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Root and Crown Rot of Wheat

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Summary

Root and crown rot are among the most widespread and damaging diseases of cereal crops, including common (*Triticum aestivum* L.) and durum [*T. turgidum* L. ssp. *durum* (Desf.) Husn.] wheat, on the Canadian Prairies. Due to the drier growing conditions experienced in the western Prairies over the last decade, these diseases have been increasing in incidence and severity, especially in durum wheat. Root and crown rot can cause significant yield losses in wheat. In western Canada, they are mostly caused by *Cochliobolus sativus* (Ito & Kurib.) Drechs. ex Dast. [anamorph *Bipolaris sorokiniana* (Sacc.) Shoemaker] and *Fusarium* spp. Many of the *Fusarium* spp. causing root and crown rot have also been associated with Fusarium head blight (FHB), such as *F. avenaceum* (Fr.:Fr.) Sacc. (teleomorph *Gibberella avenacea* Cook). Colonization by *Fusarium* pathogens of roots and crowns, and their subsequent survival and multiplication in those tissues after harvest, might play a role in the future development of FHB and contribute to its westward spread. Past research has shown that the presence of *C. sativus* and *Fusarium* spp. in underground tissue of wheat was affected by crop rotation, tillage method, and chemical input. Furthermore, results from a study in west-central Saskatchewan showed a differential effect of chemical input system on the presence of the most common *Fusarium* spp. in subcrown internodes and crowns of spring wheat. The pathogens *F. avenaceum* and *F. culmorum* (Wm. G. Sm.) Sacc. were less associated with organic systems than the weak pathogen/saprophyte *F. equiseti* (Corda) Sacc. present at its highest levels in organic-managed treatments. These observations agree with results from European studies on organic versus conventional systems. The expected hotter and drier weather is likely to promote the development of root and crown rot on the Prairies, and increase yield losses. Thus, research on these diseases and their management should be of greater importance in the future.

Root and Crown Rot in Common and Durum Wheat

Root and crown rots are important and widespread cereal diseases that are present in most parts of the world, including the Canadian Prairies. Root and crown or foot rot is considered a disease complex, since various pathogens causing discolouration of the roots and crowns in common and durum wheat have been reported from different geographic regions, and under different environmental conditions. In Saskatchewan, the main root and crown rot pathogens in wheat, barley (*Hordeum vulgare* L.), and oat (*Avena sativa* L.) are *C. sativus* and *Fusarium* spp.[1,2,3,4,5].

Browning to rotting of the subcrown internodes, crowns and roots characterizes root and crown rot of cereals (Fig. 1). Yield loss results from infected tillers producing very few or no seed and in more severe cases because of the development of prematurely ripened spikes generally termed 'whiteheads' (prematurity blight). When root and crown pathogens are carried on the seed they can cause pre- or post-emergence seedling blight. However, above-ground symptoms of root and crown rot are often not apparent under average growing conditions in the Canadian Prairies.

In western Canada, some studies have shown that root rot, caused mostly by *C. sativus* and commonly referred to as common root rot, caused yield losses in wheat cultivars under a range of environments[6]. These losses ranged from <1% to 17%, and paralleled their disease ratings. However, other studies have shown no impact of common root rot on grain yield[7]. In the Pacific Northwest, Smiley et al.[8] reported that crown rot reduced winter wheat yield as much as 35% in commercial fields, with a 13-field mean of 9.5%.

Yield losses are higher when plants are under moisture stress during flowering and grain fill, which tends to prevail in most areas where durum wheat is presently grown. Root and crown rot occur in varying degrees wherever durum wheat is grown, but are most severe under high temperatures and dry soil conditions.

Fig. 1. Discolouration in subcrown internodes,crowns and culms of durum wheat.

Water stress from flowering onwards favours symptom expression in *Fusarium*-infected durum wheat, as does high nitrogen fertilization by increasing water stress during grain fill because of increased vegetative plant growth[9]. In West Asia and North Africa, durum wheat cultivars with no tolerance to drought stress are most affected by foot and root rot[10].

Due to the drier growing conditions experienced in the western Prairies over the last decade, root and crown rot have been increasing in incidence and severity in this region, especially in durum wheat (M.R. Fernandez, unpublished data).

Fusarium Pathogens Associated with Root and Crown Rot

Among *Fusarium* spp. associated with root and crown rot, *F. culmorum* and *F. pseudograminearum* O'Donnell & T. Aoki were reported as the most pathogenic and most common causal agents of crown rot of barley and common and durum wheat in the eastern Australian grain belt[11]. In Saskatchewan in the mid- to late-1980s, *Fusarium* isolates from the subcrown internodes of wheat sampled in different locations in the province were identified as *F. culmorum* [12]. *Fusarium avenaceum* was commonly isolated from crowns and roots of winter wheat in Manitoba, but rarely from spring wheat in 1985-1986[13]. Although no isolates of *F. avenaceum* were reported from a southern Saskatchewan study in 1995[2], this species was one of the most common and widespread *Fusarium* spp. in discoloured subcrown internodes and/or crowns of durum and spring wheat, barley, and oat crops throughout Saskatchewan in 1998-99[3,4,5], and in subcrown internodes of spring wheat in southwestern Saskatchewan in the early 2000's[14]. In the mid-1980s, *F. avenaceum* was also isolated from lesioned subcrown internodes of spring wheat sampled in Minnesota[15]. In greenhouse trials, *F. avenaceum* caused as much crown rot in winter wheat as *F. culmorum* or *F. pseudograminearum*[16].

Differences in the presence and prevalence of *Fusarium* spp. in underground cereal tissue among studies conducted in western Canada might be attributed to limited identification of isolates, differences in environmental conditions, prevalent agronomic practices, and/or differences in genetic resistance to the various components of this disease complex.

Many of the *Fusarium* spp. isolated from discoloured subcrown internodes have also been associated with FHB in eastern Saskatchewan, which is the area where the latter disease has been present at highest levels in the province[17,18]. *Fusarium avenaceum* has been one of the most commonly isolated pathogens from blighted heads in Saskatchewan, an area where FHB severity has been lower than in the eastern Priaires. Colonization by *Fusarium* pathogens of underground- and ground-level plant tissue, and their subsequent survival and multiplication in those tissues after harvest, might play a role in the future development of important cereal diseases such as FHB and contribute to its westward expansion.

In addition, Mudge et al.[19] reported significant concentrations of the mycotoxin deoxynivalenol (DON) of up to 35 ppm in the flag leaf node and the head/rachis of wheat following inoculation of the stem base with *F. graminearum* Schwabe [teleomorph *G. zeae* (Schwein.) Petch], and *F. pseudograminearum*. Their results also indicated that DON production was not necessary to cause crown rot symptoms, but deoxynivalenol appeared to have a role in stem fungal colonisation.

Tillage and Rotation Effects on Root and Crown Rot of Wheat

In recent years, western Canadian producers have become more reliant on noncereal crops, including pulses, and have increasingly adopted conservation tillage practices. It is therefore important to examine the role of currently popular cropping sequences and tillage methods on root and crown pathogen populations.

Root and crown/foot rot are caused by a complex of fungal pathogens, consequently the effects of agronomic practices on these diseases depend on the causal agents as well as the environmental conditions, and thus are often unpredictable. Some agronomic practices might favour one pathogen while causing a reduction of another. Past research showed that the presence of *C. sativus* and *Fusarium* spp. in underground tissue of wheat was affected by crop rotation, tillage method, and chemical input. In western Canada, root rot in wheat, caused primarily by *C. sativus,* was not consistently affected by tillage[20], nor did it significantly decrease in reduced tillage systems[1,12]. Furthermore, some studies reported lower levels of *Fusarium* spp. in wheat roots as the number of tillage operations increased[1,2,21,15]. While the prevalence of *C. sativus* in barley and common and durum wheat subcrown internodes decreased as the number of tillage operations decreased, *Fusarium* spp., such as *F. avenaceum*, increased with a reduction in tillage intensity and increased glyphosate use[22,23].

Studies in Saskatchewan[14,22,23] on rotation effects indicated a greater prevalence of *C. sativus* in barley and common and durum wheat that was preceded by summerfallow, or grown after a sequence that included summerfallow and a cereal crop, than in rotations that did not include summerfallow. In contrast, rotations with noncereal crops were reported to reduce the severity of root rot in cereals caused primarily by *C. sativus*[24,25,26], while the presence of *Fusarium* spp. in spring and winter wheat roots increased[2,13]. Cropping sequences that included at least one noncereal crop in the previous two years resulted in greater percentage of isolations of some *Fusarium* spp. in wheat than in monoculture cereal sequences, with a greater isolation of *F. avenaceum* being observed after a pulse crop[22] This was attributed to the greater susceptibility of pulse crops to *F. avenaceum* [27], which was reflected in its greater presence in pulse residues than in residues of other crop species[28]. Other studies reported no rotation effect on the occurrence of *Fusarium* spp. in spring wheat roots[1].

Organic Management Effects on Root and Crown Rot of Wheat

Conversion to organic systems has been shown to affect the relative prevalence of *Fusarium* spp. in roots and crowns of wheat in European studies[29,30,31]. Hannukkala and Tapio[30] detected less foot rot in winter wheat caused by *F. avenaceum* and *F. culmorum* in organic than non-organic systems. Elmholt[29] reported less frequent isolation of *F. culmorum* from the soil of organic farms that had been under organic management the longest. Lower FHB levels and concentrations of the mycotoxin DON were also observed in organic than in non-organic systems for winter wheat[32].

Results from a recent input level and cropping diversity study conducted in west-central Saskatchewan[21] also indicated a differential effect of input system on the most common *Fusarium* spp. The pathogens *F. avenaceum* and *F. culmorum* were most associated with the non-organic input systems, especially under reduced tillage, whereas the weakly pathogenic/saprophytic *F. equiseti* was favored by organic management. The low incidences of *F. avenaceum* and *F. culmorum* in the organic input system agree with the above-mentioned reports from research conducted in Europe where these *Fusarium* pathogens decreased under organic management. The results from the study in west-central Saskatchewan also agree with results by Elmholt[29] who reported a more frequent isolation of *F. equiseti* from soil of organic farms that had been under organic management the longest. Knudsen et al.[31] also reported that the density of non-pathogenic *Fusarium* spp. (including *F. equiseti*) in soil and straw was higher in an established organic farm than in a neighbouring non-organic farm, suggesting that pathogenic isolates may be suppressed by antagonistic isolates to a greater extent in the organic fields.

Observations by Fernandez et al.[21] also showed that *C. sativus* infections of subcrown internodes and crowns occurred at the highest levels under intensive tillage, including organically-managed treatments. In European studies, infection of stem bases and roots of barley and winter wheat by *C. sativus* was also greater in organic than in non-organic cropping systems[33,30].

The mechanism(s) responsible for reduced *Fusarium* infections of roots and crowns in wheat grown under organic management are largely unknown. In a recent review, van Bruggen and Termorshuizen[34] stated that it was unknown to what extent the suppression of crop diseases that commonly occurs in organic farming systems can be attributed to microbial diversity and activity, individual microorganisms, soil and plant nutrient status, induced systemic resistance, or soil physical characteristics, among other factors.

Exploring interactions among cereal pathogens and saprophytes on roots and crowns in organic versus conventionally-managed systems might explain how these practices result in differences in fungal populations. A better understanding of fungal interactions in underground/ground level cereal tissue could be exploited for the biocontrol of root and crown rot in cereals. For example, the antagonistic potential of *F. equiseti* against *Fusarium* pathogens has been shown.

Luongo et al.[35] reported that *F. equiseti* showed strong antagonism against pathogenic *Fusarium* spp., including *F. graminearum* and *F. culmorum*, when tested on wheat straw under controlled conditions. Similarly, Dawson et al.[36] reported that of all the organisms tested, *F. equiseti* was overall the best competitor with *F. culmorum* and *F. graminearum* on winter wheat spikes.

Genetic Resistance

Durum wheat is in general more susceptible to root and crown rot than common wheat[4,22]. Nsarellah et al.[37] reported that durum wheat cultivars varied in their susceptibility to root rot, and that development of resistant cultivars was complicated by the variable responses of germplasm in different environments to the multiple pathogens of this disease complex.

Despite a common aetiology, different host genes have been shown to be involved in the resistance of wheat against FHB and crown rot caused by *F. graminearum* and *F. pseudograminearum*[38].

Differences in resistance to prematurity blight, caused by *C. sativus* and *F. culmorum*, were reported among Canadian durum wheat cultivars[39]. However, there has been little progress made in finding and incorporating genetic resistance to this disease complex in this market class. None of the currently registered durum wheat cultivars in western Canada possess good resistance to root or crown rot (Fernandez, M.R., unpublished data). Identification and incorporation of resistance to these diseases has taken a backseat in wheat breeding programs to other currently more devastating cereal diseases.

Identification and incorporation of resistance to root rot in western Canada has focused mostly on *C. sativus*, the most common pathogen in this region. Given that new popular management practices favour the build-up of inoculum of *Fusarium* pathogens in roots and crowns, efforts to identify and incorporate resistance to these diseases should also concentrate on *Fusarium*. One of the most effective ways of selecting genotypes with resistance or tolerance to these pathogens is to conduct field screenings under the management systems that favour the development of *Fusarium* species, such as zero-till and rotation with pulse crops [22,23].

Concluding Remarks

Because *Fusarium* infections of the crowns and roots are less affected by environmental conditions than spike infections, the former may contribute to the maintenance of inoculum in years that are not conducive to FHB development and thus contribute to the further spread of this disease on the Canadian Prairies. Therefore, measures aimed at reducing crown and root rot caused by *Fusarium* spp. may also help reduce FHB development in wheat on the Canadian Prairies.

Further investigation into root and crown rot caused by *Fusarium* spp. and their management is warranted considering the popularity of conservation tillage practices and incorporation of noncereal crops in cereal-based cropping systems by western Canadian producers, and the increased importance of diseases caused by *Fusarium* spp. Further research into the impact of organic management on this disease complex is also warranted in light of the increased conversion to organic methods, and the apparent suppression of *Fusarium* pathogens in those systems. Investigation into the mechanisms responsible for the different relative prevalence of *Fusarium* spp. under organic management might shed light on possible natural biocontrol mechanisms occurring in those systems, and may contribute to more effective control of root and crown rot pathogens.

Currently, options for controlling root and crown rot of wheat are limited. Growers should avoid the application of excess nitrogen fertilizer and deep seeding in order to reduce disease severity. Rotation with crops other than wheat or pulse crops will reduce the severity of root and crown rot of wheat and limit yield losses caused by these diseases.

Greater emphasis needs to be placed on the development of new wheat cultivars that are resistant to this disease complex. The interaction between drought resistance and disease resistance or tolerance also should be examined.

Existing evidence indicates that climate change might have significant impact on Canadian agriculture, in particular through higher temperatures and a greater incidence and intensity of extreme weather. Hotter and drier weather are likely to increase the incidence and severity of root and crown rot on the Prairies, and increase yield losses due to these diseases. Thus, research on these diseases should receive greater emphasis.

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