

Final Project Summary

Project title	Assessing the resistance risks associated with systemic fungicide seed treatments and the effectiveness of risk modifiers		
Project number	RD-2012-3801	Final Project Report	PR562
Start date	01 January 2013	End date	30 December 2015
AHDB Cereals & Oilseeds funding	£38,578	Total cost	£328,076

What was the challenge/demand for the work?

Systemic seed treatments with efficacy against foliar diseases have the potential to improve disease control and raise yields. However, there is a potential risk of accelerated development of fungicide resistance in pathogens when the same mode of action is used for both foliar-acting seed treatment and foliar treatments. There is strong evidence that increasing the number of foliar applications of the same mode of action leads to an increased strength of selection for resistant strains of pathogens. These resistant strains then become dominant in the pathogen population more quickly and therefore reduce the effectiveness of control by fungicides. In principle, adding a foliar-acting seed treatment could have a similar effect. However, there has been very little research to assess or produce evidence for the effects of seed treatments on resistance selection.

The Fungicide Resistance Action Committee (FRAC), which represents the crop protection industry, initially advocated that for succinate dehydrogenase inhibitor (SDHI) fungicides, a foliar acting seed treatment need not be counted as one of the restricted number of applications permitted per crop, provided that certain resistance risk management practices were in place, for example, the use of mixing partners with different modes of action, or alternating modes of action. However, subsequent guidelines were more stringent, stating that if an SDHI seed treatment with efficacy against foliar pathogens gains approval, then this should count as one of the statutory limit of two SDHI applications per crop. This has made it commercially unattractive to bring foliar-acting seed treatments of any mode of action to market, as similar risks and restrictions on use are likely to apply. Hence, this project is relevant to all future fungicides which might be used as both foliar-applied and foliar-acting seed treatments.

Currently, there is insufficient evidence to assess whether the restrictions on use are more stringent than needed, or whether certain risk management strategies could be sufficiently effective to allow more flexible use of seed treatments than the current guidelines allow. In the absence of such evidence, industry and regulatory authorities are likely to continue to take a precautionary approach, resulting in constraints on fungicide use which could be unnecessary. The aim of this project was to produce evidence for and assess the resistance risk associated with foliar-acting systemic fungicide seed treatments.

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How did the project address this?

The specific project objectives were:

1. Quantify the effect of foliar-acting seed treatments on the selection for fungicide resistance.
2. Relate effective life to disease control through its effects on resistance selection, so that the resistance risk associated with future seed treatments can be assessed using efficacy data.
3. Test the extent to which risk 'modifiers' (anti-resistance strategies, e.g. mixing or alternating different modes of action) are effective for combined seed- and foliar-fungicide programmes.

The objectives were addressed by a combination of modelling and field experiments, focussing on *Zymoseptoria tritici* (causal organism for septoria leaf blotch). Field experiments provide evidence for effects over one season each time, for selected fungicide treatments. The modelling approach enables an exploration of effects over multiple years and scenarios of fungicide use.

Mathematical models of fungicide resistance, developed, tested and peer reviewed previously, were extended to incorporate seed treatment effects. The models were used to explore the resistance effects of a wide range of seed treatment foliar fungicide combinations, and quantify the rate of selection for fungicide insensitive strains and the resulting effects on the effective life of a fungicide mode of action. Field experiments were established to measure and establish evidence for selection for fungicide insensitive pathogen strains in the presence or absence of foliar-acting seed treatments, with and without risk modifiers. Wheat experiments were established in 2013-14 and 2014-15, using inoculated septoria strains of known resistance to MBC fungicides, and a range of seed- and foliar treatment and dose combinations. Infected leaves were sampled and the septoria isolates were genotyped to determine the changes in the proportion of fungicide-insensitive pathogen strains over time, for each treatment. Additional experiments were set up using azole fungicides and inoculated septoria in wheat in 2013-14, and SDHI fungicides and net blotch natural infection in barley in 2014-15, but there was insufficient infection to allow sampling and genotyping.

What outputs has the project delivered?

The modelling work explored the effects of different doses and combinations of seed treatments and foliar T1 (stem extension) and T2 (flag leaf emerged) treatments on the effective life of fungicides. The key findings from the modelling work were:

- (i) Adding a seed treatment containing a single mode of action to a spray programme with two foliar sprays reduced effective life.
- (ii) The effective life of all spray programmes that include a seed treatment is equal to or shorter than a spray programme of only two foliar applications.

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(iii) Comparing spray programmes with equal total dose, the effective life of the programme including a seed treatment is equal to or smaller than that of the programme without a seed treatment.

Field experiments with MBC fungicide-insensitive septoria strains in the presence or absence of foliar-acting MBC seed treatments, with and without risk modifiers, provided evidence for selection effects of seed treatments. In one experiment, the use of a foliar-acting seed treatment caused the proportion of the septoria population which was insensitive to increase four-fold. Movement of *Zymoseptoria tritici* airborne ascospores into the field plots confounded most of the experiments in the project. Hence, this finding was not reproduced across sites and seasons, but agrees with the single previous study published, and with the modelling results from this project.

Key messages from the project:

- Foliar-acting systemic seed treatments cause significant selection for fungicide resistant septoria strains.
- The strength of selection of a seed treatment will be related to the efficacy of the foliar treatment, with stronger selection from more effective foliar action.
- Seed treatments with nil or very low levels of foliar efficacy do not pose a material resistance risk and should not count towards one of the permitted treatments.
- For effective SDHI foliar-acting seed treatments, the current FRAC guidance on SDHIs (2 SDHI treatments in total, seed and/or foliar) is supported.
- Modelling work has identified some combinations which could allow use of a foliar-acting seed treatment and up to two foliar treatments, if: (i) the total dose of a mode of action applied by seed and foliar treatments is limited, and (ii) effective mixtures of different modes of action are used in seed and foliar treatments.
- Strategies which allow use of seed treatments could, in principle, be implemented by restricting the maximum total dose of a mode of action rather than maximum number of treatments/crop. This would allow growers greater flexibility to use seed and foliar sprays. In practice, however, such a strategy would be limited by: (i) the availability of sufficiently effective foliar-acting seed treatment mixture partners of a different mode of action, (ii) grower reluctance to accept restricted foliar dose in order to use a seed treatment, and (iii) the challenge of enforcing guidance on total dose across seed and foliar treatments.

Who will benefit from this project and why?

- AHDB funded 12% of the project. The remaining 88% was funded by the Chemicals Regulation Directorate to provide underpinning evidence for regulatory decisions on resistance risks from foliar-acting seed treatments. It is important to levy payers that pesticide regulation is evidence based. In the case of foliar-acting seed treatments, approval of a treatment which posed a substantial

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resistance risk, without sufficient restrictions on use, would substantially shorten the effective live of a mode of action used for foliar sprays. Conversely, unnecessary refusal of approval would deprive growers of a tool which could safely improve disease control and gross margins.

- The results provide evidence that current guidelines for foliar-acting seed treatments are not overly stringent, and will benefit growers by maximising effective life of the available fungicide modes of action; thus maintaining good disease control and high crop yields.
- The UK Fungicide Resistance Action Group (FRAG) and FRAC are using the results as evidence that it is essential to follow current guidelines on resistance management for foliar-acting seed treatments.
- AHDB levy payers and consultants will be able to make use of the findings to guide best-practice decisions on how to use foliar-acting seed treatments, if new generation seed treatments come to market, and will benefit from the results of strategies that maintain efficacy of fungicides and improve yield.
- Even a small increase in the active life of fungicides and maintaining their efficacy will be economically beneficial, as fungicide inputs to UK wheat are a significant cost but protect against substantial losses. Growers currently spend approx. £213 million/year on foliar fungicides (based on average spend of £112/ha, J. Nix 2016; UK wheat area of 1.94 million ha, Defra statistics), and spending on fungicides is increasing (in 2011, it was £140 million). The project has shown that pathogen resistance to fungicides will develop from seed-acting fungicide treatments as well as foliar, so applying strategies to delay this resistance will have a big impact on prolonging fungicide efficacy and maintaining crop yield.

If the challenge has not been specifically met, state why and how this could be overcome

Lead partner	ADAS UK Ltd
Scientific partners	Rothamsted Research, Modelling Group and Genotyping Group
Industry partners	
Government sponsor	Defra, via the Chemicals Regulation Directorate of HSE

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