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Short communication

The effect of fungicides applied pre-stem extension on septoria tritici blotch and yield of winter wheat in Ireland

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ABSTRACT

Ireland has the potential to produce some of the highest winter wheat yields in the world, however due to the highly disease conducive environment fungicides are heavily relied upon to achieve these yields. These fungicides primarily target control of septoria tritici blotch (STB), which if left untreated can result in significant reductions in yield. Typically winter wheat fungicide programmes are comprised of four applications, the first of which is applied pre-stem extension (PSE). It has been suggested that applying fungicides at this stage in the crops development slows disease progression to the upper canopy (final leaves three, two and one) which is responsible for the majority of yield potential. This study tested the effect of different pre-stem extension fungicide treatments on STB severity in the upper canopy during grain filling and subsequent grain yield in field trials conducted at three Irish locations over three consecutive growing seasons (2012-2014). When applied as part of a typical foliar fungicide programme significant differences in levels of STB on the final leaf three were observed at growth stage GS83between the PSE treatments ($P = 0.05$), with the solo azole resulting in higher levels of disease compared to the other fungicide treatments. Despite these differences in STB control no significant differences were observed between the treatments in final yield ($P = 0.44$). This study shows there is no yield advantage to applying fungicides prior to stem extension for control of STB, however, if they are being applied for the control of other disease e.g. yellow rust careful consideration should be taken with regards to choice of fungicide to avoid increasing STB severity later in the season.

1. Introduction

Winter wheat is the second most widely grown arable crop in Ireland and due to the prevailing climatic conditions these crops have the potential to produce amongst the highest yields per area globally (Food and Agriculture Organisation for the United Nations (FAO), 2014). Unfortunately these climatic conditions are highly conducive to the spread and development of fungal diseases and therefore to achieve these yields fungicides are heavily relied upon (Lynch et al., 2017). Septoria tritici blotch (STB), caused by the ascomycete *Zymoseptoria tritici* (synonym: *Mycosphaerella graminicola; Septoria tritici*) is the most important disease of winter wheat in Ireland and indeed Europe (O'Driscoll et al., 2014). If not properly managed potential yield losses attributed to STB can be in excess of 40% (Burke and Dunne, 2008). The ultimate aim of a foliar fungicide programme in Irish wheat crops is to reduce STB infection on the final three leaves, which together contribute to approximately 75% of the final grain yield (Paveley and Clark, 2000).

Current fungicide programmes for STB control in Ireland include a pre-stem extension (PSE) fungicide application, followed by an application at GS31/32 final leaf three fully emerged, an application at GS39 final leaf fully emerged and a final application at GS65 mid-way through anthesis (Zadoks et al., 1974). The appropriate fungicide dose at these timings is dependent on the efficacy of the specific fungicide and expected disease pressure (Paveley et al., 2000). The range of fungicides available to Irish growers for STB control is however, becoming increasingly limited due to a combination of resistance development in *Z. tritici* and changes in regulation of pesticides within the European Union (Jess et al., 2014). Whilst growers are limited in their capacity to influence the regulation of fungicides, their decisions on fungicide use can greatly impact upon resistance development. van den Bosch et al. (2014) have highlighted that the frequency of application of a specific mode of action, a key decision growers make each season, has a major effect on the speed of resistance selection. It is therefore essential that any fungicide application must provide a clear benefit not just in disease control, but ultimately yield protection.

Under U.K. growing conditions Cook et al. (1999) have previously demonstrated that fungicides applied pre-stem extension, despite

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potentially reducing the build-up of STB on lower leaves prior to ear emergence have little impact upon disease levels on the upper leaves at GS75 and hence final yields. Although PSE fungicide applications have become common practice to Irish winter wheat crops it remains unknown if these applications provide additional disease control under the high disease pressures often experienced. This study investigates whether PSE fungicide applications provide additional STB control and yield benefits.

2. Materials and methods

2.1. Trial sites and experimental design

Field trials were conducted at three Irish locations (North East, South East, South West) representing differing levels of disease pressure, during each of the 2012–2014 growing seasons. All trials were conducted on commercial crops of STB susceptible/moderately susceptible winter wheat varieties, sown at dates typical for each location (Table S1). The trials consisted of four replicate blocks, each containing six PSE fungicide treatments and an untreated control in a fully randomised design.

2.2. Chemical treatments

The six PSE treatments are described in Table 1. Each PSE fungicide treatment received a standard commercial spray at GS31/32 (0.8 L/ha Proline® Bayer Crop Science & 1.0 L/ha Bravo® Syngenta), GS39 (1.6 L/ha Adexar® BASF & 1.0 L/ha Bravo) and GS65 (2.0 L/ha Gleam® BASF in 2012 or 1.2 L/ha Prosaro® Bayer Crop science in 2013 and 2014). All fungicides were applied at 200 L/ha with a knapsack sprayer using compressed air. All other inputs (Plant Growth Regulators, fertilisers, herbicides, insecticides) were applied according to best practice.

2.3. Disease scoring and yield measurements

Disease was allowed to develop naturally at each site and was assessed visually as % leaf area covered in STB symptoms on the final leaf, final leaf two and final leaf three at GS83 (Peterson et al., 1948; James et al., 1968; James, 1971). Ten main tillers randomly selected per plot were scored. Total plot grain yield (t/ha, adjusted to 15% moisture) was recorded at harvest. No disease data was obtained from the SE trial in 2014.

2.4. Statistical analysis

Linear mixed modelling was used to evaluate differences in grain yield and disease severity between fungicide treatments. Plot yield and disease scores were analysed in separate models including the main effects of site-season and fungicide treatment as fixed factors, and any significant ($P > 0.05$, F-test) interactions between them. Experimental blocks were included as random effects. As the untreated controls were in most instances completely diseased by the time of assessment they were excluded from the analysis of the disease. The remaining disease severity data was square root transformed to normalize the distribution of residuals and to make them approximately independent of fitted values. Non-significant interaction terms were removed from the model. All statistical analysis was performed in Genstat V14 (VSN International Ltd. 2011).

3. Results & discussion

Combined data for the five site-seasons in which disease data was attained shows that the different PSE treatments had significant effects on STB disease severity on final leaf three (Table S2a, $P = 0.05$). A solo azole application (Marked 'Azole' on Fig. 1) prior to stem extension resulted in significantly higher levels of STB on final leaf three when compared to the azole mix, the multisite, and the azole mix with multisite mixture (Table S2a, Fig. 1). The effect of the solo azole application was clearly evident at sites under very high disease pressure (South West, 2012, 2014) in which the best performing PSE treatment achieved c.30% greater STB control on final leaf three when compared to the solo azole. Dooley et al. (2016) have demonstrated selection for reduced azole sensitivity in *Z. tritici* populations can occur within a season and suggested that this was likely to impact upon the sensitivity of inoculum contributing to the epidemic progression. As the fungicide application immediately following the PSE at GS31/32 was a combination of the azole prothioconazole and the multsite chlorothalonil the reduction in efficacy observed following the solo azole PSE application may indicate prior selection for azole insensitivity, which impacted upon the efficacy of the subsequent application. This would have been compounded in the high disease pressure environments where the contribution of chlorothalonil (protectant only) would have been reduced. Significant differences in PSE treatments on STB disease severity on the final leaf ($P = 0.03$, Table S2b) were also observed. These differences were highly dependent to upon site season (Fig. S1), with 2012 being a very high disease pressure year. In these situations the multisite fungicide was equally effective at reducing disease as the azole, azole mixture, either with or without the multisite. Although no significant effect of PSE treatments was seen on final leaf 2 ($P = 0.06$), the trend was similar to that observed on the final leaf.

Final grain yield was significantly affected by an interaction between year, region and fungicide treatment (fungicide including a PSE/fungicide excluding a PSE/no fungicide) ($P < 0.02$; Table S3, Fig. 2). In seven of the nine site seasons the application of a fungicide programme increased yield > 1.4 t/ha, with only two sites in 2013 showing < 1.0 t/ha yield response. The 2013 season can be characterised as an unusually low disease pressure season, reflected in the absence of disease data from this season. However, as demonstrated by Burke and Dunne (2008) given the unpredictability of the Irish climate and associated disease pressures, routine foliar fungicide programmes are most consistent in protecting yields and profits.

Even though differences were observed between the PSE treatments in disease control on both the final leaf three and final leaf, no significant differences were observed between the treatments in final yield (Table S4; $P = 0.44$). Dooley et al. (2016) have similarly found that whilst differences in disease levels could be identified between fungicide programmes, these differences did not always contribute to differences in final yield. For both the emergence and selection of partial or complete fungicide resistance trying to achieve complete disease control through increased applications or doses may have a detrimental

Table 1
Fungicides treatments applied pre-stem extension (< GS31). All treatments were followed with a three-spray fungicide programme (GS31/32; GS39; GS65).

Application Type	Product	Active Ingredient (g/L)	Rate Applied (L/ha)	Manufacturer
Untreated	–	–	–	–
Multi-site	Bravo	Chlorothalonil (500)	1.0	Syngenta
Azole	Rubric	Epoxiconazole (125)	0.5	Headland Agrochemical
Azole mixture	Gleam	Epoxiconazole & Metconazole	1.0	BASF
Azole & Multi-site	Rubric & Bravo	Epoxiconazole (125) & Chlorothalonil (500)	0.5 & 1.0	–
Azole mixture & Multi-site	Gleam & Bravo	Epoxiconazole & Metconazole Chlorothalonil (500)	1.0 & 1.0	–