A guide to fungicide performance in wheat, barley and oilseed rape

Figure 1. Fungicide performance barley trial plots at Lanark, Scotland (2018)

Introduction

The AHDB fungicide performance project on wheat, barley and oilseed rape is consistently rated by AHDB Cereals & Oilseeds levy payers as one of the research projects they value the most, after the AHDB Recommended Lists.

High quality, independent information on the performance of new and established benchmark fungicides is vital to maintain a competitive UK arable sector and AHDB is committed to the long-term future of the project.

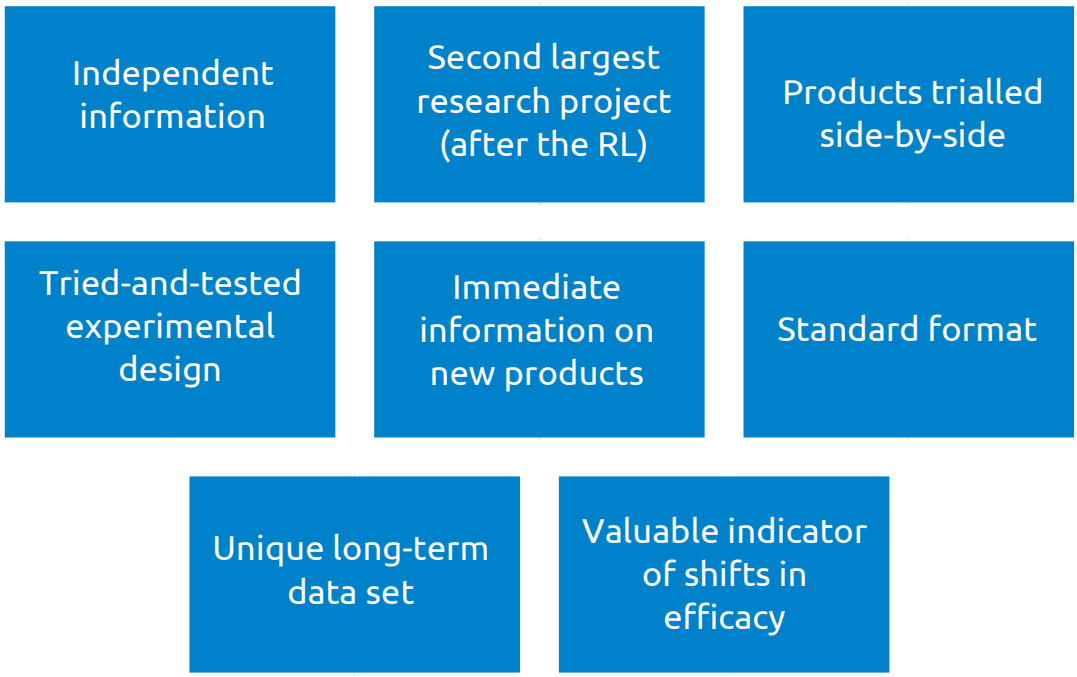
The aim of the project to provide information on the relative efficacy of individual fungicides against specific diseases, to identify their strengths and weaknesses. Growers and agronomists use the results to build fungicide programmes, based on mixtures of active ingredients and products appropriate to the local disease threat profile. As such, there is a preference to test single active ingredients, rather than mixtures, even though this may not be the appropriate way to use them in a commercial situation. Diseases targeted are those with the highest potential economic impact on the levy payer and, as such, the resources applied to specific diseases and the diseases targeted are under continual review.

In addition to providing information of immediate value for the development of fungicide programmes, the project provides a long-term information resource, enabling trends in performance of individual products and active ingredients to be monitored. The wheat trial series is the longest, going back to 1994, with the barley series beginning in 2002 and the oilseed rape in 2006.

Overall management of the project is the responsibility of AHDB, guided by the Fungicides Working Group (FWG). Trial management is undertaken by a consortium of project partners (ADAS, NIAB, SRUC (with Scottish Agronomy) and Harper Adams University). Additional trials are conducted and funded by Teagasc (Agriculture and Food Development Authority – Eire) under the same protocols. Analysis of results is undertaken by AHDB staff in consultation with the FWG. A robust scientific approach, based on methodology published in the scientific literature combined with relevance to on farm practice, is ensured by the inclusion on the FWG of some of the leading UK experts on fungicide use in arable systems, including resistance management, with statistical advice being provided by Biomathematics and Statistics Scotland (BioSS).

The project maintains regular links to the UK agrochemical manufacturing industry. This link is important in enabling the project to trial fungicides while still in their pre-registration development phase, so that, upon registration, levy payers can receive a robust analysis of product performance against a range of industry 'standard' products. In return, the manufacturers' products receive a high-profile independent test, providing additional insight into their relative performance against key diseases. The results are made readily available to manufacturers to support best use of their products.

This guide provides an overview of the testing programme. It aims to help users of fungicide performance data to better understand how results are produced and interpret them in their appropriate context.



Trials

Diseases and location

The diseases targeted reflect those most economically damaging to cereal and oilseed crops. Resources are weighted towards the most important of these, both in terms of the number of trials and the number of products tested. The diseases targeted and the number of trials for each disease (as of 2015) are shown in Table 1. The balance of diseases and trial resources is continually under review and there have been a number of changes over the years; for instance, the number of light leaf spot trials has recently increased from two to three to reflect the increasing incidence of this disease in England.

Table 1. Key disease targets in the fungicide performance work. Number of trials indicated in ().

Key disease targets	
Wheat	Septoria tritici – *Zymoseptoria tritici* (6) Yellow rust – Puccinia striiformis (1) Brown rust – *Puccinia triticina* (1) Head blight – *Fusarium and Microdochium spp* (1)
Barley	Rhynchosporium – *Rhynchosporium commune* (3) Net blotch – *Pyrenophora teres* (2) Mildew – *Blumeria graminis f.* sp. *hordei* (1) Ramularia – *Ramularia collocygni* (1)
Oilseed rape	Light leaf spot – *Pyrenopeziza brassicae* (3) Phoma – *Leptosphaeria maculans* and *L. biglobosa* (2) Sclerotinia – *Sclerotinia sclerotiorum* (2)

Individual trials target specific diseases through a combination of location and variety. Trials are located in areas expected to produce high disease pressure for the target disease (Figure 2). For instance, wheat yellow rust trials are located in the East of England, while septoria trials are located in the South and the West, including Scotland. For the sporadic diseases, wheat brown rust and head blight, artificial inoculation is used to ensure consistent results.

Targeting of individual diseases is further enhanced by using crop varieties with high susceptibility to the target disease but good resistance to other diseases. Where possible, current Recommended List varieties are used. Winter varieties are used, with the exception of the ramularia trial, which uses spring barley.

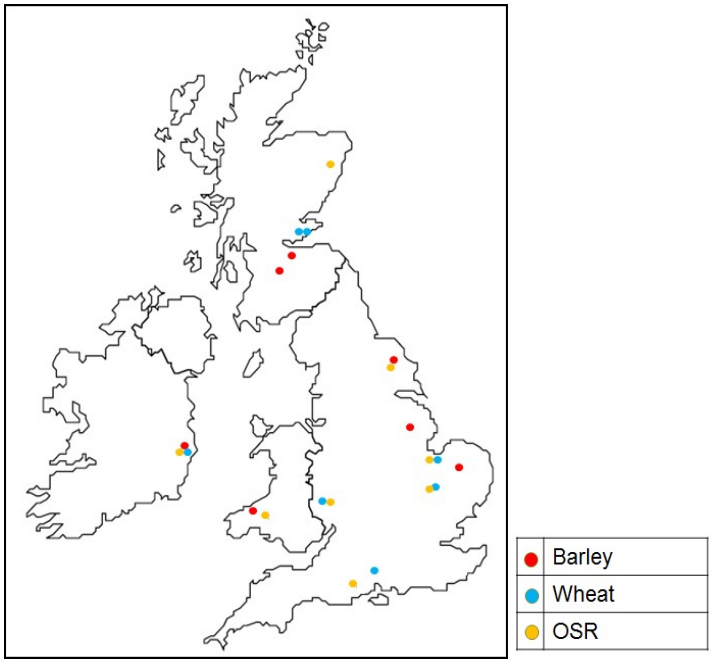


Figure 2. Approximate location of fungicide performance trials

Trial design

Trials use a conventional small plot design, with plot areas between 20m^2 and 60m^2 and three replicates per treatment. Because of the size of the trials, an incomplete block (alpha design) plot layout is used (see Box 1).

Trials are managed according to best local practice – for example, cultivations, fertilisers and herbicides. Ramularia trials in barley may receive an overspray of a strobilurin fungicide to control early season disease. Light leaf spot and phoma trials in oilseed rape receive a sclerotinia overspray, if disease pressure is high. Sclerotinia trials receive an autumn fungicide to control phoma and light leaf spot.

Box 1: Alpha design

Alpha designs are a flexible class of resolvable incomplete block designs.

A resolvable design is one in which each block contains only a selection of the treatments but the blocks can be grouped together into subsets, in which each treatment is replicated once. The groupings of blocks form replicates.

Such designs are particularly useful when there are many treatments to examine and the variability of the plots is potentially such that the block size needs to be kept small.

Alpha designs were devised originally for the analysis of plant breeding trials and are the standard trial design used in AHDB Recommended List trials.

Treatments

Products tested are decided by the FWG guided by a set of Ground Rules (Appendix 1). These are intended to provide results that are relevant to levy payers and give equal opportunity for the agrochemical companies to have their products included in trials. The emphasis is on testing new active ingredients against ‘standards’ for which we have a good understanding of performance. Inclusion of products in development, pre-registration, is an important part of the work, providing levy payers with early information on product efficacy when they are first approved. Older products/active ingredients may be added back into trials, where performance is thought to have shifted due to changes in pathogen populations.

For cereal trials, treatments are applied once at a growth stage appropriate to the disease. At some sites, septoria fungicides are tested in separate trials as a T1 spray (GS32) and a T2 spray (GS39). At other sites, an intermediate timing (emergence of final leaf 2) is used. Light leaf spot and phoma trials receive two treatment sprays. For light leaf spot, treatments are applied at or before the first appearance of visible symptoms in October or in early November. The second application is made when symptoms are found readily in treated plots. For phoma, the first treatment is applied at early disease onset (20–40% plants affected) and the second about six to eight weeks later. For sclerotinia, treatment is at early flowering.

Four different doses are tested for each product/active ingredient to enable a full dose-response curve to be generated. For cereals, the doses are quarter, half, full and double the label recommended rate. The inclusion of the double rate is to improve the ‘fitting’ of the dose-response curve. For oilseed rape, doses are quarter, half, three quarters and full. Using doses above full rate on oilseed rape can have negative impacts with products that have a growth regulatory (PGR) effect.

Disease assessments

Cereal diseases are assessed three and six weeks after treatment, although trials are continually monitored and these timings may be changed, if the disease progresses faster or slower than normal. For cereals, diseases are assessed separately on all non-senesced leaf layers. For phoma and light leaf spot, assessments are flexible, depending on disease progress, but are nominally at the T2 spray timing and six to eight weeks later. For sclerotinia, there are two assessments: the first is dependent on disease development and the final one is prior to harvest.

All diseases present are assessed, along with green leaf area (GLA) in cereals. Additional assessments of stem-base diseases, lodging and ear diseases are made to provide context to the target disease results. All trials, except wheat head blight trials, are harvested for yield.

Data analysis

Prior to analysis, data from trials is validated. Validation criteria for cereal foliar diseases are shown in Table 2. For septoria, rhynchosporium and net blotch, results are further categorised as protectant or eradicant by leaf layer according to the relationship of spray timing to leaf emergence. For septoria trials, the inclusion of a single chlorothalonil (Bravo 500) treatment provides an additional check on protectant versus eradicant activity.

For oilseed rape, the data exclusion criteria are broadly applied, although not all are relevant, for instance disease level exclusions. For cereals, data are meaned across validated leaf layers and assessment dates. For oilseed rape, the optimum disease assessment date is utilised.

Table 2. Data validation – criteria for excluding data from analysis

Data exclusion criteria	Comment
Severe outliers	Individual plots may be removed from the workbooks (in consultation with site managers) if they are clearly erroneous in the context of the rest of the trial.
No significant treatment effects	If there is no statistically significant difference between treated and untreated plots.
Mixed diseases	Where there is more than one disease present, at a sufficiently severe level, to have confounded the data for the other disease.
Low disease severity	Where disease level in untreated plots is less than 3%, variability of results increases. This makes results unreliable.
Excessively high disease severity	Where disease in untreated plots is more than 70% leaf area, lack of remaining green area to infect (density dependence) distorts disease progress curves and hence distorts dose-response curves. This can result in apparently poor control in high disease sites/seasons.
Illogical data	For example, logical GLA dose-response curves, but illogical disease dose-response curves. This may be caused by underestimation of disease severity in untreated plots due to senescence.
Excessive product 'stretch'	Leaves more than two layers below the treated leaf layer are excluded from the analysis.

Statistics

Statistical analysis of trial results is based on methodology developed by BioSS and curve plotting is based on methodology published by Paveley et al 2000 in *Plant Pathology*.

Analysis of disease, GLA and yield data is done using a linear mixed model, utilising the REML (residual (or restricted) maximum likelihood) algorithm. This allows utilisation of both fixed (treatment) and random (trial and year) effects in a cross-site and over-year analysis. It can be used to analyse unbalanced designs, i.e. where not all products are included in all trials/years, or incomplete block designs in single trials, which is not possible with ANOVA (analysis of variance).

Data for disease and GLA are Logit transformed prior to analysis to account for the fact that it is proportional data constrained between 0% and 100%. Yield data are not transformed. Results are back-transformed prior to curve plotting. Mean disease, GLA and yield levels are used to plot dose response curves, using a negative exponential function.

Results

Results for oilseed rape are made available as soon as possible, to inform autumn spraying decisions. Results from cereals trials are released at the annual AHDB Agronomists' Conference in December.

Fitted curves are plotted showing the level of disease at different dose levels, so-called 'dose-response curves' (Figure 3). Statistical analysis of product performance is not reported with dose-response curves. Curves are indicative only and the complex statistics used mean that statistical interpretation is not straight forward, particularly for over-year analyses.

As a rule of thumb, where curves fit well to the data points and the curves are clearly separated, then differences are likely to be real, although differences of only one or two percentage points may not be 'meaningful' in the field.

Full dose-response curves, up to twice the label rate, are shown at the Agronomists' Conference but in online and hard copy material, curves are only shown up to full label rate. This is to avoid any confusion about the use of rates above full label.

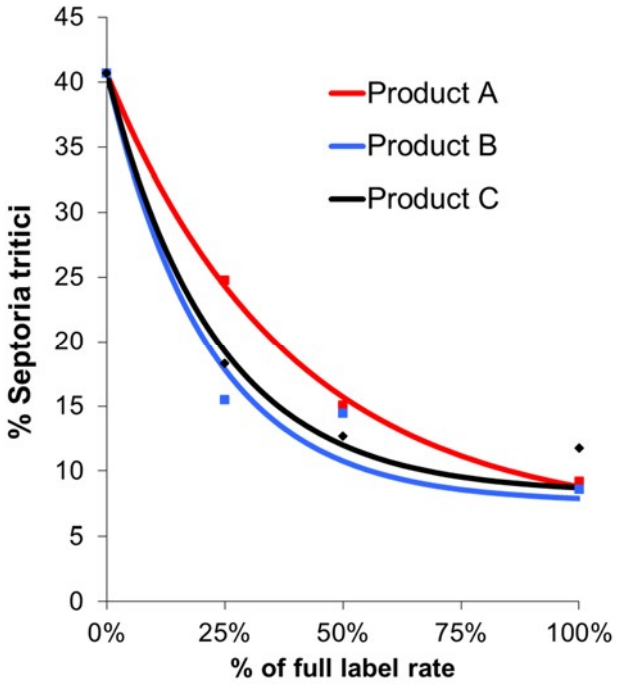


Figure 3. Example dose-response curve

GLA data is not generally shown unless it aids interpretation of disease results in some way. Yield data for cereal trials is generally only shown on platform presentations to indicate general seasonal disease pressure, as the yield responses do not represent those that would be seen in commercial situations with a full fungicide programme (although they also have some additional use in giving some indication of product persistence).

Appendix: Project Ground Rules

Following constructive consultation with industry and research contractors, AHDB fungicide performance work will operate as outlined below.

Aims

The project is designed to provide fungicide performance results that:

1. Are relevant to commercial use and simple to interpret for levy payers.
2. Focus experimental resources in proportion to the relative economic importance of the major foliar and ear/pod diseases.
3. Provide a strong test of performance under high-pressure conditions.
4. Aid in the identification and interpretation of shifts in fungicide efficacy resulting from changes in pathogen sensitivity.
5. Are compatible with the existing AHDB data sets from previous fungicide performance projects.
6. Deliver information to levy payers in time for the first season of commercial use of new fungicides.
7. Provide information, not farm-specific advice.

Management

Co-ordination of the project and data management will be 'in-house' at AHDB, with external support on pathology, statistics and technology interaction. Stakeholders will be represented on an AHDB-led Fungicide Working Group, which will:

1. Agree protocols.
2. Interpret results.
3. Exchange information (under a strict confidentiality agreement) with collaborators in Ireland.
4. Formulate messages.

FWG members: Paul Gosling (AHDB, Chair), Neil Paveley (ADAS, Lead Scientist), Stuart Knight (NIAB), Jane Thomas, (NIAB), Jonathan Blake (ADAS), Fiona Burnett (SRUC), Faye Richie (ADAS), Simon Edwards (Harper Adams), John Spink (Teagasc).

Other individuals may be invited to participate in meetings as required to meet project aims.

Liaison with industry stakeholders

The AHDB FWG Chair will ensure active liaison with the crop protection industry to co-ordinate:

1. Provision of new products for inclusion.
2. Feedback on results and messages prior to dissemination.

Inclusion of products

The priority of AHDB is to test new active substances and modes of action relative to established 'controls'. Although it is not possible to predict approval date with certainty, the aim should be to complete two years of trials on a new active prior to commercialisation, to provide robust and balanced information. The number of new products that can be tested in any season will be limited. Hence, inclusion will have to be prioritised, in the following order:

1. Products containing a new broad-spectrum active substance.
2. Products containing a new pathogen-specific active substance.
3. Filling data 'gaps' for recent active substances, where data for particular diseases are inadequate.
4. Comparing active substances against their baseline performance (where performance may have improved, due to formulation/mixtures, or deteriorated, due to pathogen insensitivity).

Spectrum of activity will be used to determine the target diseases (and hence trial sites/varieties) against which each new product should be tested. Hence, the number of products that can be tested cannot be predicted exactly. Where a new active substance will only be available commercially as a formulated mixture, where possible, the relevant mixture partner/s will also be included in the trials to determine the extent to which the new active substance is adding to spectrum and/or efficacy (whether by innate activity or synergy). In the event that trial space becomes limiting, new active substances will be prioritised accounting for the space required to test them as follows:

1. Straight new a.s.
2. Two-way mix – new a.s. with a standard
3. Two-way mix – new a.s. with a non-standard
4. Three-way mix – new a.s with one or more standards.

Control products will be included in all trials. These will be widely recognised products within the industry with good understanding of their performance. These will act as baseline products against which performance of new products can be assessed. Plots may be available adjacent to the AHDB plots at some sites for commercially funded testing. Partners may co-locate commercially funded testing at their discretion but, in doing so, such experiments do not in any way become associated with or linked to the AHDB project. Trials may be used for demonstration purposes, with permission of AHDB. Visits to experimental sites by industry partners are welcome, to view standards and own products.

Data confidentiality

Project participation will be subject to the confidentiality agreement contained in the project tender documents. All data (disease severity, green area and yield) remains confidential, unless and until permission for release has been given by AHDB. The only exception to this is for feedback to industry partners on results and messages prior to dissemination. After information has been published by AHDB, data can be used in knowledge transfer activities by the project partners. Access to the plot data will be limited to the FWG and those working directly for them. Data on new products will remain confidential until approval. The identity of coded products will not be disclosed by any party until approval.

Message formation and Knowledge Transfer

Messages will be:

1. Fair.
2. Technically sound.
3. Timely.

Industry partners will be alerted to the messages coming out of the work, so that their views can be taken into account prior to dissemination. Communication will be via the FWG Chair. If there are issues with messages that cannot be resolved by this route, a direct meeting of the FWG will be organised prior to dissemination. Yield information from single spray timings will only be presented with caution and will be interpreted in context.

Key dates

1. FWG meeting (end November latest) – to discuss trial data from preceding season/s and agree knowledge transfer messages.
2. FWG meeting (end January latest) – to finalise products for inclusion in cereal trials and OSR sclerotinia trials and draft trial plans for coming season.
3. April – select products for inclusion in OSR LLS and phoma trials
4. Early July – optional in-season trial visits.

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