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Fungicide application at anthesis of wheat provides effective control of leaf spotting diseases in western Canada

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ABSTRACT

Leaf spotting diseases commonly occur on spring wheat crops grown in Saskatchewan, causing yield losses of up to 15%, although greater losses have been documented during severe epidemics. In the past decade, Fusarium head blight (FHB) has become a major concern for growers resulting in extensive use of fungicide to mitigate the disease. The optimal fungicide timing for leaf spot control is generally at the flag-leaf stage, while the optimal timing for FHB is during anthesis. The objective of this study was to determine whether applying fungicide at anthesis timing can provide adequate control of leaf spots when compared to application at flag-leaf stage. Fungicide treatments applied at flag-leaf, anthesis, and both growth stages were evaluated on the cv. Carberry. Prothioconazole + tebuconazole and tebuconazole (only) applied at anthesis provided adequate control of leaf spots, although the severity of leaf diseases was slightly higher in this treatment than application at flag-leaf stage but yields were similar. Test weight and thousand kernel weight were improved with the application at anthesis relative to that at flag-leaf stage. Two applications of fungicide provided only a small incremental benefit to the anthesis application, and would not be economically justified in western Canada at this time. Anthesis fungicide application provided adequate leaf spot disease control and is the optimum timing for the control of FHB.

1. Introduction

Fungicide application timing is critical for effective control of fungal plant diseases. In cereal crops such as wheat and barley, the flag and penultimate leaves are major contributors to grain yield and quality (Bhathal et al., 2003) and therefore fungicides are used to protect these leaves from leaf spotting diseases. Previous work has proven that very early application of fungicide at the seedling stage (BBCH 12–14, Lancashire et al., 1991) in barley to mitigate leaf spotting diseases provides very little to no improvement in yield and quality (Turkington et al., 2015). In recent years, wheat growers in western Canada have applied fungicide at the anthesis stage (BBCH 61–65), instead of, or in addition to application at flag leaf stage (BBCH 39). The anthesis stage is the recommended time for fungicide application to suppress fusarium head blight (FHB) caused by *Fusarium graminearum* Schwabe *sensu lato* (syn. *Gibberella zeae* (Schwein.) Petch), but the effectiveness of fungicide applied at this timing against leaf spotting diseases is unknown.

Fusarium head blight is a major disease of cereals that has become common over the past two decades across the Canadian Prairies and the Pacific northwest of the United States. The disease results in the premature senescence of the entire spike or a portion of the spike, causing a reduction in yield and grain quality (Haidukowski et al., 2005). Yield losses of over 70% have been reported when FHB reaches epidemic levels. *Fusarium graminearum* can also produce a wide assortment of mycotoxins, the most common of which is deoxynivalenol (DON) (Bottalico and Perrone, 2002). DON is neurotoxic and immunotoxic and even a low concentration can have detrimental effects on both humans and livestock (FAO/WHO, 2001). Several European countries have placed limits on the levels of DON allowable in wheat and cereal products intended for human consumption. These limits are 2.0 mg kg^{-1} for wheat and unprocessed wheat products, 1.0 mg kg^{-1} for wheat

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flour, pasta, and bakery products, and 0.5 mg kg^{-1} for food products intended for infants and young children (Koornneef et al., 2002). The allowable DON limits in Canadian wheat are 2.0 mg kg^{-1} for uncleaned soft wheat for use in non-staple foods and 1.0 mg kg^{-1} for uncleaned soft wheat for use in baby foods (Haidukowski et al., 2005). Due to the serious consequences of this disease, many wheat growers in western Canada have adopted fungicides as part of an integrated strategy for FHB management.

There are several leaf spotting diseases that affect spring wheat, including tan spot, caused by *Pyrenophora tritici-repentis* (Died.) Drechsler and multiple pathogen species that constitute the septoria leaf spot complex. These include *Zymoseptoria tritici* (Desm.) Quaedvlieg & Crous (syns. *Mycosphaerella graminicola* (Fuckel) J. Schröt.; *Septoria tritici* Desm., causal agent of septoria tritici blotch, as well as *Parastagonospora nodorum* (Berk.) Quaedvlieg, Verkley, & Crous and *Parastagonospora avenae* (A. B. Frank) Quaedvlieg, Verkley, & Crous, causal agents of stagonospora blotch (Goodwin, 2012; Murray et al., 2015). Tan spot may lead to yield losses of 50–75% in wheat in severe cases (Hosford, 1971; Hosford and Busch, 1974; Rees and Platz, 1980) and yield losses of 30–50% have been attributed to septoria leaf blotch during severe epidemics (Eyal et al., 1987). Stagonospora blotch infection generally leads to minor yield loss, most often resulting in 10–15% lower production overall (King et al., 1983). The environment and cultural practices play large roles in the severity of leaf spotting diseases, hence resulting in variable impact on yield depending on the year and location. For instance, Evans et al. (1999) reported that leaf spots reduced wheat yield in inoculated plots by 15% in Oklahoma, which was similar to the findings of Shabeer and Bockus (1988) in Kansas. Rees et al. (1982), however, reported wheat yield losses of nearly 50% in fungicide untreated plots in Australia.

Fungicides are strategically applied to protect the flag leaf from leaf spot pathogen infection (Wegulo et al., 2012), because most fungicides are ineffective once leaf spot symptoms have appeared (McGrath, 2004). Protecting the flag leaf is paramount because it is responsible for a large portion of grain filling in wheat (Ruske et al., 2003; Simpson, 1968). The optimal time to apply fungicide in wheat has been contested, although several studies have suggested that early fungicide application, at flag leaf stage, is imperative to improve yield (Wegulo et al., 2012). Optimal fungicide timing to control FHB has been suggested to be at the anthesis stage (Halley et al., 2001); however, the optimal timing to control leaf spots has been reported to be at the flag leaf stage (Wiersma and Motteberg, 2005). In durum wheat in Saskatchewan, fungicide application at the flag leaf stage reduced leaf spotting diseases on the flag and penultimate leaves more than application at anthesis, as determined from disease assessment at the early milk stage; however, when leaf diseases were measured at the soft dough stage an application at both flag leaf and anthesis stages resulted in the lowest disease severity and highest grain yield (May et al., 2014).

Prothioconazole + tebuconazole (Prosaro®) has been recommended to control FHB, as it has been shown to be more effective than tebuconazole alone (Folicur® 432F; Folicur 250EW; Palliser®; Fuse®; Hornet® 432F) at reducing DON (Paul et al., 2007). Before the availability of prothioconazole, experiments conducted in both Minnesota and North Dakota indicated that tebuconazole was the most effective of the triazole fungicides (McMullen et al., 1997; McMullen, 1998). Serenade® Optimum is a bio-fungicide made from the QST 713 strain of *Bacillus subtilis* (Bayer Crop Science), a gram-positive endospore-forming bacterium that can produce more than two dozen antibiotics (Moszer et al., 2002). Serenade Optimum is the only Group 44 fungicide and possesses a unique mode of action making it difficult for pathogens to develop resistance (Bayer Crop Science). However, there are no studies on the effect of this product on leaf spotting diseases of wheat from western Canada and it is not currently registered for use on wheat.

The objective of this study was to assess whether applying fungicide at anthesis stage (BBCH 61 to 65), the recommended timing for FHB management would adequately control leaf spots in spring wheat compared to an application at flag leaf stage (BBCH 39), while providing economic benefits to growers.

2. Materials and methods

2.1. Study area

The study was conducted at Saskatoon (52.1332°N, 106.6700°W, Black soil zone), Indian Head (50.5334°N, 103.6699°W, black soil zone), and Melfort (52.8608°N, 104.6143°W, Black soil zone) in Saskatchewan, as well as Lethbridge (49.6935°N, 112.8418°W, Brown soil zone) and Brooks (50.5334°N, 111.8992°W, Brown soil zone) in Alberta in 2013. The study was repeated in 2014 at Saskatoon and Melfort, SK, and at Lethbridge, Brooks and Lacombe (52.4631°N, 113.7286°W, Black soil zone), Alberta. In 2015, the locations were Saskatoon, Indian Head, Melfort, Brooks and Lethbridge, while Lacombe was lost to hail. Plots were established at Saskatoon in a field previously sown to canola in 2012 and wheat in 2013, at Indian Head in a field previously sown to wheat in 2012, at Melfort in a field previously sown to canola in 2012 and 2013, at Brooks in a field previously sown to alfalfa in 2012 and summer fallowed in 2013, at Lethbridge in a field previously sown to barley in 2012 and 2013, and at Lacombe in a field previously sown to wheat in 2013. At all sites, glyphosate (900 g a. i. ha^{-1}) was applied to the entire plot area prior to seeding to suppress weeds. Subsequent herbicide treatments were applied at recommended rates and timings following Guide to Crop Protection (www.saskatchewan.ca/agrcuture) to control weeds as necessary at each site. Soil samples were collected at each site in early spring and fertilizer applied to achieve 100% of the soil test recommendations. Precipitation and temperature values were recorded at each site-year for the growing period from April until August and were compared to the long-term climate normal calculated from data over the period 1981 to 2011 (Table 1).

2.2. Experimental design

The plot sizes were 2 × 8 m at Saskatoon, 4 × 10.7 m at Indian Head, 4 × 10 m at Melfort, 1.2 × 6 m at Brooks, 2 × 6 m at Lethbridge and 1 × 5.5 m at Lacombe. Seeding depth at each site varied from 3.81 cm to 7.62 cm, while row spacing varied from 20.3 to 30.5 cm and seeding rate from 250 to 275 seeds m^2. Experiments were designed as randomized complete blocks of four replicates. Each trial consisted of a 3 × 3 factorial arrangement plus an unsprayed check, for a total of 10 treatments. Three fungicide application timing treatments consisted of a single application at flag leaf stage (ZGS39), a single application at anthesis (ZGS60) and a dual application at each ZGS39 and ZGS60. The fungicide treatments were: 1) prothioconazole + tebuconazole (Prosaro at 800 mL ha^{-1}), 2) tebuconazole (Folicur 250 EW at 499 mL ha^{-1}, or at Lacombe, 2014; Folicur 432 F at 291 mL ha^{-1}), 3) *B. subtilis* (Serenade Optimum 500 g ha^{-1}), all applied in 100 L ha^{-1} of water.

The Canada Western Red Spring wheat variety 'Carberry' was chosen for this study as it is moderately susceptible to leaf spotting diseases, but moderately resistant to FHB (Anon, 2014). This choice of variety was made to help reduce the confounding effects between leaf spots and FHB. Disease ratings were conducted at the soft dough stage (ZGS 85). Leaf spotting disease severity was determined by assessing ten flag leaves and ten penultimate leaves from each plot using the Horsfall–Barratt (0–11) scale (Horsfall and Barratt, 1945). Ratings were then converted to percent leaf area affected by the disease according to the grade formula specified in the scale. Fifty random spikes were assessed from each plot at the early dough stage of development for FHB severity (proportion of the spike bleached) by taking the average disease severity (%) of the 50 heads collected using the scale of Stack and McMullen (1995). Wheat was harvested from a 10–42 m^2 area of each plot, excluding outer row on each side of each plot, using a small-plot