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Glyphosate associations with cereal diseases caused by *Fusarium* spp. in the Canadian Prairies

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ABSTRACT

Fusarium pathogens cause important diseases, such as root/crown rot and Fusarium head blight (FHB), in cereal crops. These diseases can be caused by similar *Fusarium* spp. Common root rot (CRR) is widespread in the western Canadian Prairies, whereas FHB has potential of becoming an important disease in this region. There are no commercially available cereal cultivars with good resistance to these diseases. It is therefore important to identify agronomic practices that could affect levels of *Fusarium* pathogens in cereals. This review deals primarily with the effects of tillage systems and glyphosate use on the development of FHB and CRR in wheat and barley in eastern Saskatchewan. Although the FHB study in 1999–2002 indicated that environment was the most important factor determining FHB development, previous glyphosate use and tillage practice were among the production factors with the greatest association with FHB. Overall, disease was highest in crops under minimum-till management. Previous glyphosate use was consistently associated with higher FHB levels caused by the most important FHB pathogens, *Fusarium avenaceum* and *Fusarium graminearum. Cochliobolus sativus*, the most common CRR pathogen, was negatively associated with previous glyphosate use, while *F. avenaceum*, *F. graminearum*, and other fungi were positively associated, suggesting that glyphosate might cause changes in fungal communities. The occurrence and isolation of *F. avenaceum* from cereal residues were greater under reduced-till than conventional-till while *C. sativus* was most common under conventional-till, and *F. graminearum* was lowest under zero-till. Previous glyphosate applications were again correlated positively with *F. avenaceum* and negatively with *C. sativus*. These observations agreed with results from the FHB and CRR studies. These are the first studies that established a relationship between previous glyphosate use and increased *Fusarium* infection of spikes and subcrown internodes of wheat and barley, or *Fusarium* colonization of crop residues. However, because of the close association between noncereal crops, reduced tillage and glyphosate use, it was not possible to completely separate the effects of these factors on *Fusarium* infections. Determining the relative contribution of these popular production trends to the development of diseases caused by *Fusarium* spp. are essential for devising appropriate agronomic recommendations to prevent their further spread in western Canada, and to reduce the impact that these diseases are having in areas where they are already established. The consistent association between previous glyphosate use and *Fusarium* infections also warrants further research to elucidate the nature of this association and the underlying mechanisms determining these effects.

1. Introduction

Fusarium pathogens cause important diseases of cereal crops in western Canada. Root and crown rot (Fernandez and Jefferson, 2004) and Fusarium head blight (FHB), also known as scab or tombstone (Gilbert and Tekauz, 2000), can be especially severe. Common root rot (CRR) is a prevalent disease throughout the western Canadian Prairies (Ledingham et al., 1973). In the province of Saskatchewan, root and crown rot is generally caused by *Cochliobolus sativus* (Ito & Kurib.) Drechsl. ex Dastur (anamorph *Bipolaris sorokiniana* [Sacc.] Shoemaker) and *Fusarium* spp. (Fernandez and Jefferson, 2004). *Fusarium avenaceum* (Fr.:Fr.) Sacc. (teleomorph *Gibberella avenacea* Cook) is one of such species found in underground and ground-level tissue of common (*Triticum aestivum* L.) and durum (*T. turgidum* L. ssp. *durum* [Desf.] Husn.) wheat (Fernandez and Jefferson, 2004; Fernandez and Zentner, 2005; Fernandez et al., 2007a). This pathogen is also frequently isolated from discoloured roots of noncereal crops, being found at high-

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est levels in pulse crops (Fernandez, 2007). Many of the *Fusarium* isolates in discolored subcrown internodes or crowns are also associated with FHB in wheat and barley (*Hordeum vulgare* L.) (Fernandez et al., 2002a,b).

Of the several *Fusarium* species that can cause FHB, the most important pathogen in North America is *F. graminearum* Schwabe (teleomorph *G. zeae* [Schwein.] Petch). This pathogen produces mycotoxins harmful to humans and livestock. The most commonly found mycotoxin in infected grain is deoxynivalenol (DON). Tolerance levels for *Fusarium*-damaged kernels (FDK) are very low due to processing problems and potential food safety concerns. For example, FDK greater than 0.25% by weight will cause Canada Western Red Spring (CWRS) class of wheat, to be downgraded from CWRS #1 to CWRS #2. A FDK value of over 1% down grades it to CWRS #3, and over 2% to CWRS #4 (Canadian Grain Commission, 2007). For malting barley, the tolerance for FDK is nil for Super Select and 0.2% for Select, whereas FDK for feed barley is 1%. These low tolerance levels cause significant economic losses to producers in affected areas.

Relative to other *Fusarium* pathogens, *F. graminearum* has been less commonly isolated from infected cereal spikes and kernels in western regions of the Canadian Prairies than in areas where this disease has been historically more prevalent. The other *Fusarium* pathogens commonly found in Saskatchewan are also mycotoxin producers. Among these are *F. avenaceum*, *F. culmorum* (W.G. Smith) Sacc., and *F. poae* (Peck) Wollenw., with *F. avenaceum* reported as the most, or one of the most, common species in infected spikes and kernels of wheat and barley (Clear et al., 2000; Fernandez et al., 2003, 2007d; Pearse et al., 2007b; Turkington et al., 2002). Although neither *F. avenaceum* nor *F. poae* produce DON, they produce other harmful mycotoxins (Abramson et al., 2002).

Unfavourable weather conditions have caused FHB to occur at lower levels in the last few years in Saskatchewan (Pearse et al., 2007a,b) than in the late 1990s and early 2000s when province-wide surveys showed the disease to be well established in wheat and barley in eastern regions of the province and spreading westward (Fernandez et al., 1999, 2000, 2001, 2002a,b; Pearse et al., 2003). Thus, FHB still has potential to spread further west, and adversely impact production and marketing opportunities for wheat and barley throughout the western Prairies when conditions are favourable for its development.

There are no commercially available wheat or barley cultivars with good resistance to FHB registered in western Canada (Fernandez et al., 2005, 2007d). Chemical treatment has proven inconsistent or ineffective in controlling FHB and/or preventing its spread.

Because of the continued importance of FHB in the eastern Prairies, and its potential to spread westward, strategies need to be designed to stop or reduce the rate of spread, and to decrease the damage it causes in areas where it is already well established. Understanding the impact of agronomic practices on disease and inoculum levels should form part of comprehensive strategies aimed at controlling FHB. A comprehensive strategy should also include the role of *Fusarium* infection of crop roots and crowns as sources of fungal inoculum and its potential carryover from one growing season to the next.

The adoption and use of conservation tillage (minimum- till and zero-till) practices have become widespread throughout western Canada (Zentner et al., 2002). These tillage methods are heavily dependent on the use of glyphosate formulations for weed control. Thus, it is also important to determine the possible impact that this increased use of glyphosate might have on the development of FHB.

Several studies have examined the effect of tillage practice on FHB or FDK and associated DON levels in wheat in other regions in North America and elsewhere (Dill-Macky and Jones, 2000; Krebs et al., 2000; Miller et al., 1998; Schaafsma et al., 2001; Yi et al., 2001). These findings vary with respect to the impact that tillage and amount of crop residue have on disease levels, with no difference among tillage systems often observed (Miller et al., 1998; Teich and Nelson, 1984). There are few reported studies on the impact of tillage system on FHB in barley. In studies conducted in Quebec, Rioux et al. (2005) found that DON content was greater in barley grown under minimum till than conventional-till management.

The effect of herbicides on FHB development has not been extensively examined. Teich and Hamilton (1985) and Teich and Nelson (1984) reported that there was no significant difference in disease levels in wheat fields with or without herbicides, but they did not identify the specific herbicides used. Difficulties in evaluating the possible effect of glyphosate or other herbicides on FHB include a lack of information regarding type, time and dose of herbicide applied, and lack of adequate glyphosate-free controls.

Severity of CRR was not affected by tillage method (Bailey et al., 2001; Conner et al., 1987) or declined in reduced tillage systems (Bailey et al., 2000; Tinline and Spurr, 1991). Furthermore, higher levels of *C. sativus*, and lower levels of *Fusarium* spp., in wheat or barley roots were reported with changes from less to more intensive tillage (Bailey et al., 2000, 2001; Windels and Wiersma, 1992). Although the effect of several herbicides on CRR pathogens was examined (Hsia and Christensen, 1951; Isakeit and Lockwood, 1989; Tinline and Hunter, 1982), the impact of glyphosate usage on this disease has not been reported.

The overall objective of our research was to identify agronomic practices associated with the development of high FHB levels in wheat and barley. Because of the possible impact that *Fusarium* spp. in underground plant tissue might have on the development of FHB and persistence of inoculum in the field, the objectives included an examination of the impact of agronomic practices on fungal populations in subcrown internodes. A comprehensive approach to understanding disease development includes examining the role of crop residues as reservoirs of inoculum for infection and fungal carryover from one season to the next, and how pathogen populations on these residues are affected by agronomic practices.

This information should help identify cultural and management practices that might decrease *Fusarium* populations in live and dead crop tissue, and thus lead to recommendations regarding practices that can reduce damage to wheat and barley from FHB on the Canadian Prairies. A better understanding of the factors affecting pathogen inoculum and crop infection is important for devising highly efficacious strategies to reduce inoculum levels, disease development, and further spread of cereal diseases caused by *Fusarium* spp.

The studies reported here were conducted on commercial fields in eastern Saskatchewan. Surveying commercial fields allows examination of plants in a large area, with little or no interference from fields under other agronomic practices, a common concern in experimental plot trials. Although surveys of commercial fields allow examination of a wide range of crops under different combinations of agronomic practices, they can also suffer from confounding effects of the various practices.

This review focuses on the impact of tillage system and glyphosate use on FHB and CRR diseases. Because glyphosate use is dependent on tillage frequency, these two factors are usually confounded. In order to isolate the effects of tillage frequency from those of glyphosate use, the latter was analyzed as an effect nested within tillage system. Only the most important findings concerning tillage and glyphosate associations with FHB, CRR and fungal populations on crop residues are presented here. Comprehensive reports of associations with other agronomic practices, such as cropping sequence, have been previously published (Fernandez et al., 2005, 2007a,c,d, 2008).