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Agronomic approaches to reducing disease pressure and targeting disease control strategies in cereals.

Key external stakeholders:
Farmers, Advisors, Grain Merchants, Ag. Chem Insustry, Regulators, Cereal Breeders, Cereal Researchers, Plant Pathologists

Practical implications for stakeholders:
- Foliar diseases continue to have the potential to significantly reduce the productivity of Irish wheat and barley crops
- The final application of fungicides to barley should be no later than awnes emerging
- Pre-stem extension fungicide applications to wheat for septoria tritici blotch control do not provide additional disease control when used as part of a standard fungicide programme.
- When mixing fungicides for STB control ensure they are from different modes of action and provide equal levels of control
- Tolerance to STB is conferred by a range of complex traits

Main results:

- Changes in the sensitivity of Irish cereal pathogens to the azole fungicides is affecting the efficacy of the main fungicides used for their control.
- Delaying the final fungicide application on both winter or spring barley provided no additional benefit to either disease control or subsequent yield.
- The application of fungicide pre-stem extension provided no additional disease control or yield irrespective of composition when included in a standard fungicide programme.
- Minimising the number of applications of an individual azole reduced selection for insensitivity to it within local Z. tritici populations.
- Mixing an azole with an SDHI reduced selection in *Z. tritici* populations for azole resistance
- The response to fungicide application in wheat varieties can vary significantly even when they have similar septoria resiustance ratings.

Opportunity / Benefit:

The identification of correct fungicide application timing and product efficacy, together with detailed analysis of their impacts on the sensitivity of local pathogen populations will ensure opimum disease control is achieved in Irish winter and spring barley and wheat crops. Identification of the key traits involved in STB tolerance provides a platform from which further studies can be initated.

Collaborating Institutions:

University of Reading, University of Nottingham, ADAS

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1. Project background:

Foliar disease of wheat and barley represents the single biggest risk to achievement of yield potential of a crop under Irish growing conditions. The impact of foliar disease on yield formation in wheat is primarily through reduced persistence of the crops green canopy (primarily the last 3 leaves) during the grain filling period, often refered to as the source. Conversley in barley the importance of sink size (the capacity to store carbohydrates) which is set early in the life of the crop is more important in determining the yield potential of both winter and spring barley. There is a need therefore to ensure that fungicide inputs are being targeted at those stages in the crops life cycle where the largest return on investment can be achieved. In addition to identifying factors which determine the timing and level of disease control required as outlined above there is an on-going need to appraise the fungicide products available. Repeated use of fungicide products or groups of chemistry invariable leads to selection within the pathogen population and shifts in the relative performance of products. There is a need to continually assess the relative performance of these products individually and as components in fungicide programmes in the field to identify the most effective and sustainable ways of incorporating them into cereal production systems. To ensure the longevity of these products it is equally important to understand how they are impacting upon the sensitivity of local pathogen populations and whether measures can be applied that reduces the potential for resistance development and spread.

2. Questions addressed by the project:

- Can current agronomic practices be optimized to reduce the risk of yield loss due to disease
- How do fungicide mixtures of the same or different modes of action impact upon Irish *Zymoseptoria tritici* population
- To identify factors contributing to septoria tritici blotch (STB) tolerance in winter wheat
- To determine the strengths and weakness of current and near market fungicides through fungicide dose response trials for their control of foliar diseaess of winter wheat and winter barley
- To better understand the variation in response to fungicides seen in varieties that can't be explained by variation in disease resistance

3. The experimental studies:

A combination of replicated field trials, glasshouse studies and detailed microbiological and molecular assays were used to investigate the above questions. To ensure the validity and applicability of the research findings for Irish production systems, the field trials were conducted throughout the main cereal producing regions and reflecting differences that occur in disease pressures. These sites included Teagasc farms, the tillage BETTER Farms and commercial crops across the main tillage regions. The development of disease in response to various treatments (e.g. fungicide timing, choice and application rate) was routinely assessed during the grain filling period and subsequent impacts on yield determined. Fungicide dose response trials were annually conducted on winter wheat and winter barley at Teagasc Oak Park for control of STB and Rhynchosporium in collaboration with the AHDB (formly HGCA). Further investigations into the impact of fungicide mixtures on the sensitivity of *Z. tritici* were performed using a microtiter plate assay on strains of the pathogens retrived from plots treated with various combinations of representative fungicides. Sequence analysis of the fungicides target sites was used to confirm any changes in sensitivity observed. The quantity of *Z. tritici* present in the leaves of various wheat lines was determined using a qPCR assay and used to determine if assymoptomatic infection results in the differences in tolerance often observed in field studies. This in addition to detailed phentotypic analysis were examined in a range of lines selected from crosses of parents differing in tolerance to determine if specific factors can be used to determine tolerance.

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4. Main results:

Fungicide Timings

In both winter barley and spring barley the optimium timing for fungicide applications must take account of the development of the crop. In winter barley these include stem extension (GS32) and booting/awns emerging (GS39-49). Where high levels of disease are present early in the season a benefit from an additional application during tillering (GS<30) can be expected. In spring barley optimium timings are during tillering and during booting/awns emerging. No benefit in terms of disease control or yield were identified from a late season application (GS59). In wheat no yield benefits were recorded from the application of a fungicide (irrespective of composition) pre-stem extension (PSE) for control of STB. In some instances the application of an azole fungicide PSE had a negative impact on disease. The main fungicide timings were confirmed as leaf 3 fully emerged, flag leaf fully emerged and flowering.

Fungicide Dose Response

A decline in the efficacy of the azole fungicides for the control of STB, whether as solo products or mixtures was observed during the course of the project. This was initially detected in the curativity of the products, but in now also detectable in their protectant activity. This is directly related to a decline in sensitivity of the Irish *Z. tritici* population. Since 2011 a new generation of the SDHI fungicides have been available and these have exhibited excellent activity against STB (resistance to the SDHIs has been detected in the Irish *Z. tritici* population and has the potential to dramatically affect the efficacy of all SDHI fungicides). In barley the azole prothioconazole continues to provide excellent control of Rhynchosporium, however the newer SDHI also provide excellent control and provide an additional alternative means of control that should be utilised to reduce the risk of resistance development.

Impact of fungicides mixtures on *Z. tritici* sensitivity

Differences in sensitivity between the azole fungicides epoxiconazole and metconazole exist in the Irish *Z. tritici* population and alternating these fungicides within a programme provides the best means of manipulating the sensitivity of a population. Mixing both fungicides selected for insensitivity to both components of the mixture. A large diversity exists within the Irish population in relation to the CYP51, with various mutations emerging independently. Mixing an azole with an SDHI reduces selection for azole resistance, but did not prevent selection for reduced sensitivity to the SDHI. It should be noted that these trials were conducted on SDHI sensitive populations and the findings may be different in the presence of resistance.

Dissecting STB tolerance

Large differences in the yield response to disease control for a given amount of disease symptom were measured. It was though this could be related to variation in the visible symptom area for a given pathogen load. Analysis of samples using qPCR confirmed that there was a large variation in the visible symptom area for a given pathogen load, however, this variation did not explain the variation in yield response due to disease control.

5. Opportunity/Benefit:

The work highlighted the importance of correct fungicide timing to minimise fungicide spend and maximise return to the grower. It also highlights the importance of using the correct mixtures and sequences of fungicides to minimise resistance development and optimise disease control. The underlying principles developed in this work are applicable for future disease control chemistries and their application will be critical to maintaining the efficiacy of future products. The value of varieties in reducing reliance on chemical disease control was demonsrated as was the value of disease tolerance, however, much more work is needed to unravel this very complex trait before it can be actively utilised in breeding programmes.

6. Dissemination:

Contributions to disease control sections of the spring barley and winter wheat guides, numerous open day, conference and meeting presentations.

Main publications:

PhD Thesis

Dooley H (2015) Fungicide Resistance Management Tatics: Impacts on *Zymoseptoria tritici* populations. University of Reading

Kock Applgren P (2016) Investigating Tolerance to *Zymoseptoria tritici* in Wheat. University of Nottingham.

Peer-refereed journal articles

Dooley H, Shaw MW, Mehenni-Ciz, Spink J and Kildea S (2016) Detection of *Zymoseptoria tritici* SDHI insensitive field isolates carrying SdhC-H152R and SdhD-R47W substitutions. *Pest Management Science 72: 2203-2207*

Dooley H, Shaw MW, Spink J and Kildea S (2016) The effect of SDHI/azole mixtures on selection of *Zymoseptoria tritici* isolates with reduced sensitivity. *Pest Management Science* 72: 1150-1159

Dooley H, Shaw MW, Spink J and Kildea S (2016) Effect of azole fungicide mixtures, alternations and dose on azole sensitivity in the wheat pathogen *Zymoseptoria tritici*. *Plant Pathology 65:124-136*

Popular publications:

Kildea S (2015) Understanding Disease Control in Cereal Crops. *IFJ Crop Protection Supplement 2015 p8-10*

Kildea S & Spink J (2014) Pesticide regulations and cereal disease control. *TResearch 9 (4) p30-31*

Spink J & Kildea S (2013) Controlling diseases in barley. *IFJ Crop Protection Supplement 2013 p8-11*

A season of two halves for disease development. *Irish Farmers Journa, June 4th 2015*

T3 on wheat: the what, the where and the how. *Irish Farmers Journal, June 4th 2015*

7. Compiled by: Steven Kildea