Field Performance of DMI Fungicides against *Zymoseptoria tritici* across Europe - Compromized by Further Sensitivity Shift?

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**ABSTRACT**

DMI-fungicides have been under discussion in light of eroding field performance against *Zymoseptoria tritici* in some parts of Europe. The detection of a further shift to lower DMI sensitivity in some countries, detected by microtitre assays, seems to explain the weaker DMI activity. However, there are large variations in sensitivity of *Z. tritici* isolates within individual sites and also between regions and countries. Moreover, the sensitivity pattern differs for individual DMIs, suggesting a diverse population despite general cross-resistance. In spite of these sensitivity differences, field performance of strong DMIs against *Z. tritici* is generally good and does not correlate well with these findings. This suggests that other factors such as disease pressure, weather conditions, and application timing also have a significant impact on DMI performance as well as the population sensitivity.

Although sensitivity adaptations can affect the activity of DMI fungicides, especially under high disease pressure situations, the most active candidates remain a valuable backbone for fungicide protection as well as for resistance management particularly in spray programs. To maintain reliable and consistent disease control and resistance management, a diverse portfolio of DMIs as well as fungicides with different modes of action are needed.

**INTRODUCTION**

In recent years, epidemic levels of *Zymoseptoria tritici* have led to significant yield losses in several key cereal-growing regions across Europe. Despite robust professional fungicide programs, disease control of DMI fungicides was sometimes poor.

This paper describes studies on the current field performance of various DMIs in major cereal-growing regions of Europe. For selected trial sites, the sensitivity of the *Z. tritici* population in untreated plots was determined against a range of DMI fungicides using microtitre tests.
MATERIALS AND METHODS

Sensitivity analysis
Samples from two monitoring programs were utilised:

- The multi-year BASF routine monitoring, where every year leaf samples with *Z. tritici* symptoms were taken randomly from field sites across Europe with 2-3 isolates per sample analysed for epoxiconazole sensitivity.

- The EUROWHEAT initiative (Jørgensen et al. 2017) with dedicated trials at various locations in Europe with sampling of different azole treatments. For each sample, 10 isolates per sample were analysed for their sensitivity to epoxiconazole, metconazole, tebuconazole, and prothioconazole-desthio. Prothioconazole-desthio was used instead of prothioconazole due to its’ recognised role in disease control (Parker et al. 2013).

Sensitivity of single pycnidial isolates towards individual DMIs was determined by microtiter assays using a range of different concentrations in YBG-medium (1% yeast extract, 1% Bacto peptone, 2% glycerol) and subsequent EC₅₀ calculation by EpiLogic (Freising, Germany).

Field performance
Efficacies of DMI products were evaluated in replicated small plot field trials at various European locations in 2014 and 2015. Wheat was grown according to local standards and a single application of the test compounds with registered dose rates was done at BBCH 32 - 61. Trials were evaluated for the severity of *Z. tritici* attack. For each trial, the latest suitable assessment timing was chosen and disease levels were converted into efficacies for mean value calculation or graphical illustration. Field efficacy results from the EUROWHEAT initiative were incorporated in the geographic overview.

RESULTS AND DISCUSSION

Sensitivity of *Z. tritici* to DMI fungicides in Europe
Figure 1 shows the sensitivity distribution of *Z. tritici* to epoxiconazole over Europe in the years 2003 to 2015 from the BASF routine monitoring. A sensitivity shift towards higher EC₅₀ classes over years is visible. However, there are large geographic differences when comparing mean DMI sensitivity levels per site across European countries. The sensitivity clearly decreased in UK and Ireland as well as in coastal areas of France, Belgium, Germany, and Poland. Clearly, this shows a gradient of the *Z. tritici* population from the West of Europe towards the East. In contrast, the level of shift is lower further to the East of Europe and to the South, which is likely to indicate the lower levels of disease occurrence and lower intensity of use of DMI fungicides.
Field performance of DMI Fungicides Against Zymoseptoria tritici Across Europe …

Figure 1  Sensitivity distribution Z. tritici isolates Europe 2003-2015 (left; BASF monitoring) vs. sensitivity distribution Europe 2015 (right; BASF monitoring + EUROWHEAT samples from untreated plots). Test substance in both cases: Epoxiconazole.

Traffic light methodology
As a general characteristic of the diversity of the sensitivity shift of Z. tritici to DMIs, large differences between individual isolates at the same location can occur. In some cases, the variation at an individual site can be as high as the level of variation across a whole country or region (Stammler & Semar 2011). In addition to the geographical variation and site-specific heterogeneity, there is only partial cross-resistance of Z. tritici to DMIs which adds further complexity to the sensitivity patterns of the disease population to different DMIs at different locations (Figure 2).

Figure 2  Partial cross-resistance of prothio-desthiocouazole, metconazole, and tebuconazole to epoxiconazole based on all investigated Z. tritici isolates from the EUROWHEAT initiative 2015 (n = 730).

Due to this level of complexity, a method was required to visualize the diversity of a population considering all the mentioned aspects. As a result, the “traffic light methodology” was developed in order to more clearly illustrate the heterogeneity of the population. All sensitivity results for an individual DMI were sorted by their EC$_{50}$ value and three different classes were established. The results were then colour coded as follows: one third of isolates with the highest sensitivity in green; the middle third with medium sensitivity in yellow; and the last third with the lowest sensitivity in red. Once this sorting and colouring was done for each DMI data set, the overall results could be more effectively compared (Figure 3).
By using this methodology, EUROWHEAT field sites were characterized according to their DMI sensitivity in untreated plots across Europe (Figure 4).

Field performance
In spite of the sensitivity differences to DMI fungicides found across Europe (Fig. 1 and Fig. 4), the available efficacy data from a broad range of field trials from 2015 demonstrated stable and reliable field performance with a full dose rate of epoxiconazole even at regions with
decreased sensitivity (Figure 5). This suggests that for epoxiconazole, the observed sensitivity differences play only a minor role in field efficacy and other factors such as disease pressure, weather conditions, and application timing can have a stronger impact on field performance.

When comparing current average efficacy results of DMI fungicides with historic levels (Defra 2007), a certain drop in performance is visible but the sensitivity hierarchy of DMIs remains unchanged and reliable control is still achievable with most efficient DMIs at the full label rate, i.e. epoxiconazole and prothioconazole.

Therefore, DMIs remain a valuable backbone for fungicide programmes for both disease control as well as resistance management. The availability and use of a diverse range of DMIs strengthen resistance management in order to achieve reliable and consistent disease control in future. Maintaining DMI diversity is of special importance as, apart from DMIs, only preventative acting contact fungicides or highly selective single-site inhibitors such as the SDHIs are currently available for the effective control of Z. tritici.
Figure 6  Efficacy of a range of DMIs today (2014-2015; mean of 31 field trials) vs. historically (1994-2004 according to Defra Project PS 2711/CSA 7236).

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