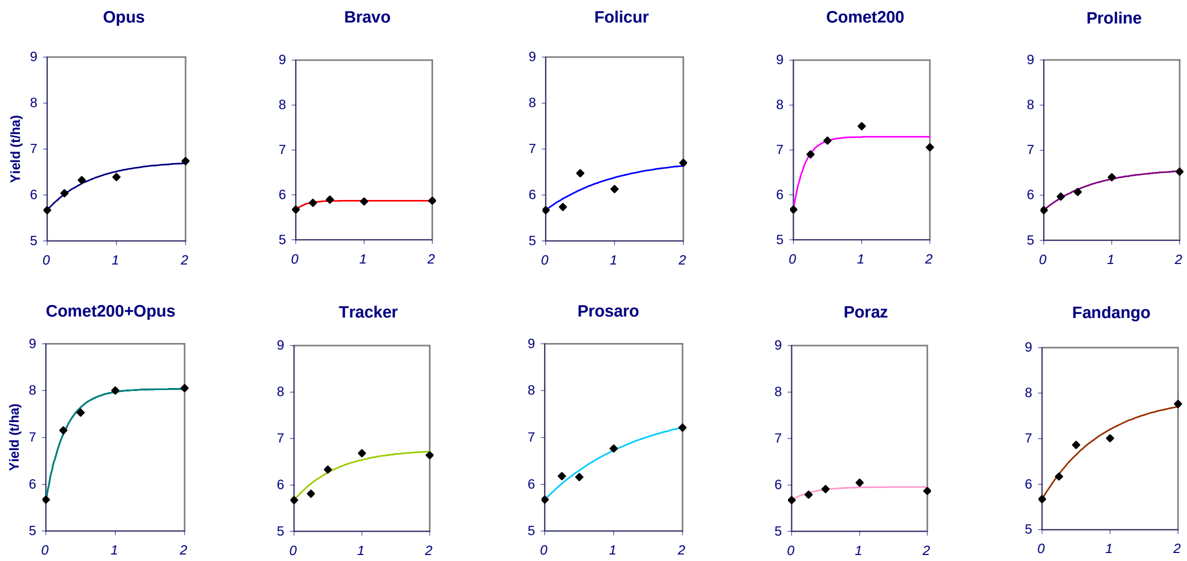


Figure 4.41 Fungicide dose-response curves for yield for site 18 in 2007.

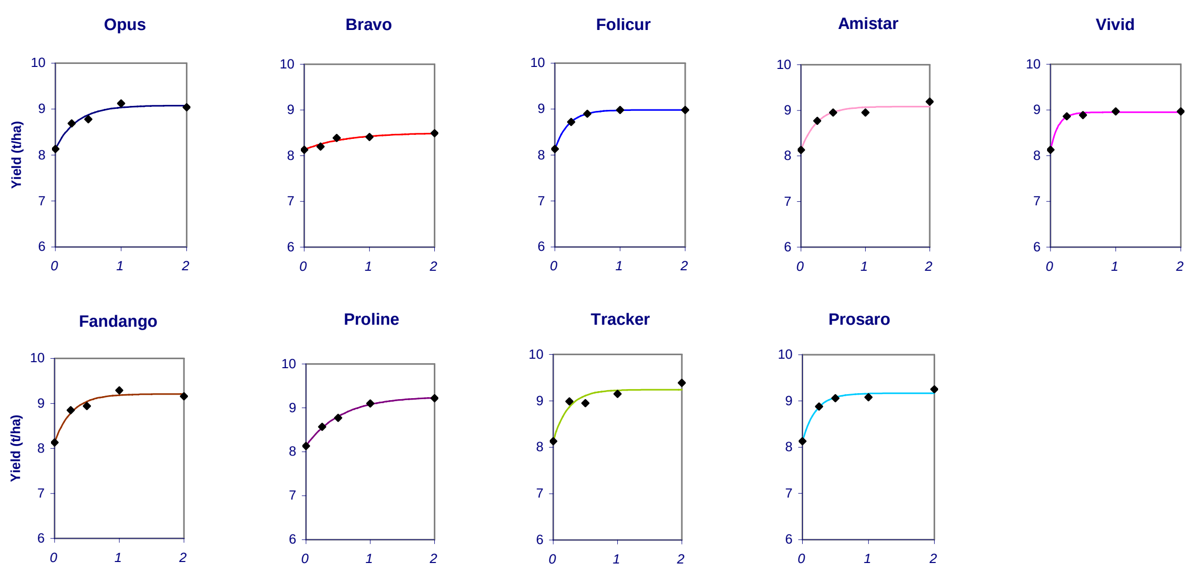


Figure 4.42 Fungicide dose-response curves for yield meaned across sites 4 and 11; 2005 - 2006.

#### 4.4.3 Specific Weight.

Amistar and Vivid increased specific weight by 3.4 kg/hl at full dose in 2005 (Figure 4.43). Full doses of Opus and Tracker gave increases of 3.2 and 3.3 kg/hl while Proline, Prosaro and Fandango gave increases of 2.7, 3.1 and 3.0 kg/hl respectively. Amistar and Vivid both increased specific weight by 3.4 kg/hl. The increase given by a full dose of Folicur was 2.6 kg/hl and that of Bravo was 0.9 kg/hl.

The effects of fungicides on specific weights were small in 2006 (Figure 4.44). Full doses of Proline, Prosaro and Fandango increased specific weight by 0.9, 1.0 and 1.6 kg/hl respectively. Increases from Opus and Tracker were 1.3 and 1.2 kg/hl at full dose. Amistar and Vivid increased specific weight by 0.9 and 0.8 kg/hl. The increase from a full dose of Folicur was 0.7 kg/hl and from Torch Extra, 0.6 kg/hl. Bravo applied at full dose resulted in an increase in specific weight of 0.3 kg/hl.

Specific weight data were variable in 2007 and dose-response curves could not be fitted for many products (Figure 4.45). A full dose of Comet plus a half dose of Opus increased specific weight by 4.8 kg/hl. This compared with an increase of 3.9 kg/hl from full dose Comet alone and 0.7 kg/hl from half dose Opus. Full dose Opus increased specific weight by 1.2 kg/hl and Tracker did so by 1.7 kg/hl. The increase in specific weight given by a full dose of Fandango was 2.4 kg/hl.

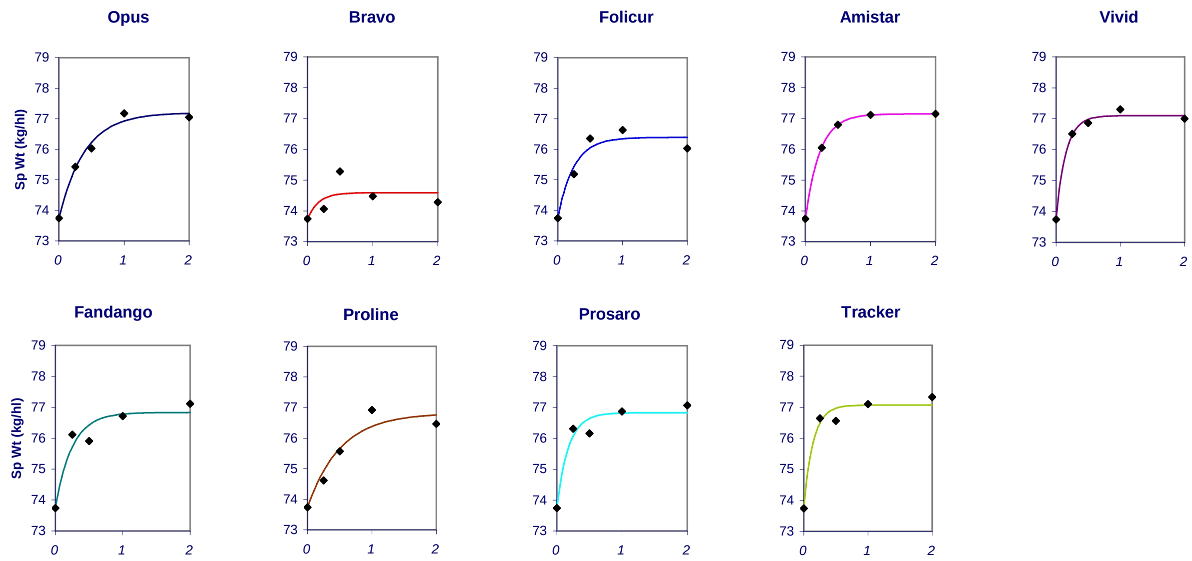


Figure 4.43   Fungicide dose-response curves for specific weight for site 4 in 2005.

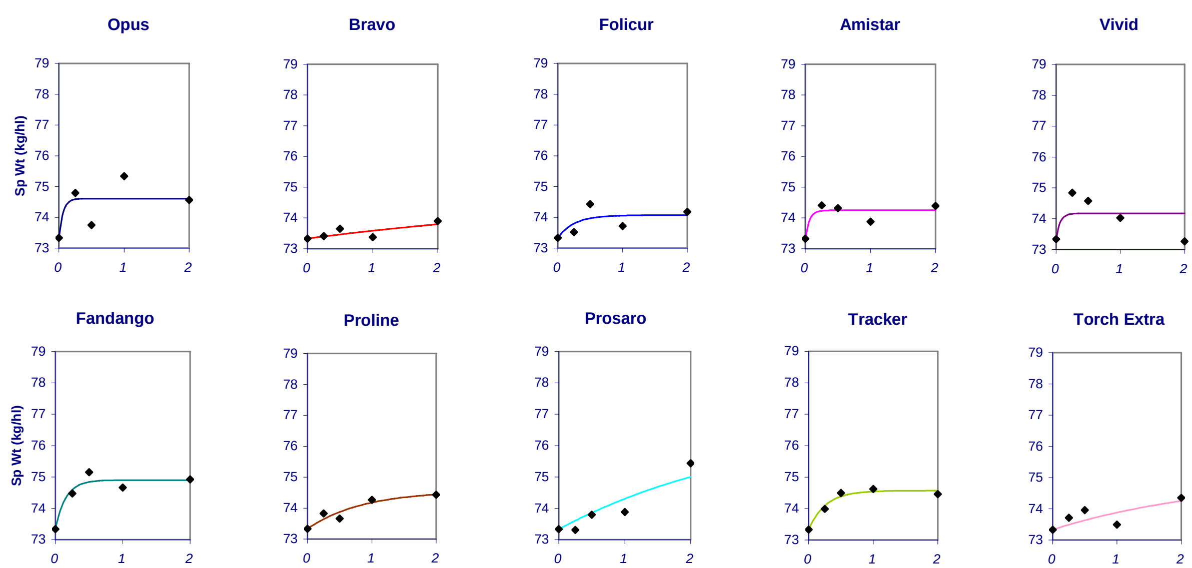


Figure 4.44   Fungicide dose-response curves for specific weight for site11 in 2006.

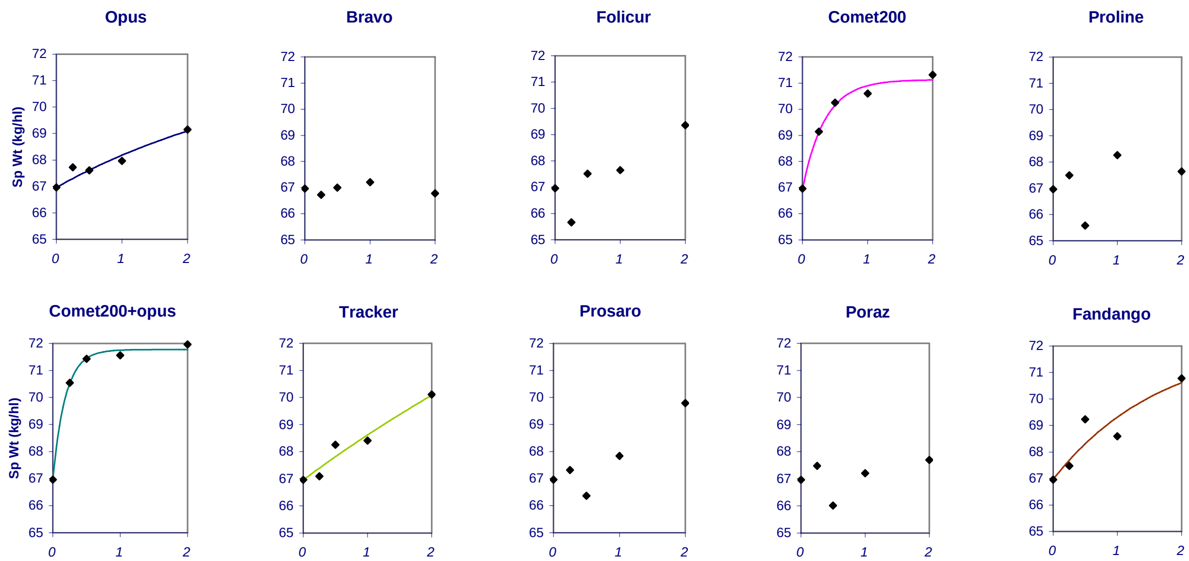


Figure 4.45 Fungicide dose-response curves for specific weight for site18 in 2007.

## 4.5 Mildew experiments

### 4.5.1 Disease control.

Figure 4.46 shows the 2005 dose-response curves for mildew averaged over the upper four leaves, combining eradicant and protectant activity. Flexity and Talius both gave very good mildew control, even at low doses. Other products were less effective, with the least effective being Corbel.

The mildew data for 2006 was also averaged over the upper four leaves (Figure 4.47). Again, Flexity and Talius stood out as giving very good control even at low doses. The new mildewicide, Cyflamid, also gave good control at full dose. There was little to choose between Opus, Proline and Torch Extra. Corbel gave poor control and Unix appeared to give no control, although a response curve could not be fitted to the data.

Again, the upper four leaves were included in the data for the dose-response curves in Figure 4.48 for 2007. More products gave good control at low doses in 2007. Flexity and Cyflamid gave good control at quarter dose, but Talius required half dose to achieve good control. Torch Extra, Tern and Fortress also gave good control at a quarter or half dose. Of the azoles, Proline was more effective than Opus at higher doses. The control given by Corbel was slightly better than in previous years and Unix gave some control at higher doses.

The mildew dose-response curves obtained when all the data were averaged across the three years/sites show Flexity and Talius gave almost complete mildew control at half dose, closely followed by Cyflamid. Fortress gave optimum control at a quarter dose, but did not achieve as greater reduction in disease as Flexity, Cyflamid or Talius. Tern, Torch Extra Proline and Opus all required higher doses to give their best control.

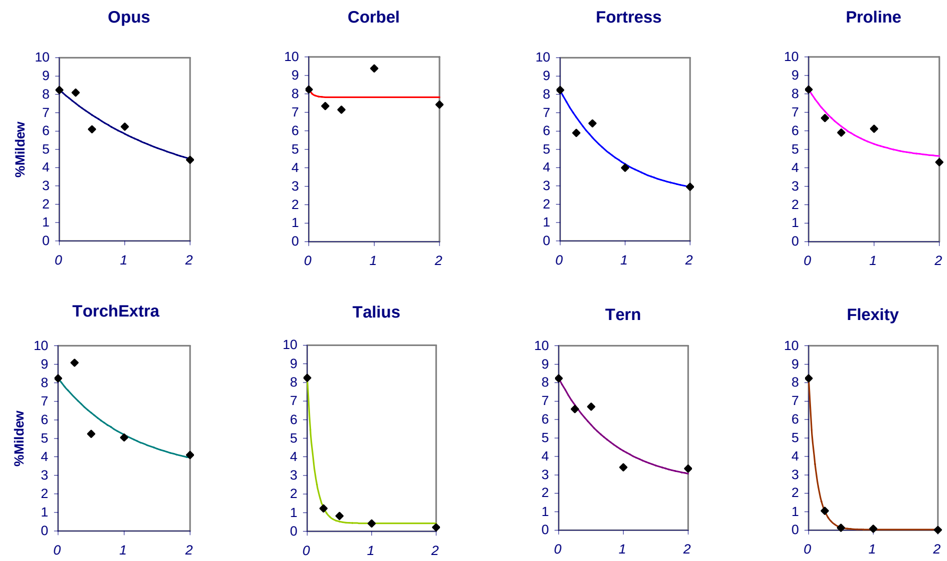


Figure 4.46 Fungicide dose-response curves for mildew (% leaf area affected) for site 6 in 2005.

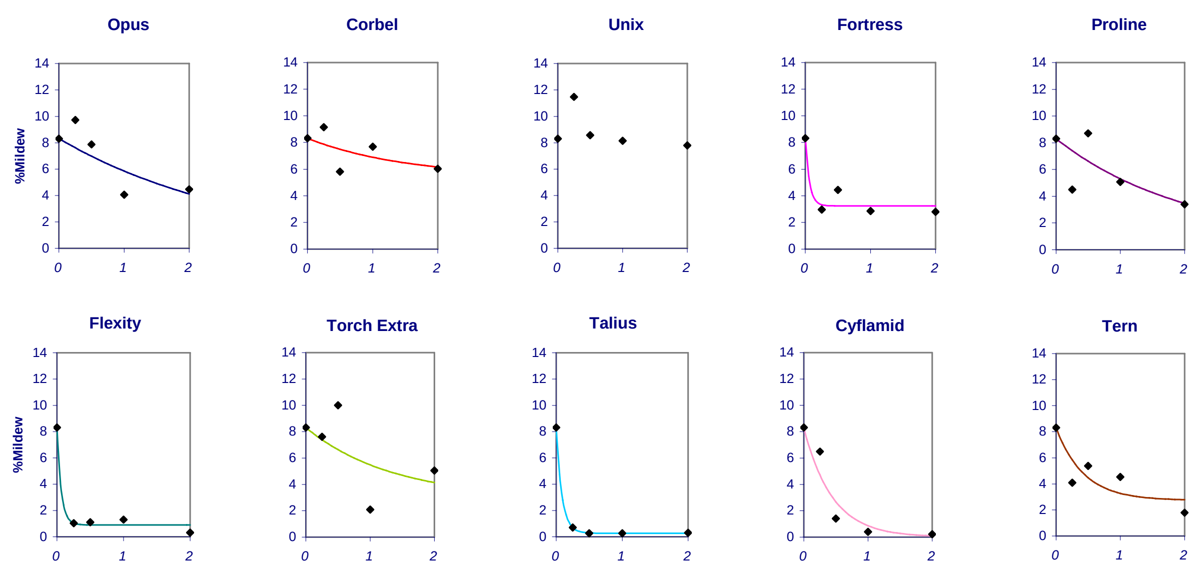


Figure 4.47 Fungicide dose-response curves for mildew (% leaf area affected) for site 13 in 2006.

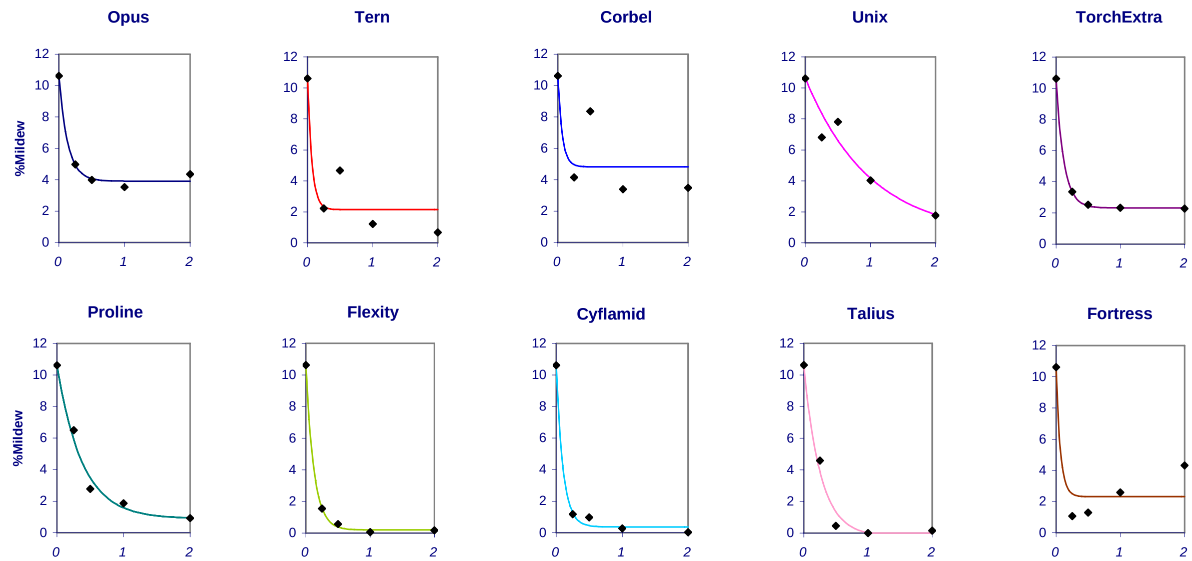


Figure 4.48 Fungicide dose-response curves for mildew (% leaf area affected) for site 20 in 2007.

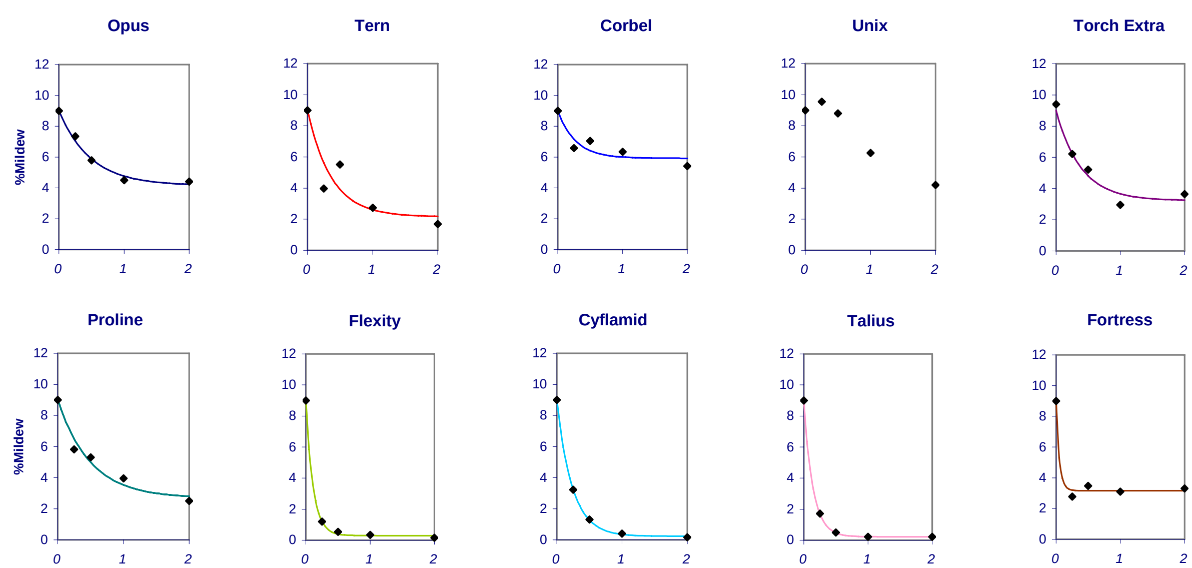


Figure 4.49 Fungicide dose-response curves for mildew (% leaf area affected) meaned across sites 6, 13 and 20; 2005 - 2007.

#### 4.5.2 Yield.

Yield responses to mildew control are usually relatively low and these sites are no exception. Nevertheless, the responses from the effective products were economic on the mildew susceptible variety used in these experiments. In 2005 (Figure 4.50) the maximum yield increase resulting from a fungicide application at full dose was 0.9 tonne/ha from Proline. Flexity gave 0.6 tonne/ha; Opus 0.5 tonne/ha and Talius 0.3 tonne/ha. Dose-response curves for yield data for other products could not be fitted.

In 2006, Proline again gave the greatest yield increase of 0.8 tonne/ha from full dose applications. Opus, Flexity, Talius and Cyflamid all increased yield by 0.7 tonne/ha at full dose. Tern increased yield by 0.6 tonne/ha and Unix and Fortress both gave increases of 0.4 tonne/ha at full dose.

Yield increases were smaller in 2007 with full dose Proline giving just 0.6 tonne/ha and Opus 0.5 tonne/ha. Flexity and Fortress increased yield by 0.4 tonne/ha at full dose and Cyflamid and Talius gave increases of 0.3 tonne/ha. Full doses of Tern and Torch Extra gave yield responses of 0.2 tonne/ha while Corbel and Unix gave no yield response.

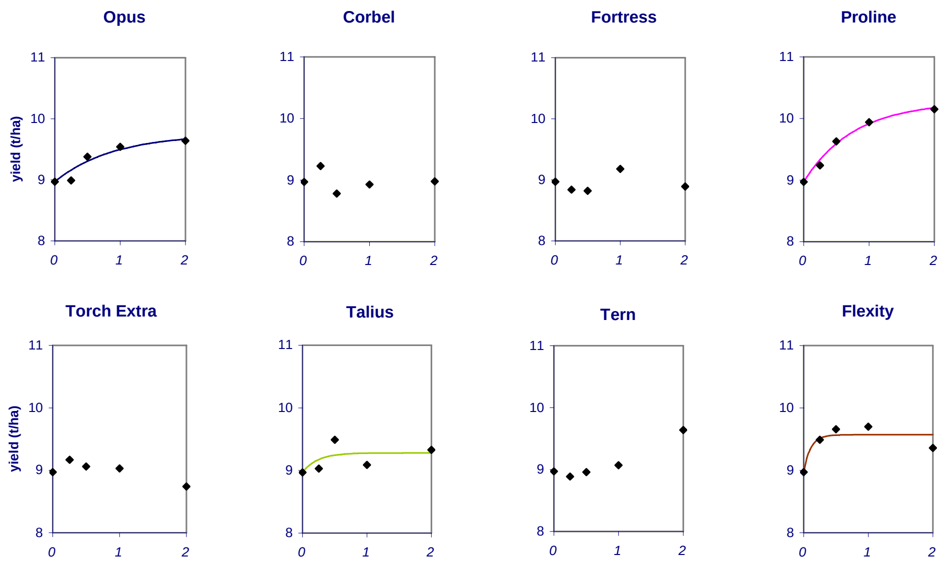


Figure 4.50 Fungicide dose-response curves for yield for site 6 in 2005.

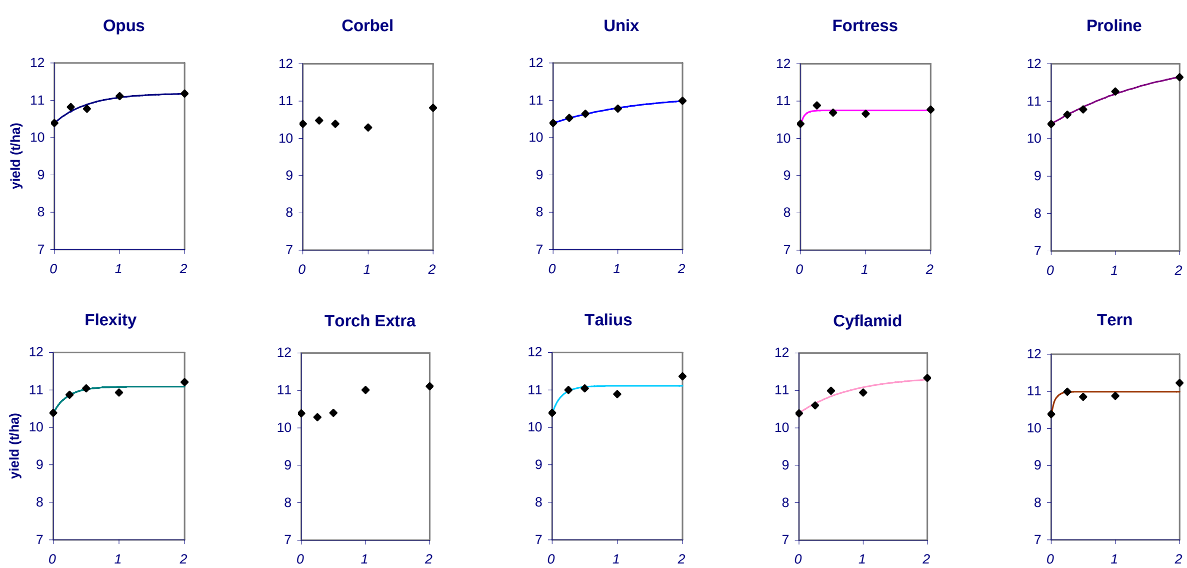


Figure 4.51 Fungicide dose-response curves for yield for site 13 in 2006.

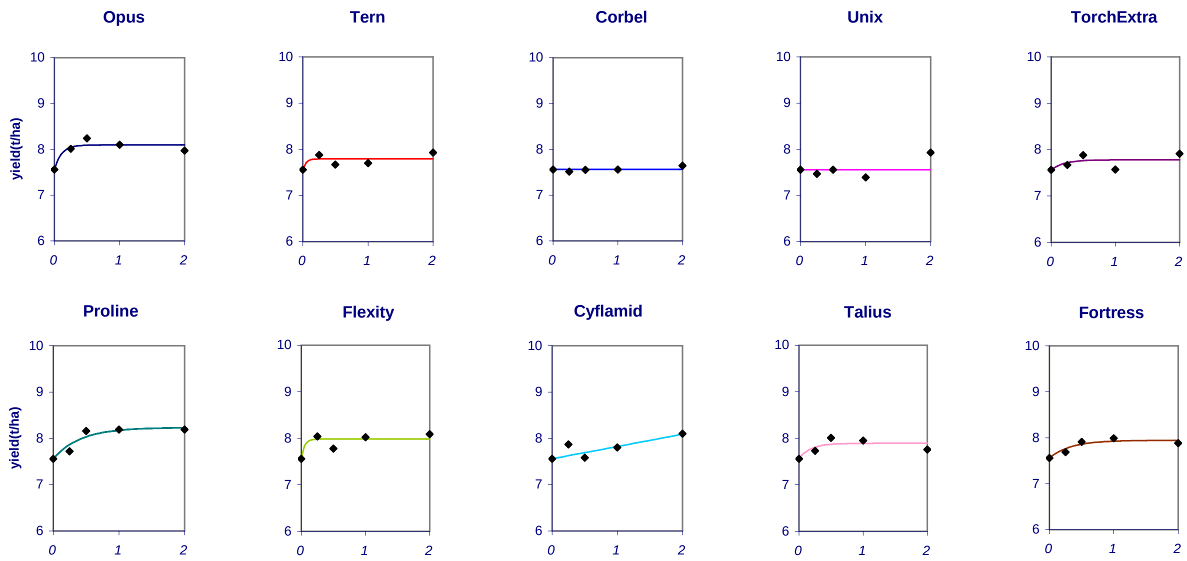


Figure 4.52   Fungicide dose-response curves for yield for site 20 in 2007.

### 4.5.3 Specific weight.

Specific weight data were only available for 2006 harvest (Figure 4.52) and the effects of controlling mildew on specific weight were small. Full doses of Proline and Flexity increased specific weight by 0.9 kg/hl. The increase from full doses of Talius and Tern was 0.5 kg/hl and Opus, Unix and Cyflamid all increased specific weight by 0.4 kg/hl at full dose.

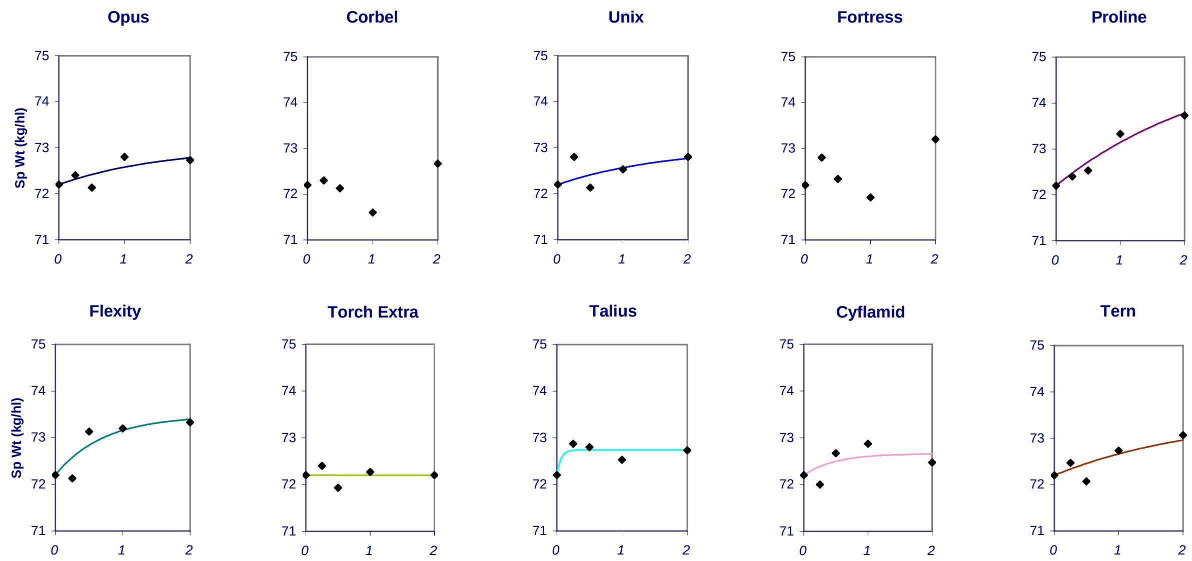


Figure 4.53 Fungicide dose-response curves for specific weight for site 13 in 2006.

## 5.0 CONCLUSIONS

***Stagonospora (Septoria) nodorum***

- Products based on epoxiconazole or prothioconazole gave good control of glume blotch.
- Chlorothalonil and prochloraz did not give effective control of glume blotch when applied to leaves.
- Pyraclostrobin continues to give reasonable control of glume blotch, even at low doses.
- Some large yield responses were recorded, up to 4 tonnes/ha, but it was not possible to determine how much of this was due to glume blotch control and how much was due to the control of *S. tritici.*
- Yield increases were reflected in increases in specific weight.

***Septoria tritici***

- The decline in activity of strobilurin fungicides against *S. tritici* appears to have stabilised and there is a suggestion that pyraclostrobin (Vivid or Comet) gave slightly better disease control in 2006 and 2007 than in 2005.
- However, there was no evidence that the addition of a strobilurin product to an effective azole fungicide enhanced *Septoria* control (Fandango v Proline or Opus + Comet v Opus).
- Tebuconazole (Folicur) was consistently less effective in controlling *S. tritici* than epoxiconazole (Opus) or prothioconazole (Proline).
- The activity of prochloraz (Poraz) against *S. tritici* remains weak and at the moment, there seems little, if any, benefit from its slightly different target site.
- Increases in specific weight were generally in line with yield increases.

**Yellow Rust**

- Fungicides or fungicide mixtures containing the azoles epoxiconazole, prothioconazole and tebuconazole all gave good control of yellow rust, usually even at a low doses.
- The strobilurins azoxystrobin and pyraclostrobin were also effective, except when *S. tritici* compromised disease control.

- The control of yellow rust by prothioconazole (Proline) appeared to be improved by the addition of fluoxastrobin (as Fandango)
- Spiroxamine (Torch Extra) had some activity against yellow rust, but was inconsistent.
- Levels of yellow rust at the three sites were not high and yield responses from the control of the disease in the absence of significant *Septoria* were modest, but often achieved by quarter doses.
- Where *Septoria* infection was more severe, as in 2006, the shape of the dose-response curves for yield for the azole fungicides was different. These curves did not level off after quarter dose and full doses were needed to give maximum yield responses.
- Increases in specific weight were generally small.

**Brown Rust**

- The most effective control of brown rust was given by Fandango, Tracker and Vivid.
- The activity of Fandango was largely due to the strobilurin component of the fungicide mixture.
- Prothioconazole (Proline) consistently gave poorer control of brown rust than other azole  products (Opus and Folicur)
- The inclusion of boscalid in Tracker improved brown rust control compared with Opus alone.
- Data for spiroxamine (Torch Extra) was limited to one year and no firm conclusions can be drawn concerning its activity against brown rust.
- Yield responses were generally modest except in 2007. Even in 2007, yield responses were not as great as might be expected considering the brown rust severity. However, treatments were applied when the crop was already at the beginning of ear emergence, and this was probably too late to achieve effective control due to the early development of the brown rust epidemic.
- Fandango, Tracker, Prosaro and Comet plus Opus gave the greatest yield responses.

**Mildew**

- The new generation of mildewicides - metrafenone (Flexity) and proquinazid (Talius) and more recently cyflufenamid (Cyflamid) gave very good control of mildew, often at quarter or half doses.

- Other recent introductions such as quinoxyfen (Fortress) and spiroxamine (Neon, Torch Extra) were not quite as effective.
- Fenpropimorph (Corbel) and Cyprodinil (Unix) generally gave poor control of mildew.
- Of the azole fungicides, prothioconazole gave slightly better mildew control than epoxiconazole.
- As usual, yield responses and any increase in specific weight from mildew control were small.
- Prothioconazole (Proline) consistently gave the greatest yield increase despite its poorer mildew control, probably due to the control of low levels of *Septoria*.

## 6.0 REFERENCES

Patterson HD (1997). Analysis of series of variety trials. In: Statistical methods for variety evaluation. Eds. RA Kempton & PN Fox.

## 7.0 ACKNOWLEDGEMENTS

This work was funded by the Home-Grown Cereals Authority. The considerable effort given by ADAS, SAC, TAG and Teagasc staff in spraying and assessing the experiments is gratefully acknowledged. Thanks are also due to Dr Anne Ainsley and Dr Chris Dyer for their work on the statistical analysis of the data.

## ADDENDUM

### Interpretation of dose-response curves

#### The dose-response curve

If the severity of foliar disease is measured in experimental plots that received fungicide treatment, at a range of doses, some time before, the results will typically look like those in Figure 1. Those plots that receive no treatment will suffer a level of disease determined by the local 'disease pressure'. Fungicide treated plots will suffer less disease and the higher the dose, the lower the disease severity. However, a law of diminishing returns operates and each successive increase in dose causes a smaller additional effect. The decrease in disease with increasing dose is commonly represented by a line, rather than bars, and is described as a 'dose-response curve'.

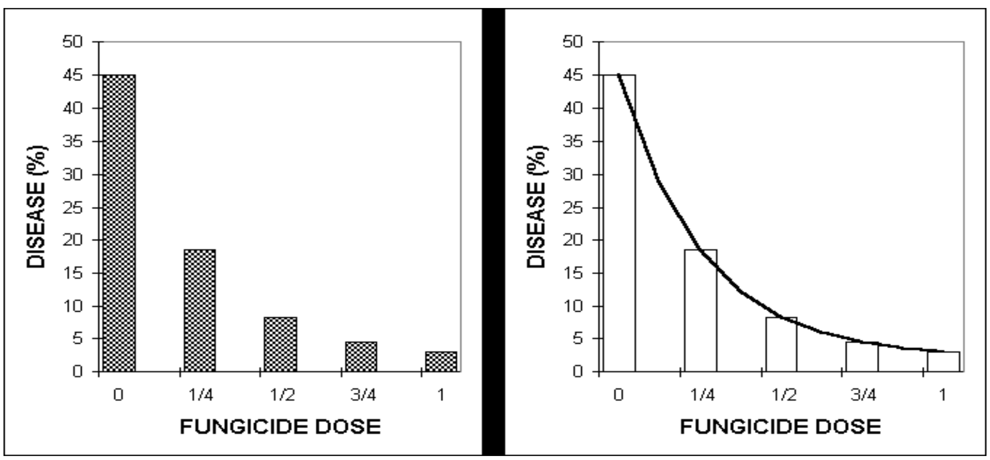


Figure 1 . Disease severity following fungicide treatment at a range of doses and the dose-response curve

The maximum dose that can be used is specified on the product label, as the recommended dose, and must not be exceeded. However, there is no legal limit to the minimum dose that should be applied, and the majority of crops now receive fungicides at doses substantially below those recommended on the product label. To understand why, it is helpful to consider how the recommended dose is set.

#### The recommended dose

Complete disease control is usually either technically unachievable in the field on a consistent basis, or is not cost effective. Furthermore, when the same fungicide is applied to control the same disease at a range of locations, the response to the applied chemical varies from place to place. The dose that gives 90% control in one field can be quite different to that which gives 90% control in another. To allow for this inherent variability and to avoid product dissatisfaction, the label recommended dose is usually set at a level that consistently gives a high level of control across locations and seasons, typically 80-90% control 80-90% of the time. During the late 1980's and early 1990's, growers began to appreciate the safety margin built into the label recommended dose and, under pressure to reduce input costs, began to reduce the doses of fungicides applied to cereal crops. Survey data suggest that these reductions were, and still are, often made in an arbitrary manner.

**Appropriate fungicide doses**

Fungicide cost increases in direct proportion to the dose applied. As the loss of yield and grain quality is proportional to the level of disease, a point can be found on the dose-response curve, beyond which the cost of any further increase in dose would not be paid for by the resulting yield increase. At this point, profit is maximised (Figure 2) and unnecessary pesticide use minimised - by definition the **appropriate dose** to apply.

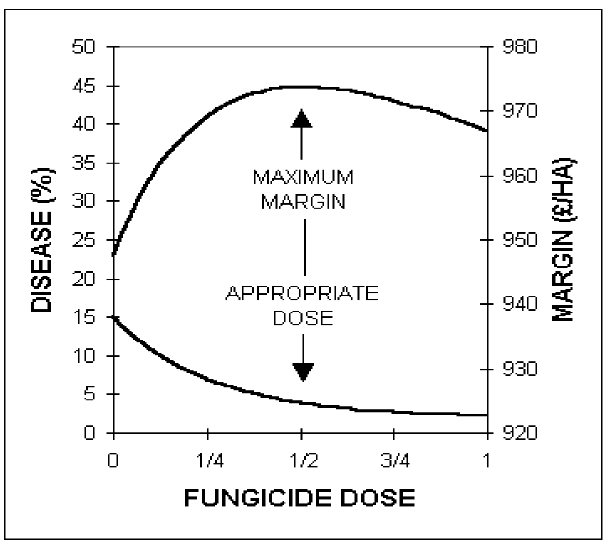


Figure 2. Dose-response curve, margin over fungicide cost and appropriate dose

At doses below the appropriate dose, profit is reduced by ineffective disease control. At doses above the appropriate dose, profit is reduced by excessive fungicide cost. It is important to note that the loss of profit is more severe if the dose is reduced below the appropriate dose than if increased above it. Hence, where there is uncertainty about the appropriate dose to apply, it is prudent to apply more, rather than less. The greater the uncertainty, the greater the safety margin required.

On what basis can a crop manager decide on the appropriate dose to apply - given that, as the shape of the dose-response curve varies from site to site and season to season, so must the appropriate dose? And how can the uncertainty surrounding the choice of dose be minimised, to allow doses to be applied that are consistently close to the economic optimum, without suffering occasional severe losses due to under-application? The answers must come from taking account of the causes of the variation in disease control between sites and seasons.

**Variation in dose-response curves**

One of the main reasons for variation in disease control between sites and seasons is that, in the absence of treatment, disease severity varies between sites and seasons. Figure 3 shows the effect on the dose-response curve and the appropriate dose, of different levels of untreated disease. Curve (A) represents, for example, a crop of a disease susceptible variety, that experienced weather conditions favourable to disease development; curve (B) a more resistant variety or a susceptible variety under conditions less favourable to disease; and curve (C) a variety with complete immunity to that disease.

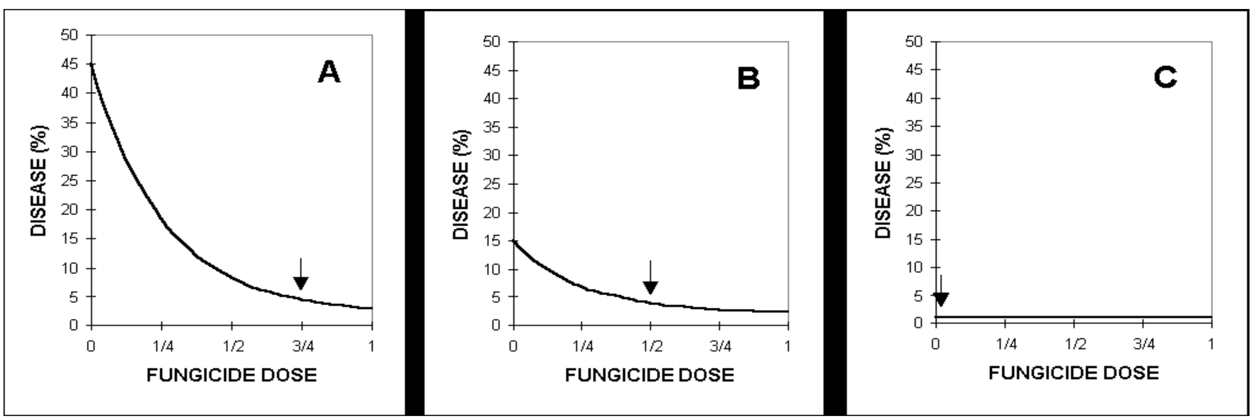


Figure 3. Effect of disease pressure on dose-response curve and appropriate dose (represented by an arrow)

Clearly, higher disease pressure justifies higher inputs. However, the appropriate dose also depends on efficiency of control. Figure 4 takes the high disease pressure case (A) and shows the effect of applying alternative products that are more (B), or less (C), effective. All else being equal, more effective products have lower appropriate doses. However, efficacy is often reflected in price, so the best product/dose combination needs to be selected to do the job.

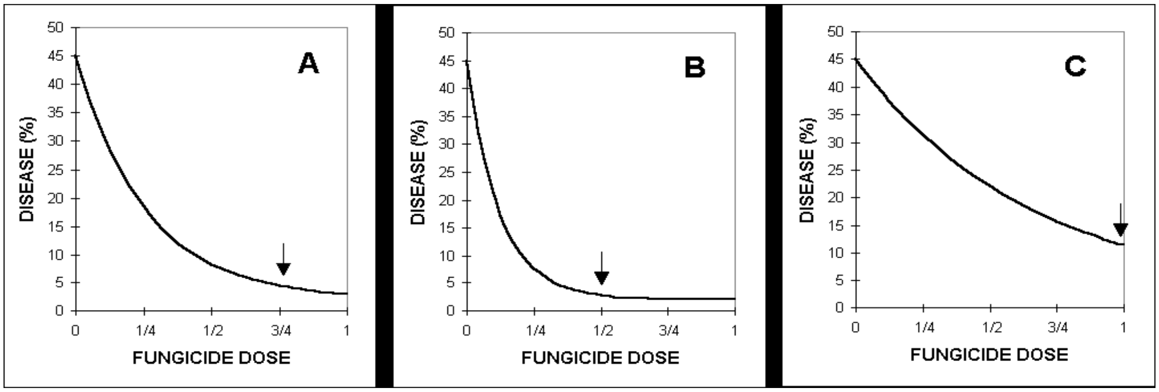


Figure 4. Effect of fungicide activity on dose-response curves and appropriate dose.

It can be seen, from the examples shown above, that the appropriate dose in a range of circumstances can vary between the recommended dose and zero. A crop manager who is better able to quantify disease pressure and predict efficiency of control, will be able to apply doses that are consistently closer to the economic optimum - to the benefit of unit cost of production and the defensibility of pesticide use.

## APPENDIX

Details of fungicide products used in the experiment and their active ingredients

| Product | Active ingredient | g a.i./litre or kg | Full (label recommended) dose (litre or kg/ha) | weight of a.i./ha at full dose (g) |
|---|---|---|---|---|
| Amistar | azoxystrobin | 250 | 1.00 | 250 |
| Bravo | chlorothalonil | 500 | 2.00 | 1000 |
| Comet 200 | pyraclostrobin | 200 | 1.25 | 250 |
| Corbel | fenpropimorph | 750 | 1.00 | 750 |
| Cyflamid | cyflufenamid | 50 | 0.50 | 25 |
| Fandango | fluoxastrobin<br>prothioconazole | 100<br>100 | 1.50<br>1.50 | 150<br>150 |
| Flexity | metrafenone | 300 | 0.50 | 150 |
| Folicur | tebuconazole | 250 | 1.00 | 250 |
| Fortress | quinoxyfen | 500 | 0.30 | 150 |
| Neon | spiroxamine | 500 | 1.50 | 750 |
| Opus | epoxiconazole | 125 | 1.00 | 125 |
| Poraz | prochloraz | 450 | 0.90 | 405 |
| Proline | prothioconazole | 250 | 0.80 | 200 |
| Prosaro | prothioconazole<br>tebuconazole | 125<br>125 | 1.20<br>1.20 | 150<br>150 |
| Swift | trifloxystrobin | 500 | 0.50 | 250 |
| Swing Gold | dimoxystrobin<br>epoxiconazole | 133<br>50 | 1.50<br>1.50 | 199.5<br>75 |
| Talius | proquinazid | 200 | 0.25 | 50 |
| Tern | fenpropidin | 750 | 1.00 | 750 |
| Torch Extra | spiroxamine | 800 | 0.90 | 720 |
| Tracker | boscalid<br>epoxiconazole | 233<br>67 | 1.50<br>1.50 | 349.5<br>100.5 |
| Unix | cyprodinil | 750 | 1.00 | 750 |
| Vivid/Comet | pyraclostrobin | 250 | 1.00 | 250 |