Fusarium Head Blight of Cereals in Western Canada - a IO-Year Retrospective

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Fusarium head blight (FHB), a disease of wheat and barley, has been a problem for producers and the agricultural industry in Manitoba for the past 10 years. During this time the disease has occasionally been reported from eastern Saskatchewan, but until 1996, FHB was largely a novelty or of minor concern in this province. A concerted effort to study FHB under prairie conditions was begun in 1988 at the Cereal Research Centre (CRC), Agriculture and Agri-Food Canada in Winnipeg MB. This work is ongoing. For this presentation the findings of this research, done by a multi disciplinary team of scientists and technicians, will be summarized. The intent is to provide a brief overview and to supply literature references for information already published. These findings have relevance to a problem that may become more acute in Saskatchewan, and should provide agronomists, extension personnel, plant pathologists and producers with insights and a 'road map' on which to base recommendations and future studies.

The information on FHB is presented under the following headings:

1. History
2. Symptoms
3. Disease Spread/Surveys
4. Fusarium spp.
5. Mycotoxins/FDK/Grading
6. Resistance
7. Seed Quality
8. Cultivar Development
9. Performance of Registered Cultivars
10. Prospects for 1997 and Beyond
11. References

1. History

Fusarium head blight is not new to the prairie provinces. It has been observed here on several occasions since 1920. However, prior to 1986 the disease was sporadic, rarely of concern, and was not widespread. All reported outbreaks of FHB in the Canadian prairies can be correlated with above normal levels of rainfall during the growing season (June, July, August). Abundant moisture during the heading/flowering/early seed development period (July) is of particular significance. The current ongoing outbreak of FHB in Manitoba began in 1984 when two samples of harvested wheat seed from a single grower in the southern Red River Valley was found to contain 'tombstone kernels' and measurable levels of vomitoxin, a metabolite produced by *Fusarium* (Clear and Abramson 1986). In 1985, a larger number of FHB-affected wheat samples were diagnosed from this same general region, plus a few sites further west (Abramson et al.

1987).

Beginning in 1986, systematic surveys for FHB as a disease of the wheat crop prior to harvest were begun, and in that same year farm fields with as many as 25% of heads with visible symptoms were found (Tekauz et al. 1986). Since then surveys for FHB in wheat have been done annually and in the last 3 years have also included barley (Gilbert et al. 1993 - 1997; McCallum et al. 1997; Tekauz and Wong 1989; Tekauz et al., 1986, 1988, 1995, 1996; Wong and Tekauz 1990; Wong et al. 1991, 1992). During this same period, 'scab', as FHB is known in the United States, was occurring in the Red River Valley regions of Minnesota, North Dakota and South Dakota, at levels comparable to those in Manitoba. This indicated that FHB was a widespread regional problem and that co-operation would be useful to expedite a better understanding of the disease and methods for its control. An annual 'Regional Fusarium/Scab Forum', involving participants from the three affected States and Manitoba has been organized for the past 4 years (the most recent in Winnipeg MB, October 1996) to facilitate collaborative studies and the exchange of information among researchers, extension personnel, producers and the industry.

Factors which may have led to the current outbreak of FHB in Manitoba and adjoining regions include: the increased adoption of conservation tillage, increase in continuous cropping, shorter rotations, increased production of corn (also susceptible to *Fusarium),* advent of semi-dwarf/CPS wheats, intensive crop management, high moisture levels in many of the last 1 O-l 5 years and, specific to the Red River Valley, the heavy, slow draining soils exacerbating some of the above.

2. **Symptoms**

As its common name implies, FHB leads to premature bleaching or yellowing of wheat and bronzing or browning of barley heads at a time when the crop normally is green. The bleaching/browning can affect single florets or spikelets, larger portions of, or the entire head. Severely infected heads can lead to development of a dark brown discoloration of the peduncle, another FHB diagnostic feature (Wong et al. 1992). Infected spikelets often have a pink or orange-pink discoloration at their bases and/or glume edges, particularly under moist conditions. The pink discoloration results from production of sporodochia or spores by the infecting fungus; these can spread the diseases to other spikes during subsequent rain-wind events.

In farm fields, infection of spikes at incidence levels of 0.5% or higher is readily visible, particularly at early stages when healthy spikes are bright green. Later, when the crop has started to turn diagnosis is still possible, as the premature bleaching of infected spikelets/heads has a somewhat different coloration compared to that of natural ripening, and often orange-pink sporodochia are still present. In addition, the head 'architecture' is somewhat different, being somewhat more 'open'. In Manitoba, farm fields with FHB incidences as high as 80% have been observed in conjunction with severities averaging 50% of spikelets diseased. Such examples are dramatic in appearance and attest to the devastating potential of the disease.

Field symptoms which may be confused with FHB include those produced by the wheat stem maggot or sawfly, and those of Common Root Rot. However, in the former, a portion of the peduncle as well as the entire head are bleached, and in the latter, severe infection of the crown and sub-crown internode lead to bleaching of the entire plant, i.e. leaves plus spikes. By contrast, the symptoms of bleaching caused by FHB are restricted to the head or parts thereof.

Following harvest, the presence of FHB remains evident, as infection usually leads to the production of tombstone, or Fusarium damaged kernels (FDK), in the grain (Symons et al. 1997). In the US, these are known as 'scabby' kernels. In wheat FDK kernels are shrunken and wrinkled compared to healthy ones, and are chalky-white in appearance, in contrast to the yellow-reddish-brown colour of unaffected grain. A pink discoloration may be found on parts of the affected kernel, but a pink or purple-red discoloration alone, in the absence of other features of FDK, is not diagnostic for FHB (a pink discoloration can also be the result of 'red smudge' caused by the tan spot fungus, frost damage, or, other factors) (Tekauz et al. 1986). Fusarium damaged kernels, which are lighter in weight compared to healthy ones, lead to reduced overall kernel weights, and are responsible in large part, for the yield reductions resulting from FHB.

3. **Disease Spread/Surveys**

In Manitoba the spread of FHB since 1984 has been tracked via surveys of grain samples analyzed by the Grain Research Laboratory of the Canadian Grain Commission and surveys of farm fields done 2-4 weeks prior to harvest (see references in Section 1). The disease can be found throughout the province, however, fields in the north-west region (Roblin, Swan River Valley) have not been surveyed systematically, and the presence of the disease there has been confirmed primarily from grain samples. Since 1984, FHB has been most prevalent and in the Red River Valley region, particularly south of Winnipeg. This region comprises parts of crop districts 7, 8 and 9. The disease was most severe in 1986, 1991, 1993, 1994 and 1996. The epidemics of 1993 and 1994, when rainfall was excessive, humidity high, and conditions cloudy, were particularly bad. The 1993 FHB epidemic in southern Manitoba was estimated to have caused losses totaling $75 million (Gilbert et al. 1994).

In 1996, FHB clearly became more widespread and severe in western Manitoba than found previously, and this observation extended to eastern Saskatchewan. This was accompanied be an increased presence of *F. graminearum* as a component of total Fusaria (R. Clear, personal communication). The 1996 situation likely was due to the high rainfall in western Manitoba and much of Saskatchewan in the summer of 1996.

4. **Fusarium species**

Fusarium graminearum and *F. culmorum* are the two fungal species most often associated with FHB world-wide. In Canada, *F. graminearum* has been most frequently isolated from diseased wheat heads and kernels, and this species is regarded as the principal causal agent of the disease (Wong et al. 1992). Several other *Fusarium* species have been isolated from FHB-affected wheat in Manitoba, but these species normally have comprised only a small proportion of the total Fusaria found (Gilbert et al.

1996). Fusarium graminearum and *F. culmorum* are the most pathogenic species and produce the greatest number of FDK kernels in grain (Wong et al. 1995).

In southern Alberta FHB occasionally occurs on soft white wheat grown under irrigation. Here the disease is associated mainly with *F. culmorum.* In Europe, resistance to one of *F. culmorum* or *F. graminearum* was also found to be effective against the other species. *Fusarium graminearum,* either as single isolates or mixtures, is used at CRC to study the disease process and to screen for resistance.

Fusarium graminearum is also the species most often isolated from infected barley in Manitoba. However, several other *Fusarium* species are found at relatively high levels, in particular *F. poae* (Tekauz et al. 1996). At this time it is not known whether these other species are highly, moderately or weakly pathogenic on barley. This difference in *Fusarium* species composition in barley vs. wheat, plus the likelihood that infection at flowering does not play as important a role in barley, suggests the development of disease in these two crops differs.

5. Mycotoxins/FDK/Grading

In addition to reducing grain yields, infection by *Fusarium* may result in the production and accumulation of mycotoxins(s) in the grain (Wong et al. 1995). The most common of these is 'vomitoxin' or DON. Levels of DON and other mycotoxins are measured in parts per million (ppm) or parts per billion (ppb), and Health Canada have set strict tolerances for mycotoxins in grain destined for human consumption. Pigs are the farm animal most sensitive to DON, and feed containing just several ppm can lead to feed refusal and loss of weight, and in pregnant sows to gestation abnormalities. *Fusarium culmorum* and *F. graminearum* are the principal producers of DON.

Levels of DON are correlated positively with amount of FDK (Wong et al. 1995), and the Canadian Grain Commission has placed limits on levels of FDK in grain, with tolerances for top grades being very low. Tolerances are based on percent FDK by weight, and on the visual characterization of FDK kernels as being small, shriveled and chalky-white (and possibly pink) in appearance. Reduction in grade due to FDK, combined with lost revenue from reduced yields can have a major impact on producers.

In barley, FDK kernels often are neither smaller nor shriveled compared to healthy ones, but can be distinguished by the presence of fungal mycelium in the dorsal crease, the presence of pink-orange sporodochia, and/or erumpent black spots or dots, the pseudothecia or fruiting bodies of *Fusarium* (Symons et al. 1997). Symptoms of FHB may also appear as a medium to dark brown discoloration of kernels at their embryo end. Since such discoloration can also be caused by other agents (the net blotch and spot blotch fungi, weathering, etc.), this is not diagnostic as FHB for grading purposes unless accompanied by the other features described above. The Canadian Grain Commission has set tolerances for FDK for the top barley grades.

Other mycotoxins occasionally detected in wheat or barley, i.e. T2, HT2, DAS, nivalenol, and acetyl derivatives of DON, are considerably more toxic than DON itself. However, in wheat these are rarely found, and are usually detected only at very low levels under Canadian prairie conditions. In barley, they may be more common, as the *Fusarium* species that produce them are more frequently associated with this crop (Abramson et al. 1996; Clear et al. 1996; Tekauz et al. 1996).

6. **Resistance**

Management of FHB world-wide has relied mainly on incorporating resistance to *Fusarium* in adapted varieties. Currently, no fully resistant nor moderately resistant cultivars of wheat or barley are available to Canadian (or American) producers. However, such cultivars are under development at CRC and several US research centres. Most of the resistance utilized is of Chinese origin, in particular 'Sumai 3' wheat. This and some other Chinese wheat lines are highly resistant to western Canadian isolates of *F. graminearum* and the resistance is usually accompanied by reduced accumulation of DON (Wong et al. 1995).

The effect of FHB on total grain yield and its components has been studied under Manitoba conditions in wheat (Wong et al. 1992). In susceptible Sceptre durum FHB caused a grain yield loss of about 35%, most of which was accounted for by a reduction in thousand kernel weight. Kernel number per spike was not affected. An enhancement of resistance to initial infection, to subsequent intra-spike spread, and to mycotoxin production and accumulation (leading to reduced yield and grade loss during FHB epidemics), is the breeding goal being pursued.

In barley, resistance to *Fusarium* appears also to be available, but this has not been investigated as extensively as in wheat. The 'old' six-row US malting cultivar Chevron is a potential resistance source, and at CRC this and many other genotypes are being evaluated. The effect of FHB on barley grain yield has not been tested under prairie conditions, but the generally lower levels of visible damage found in barley compared to wheat (Tekauz and Gilbert 1996a, 1996b), suggests that yield would be less affected. A reduction in the accumulation of mycotoxin(s) may the most desirable resistance factor to pursue in barley.

7. Seed Quality

The effects of FHB on grain yield and quality have already been noted. Producers who use common seed to plant next year's crop, can experience an additional effect from FHB, reduced quality of the seed. Infection of wheat by *Fusarium* resulting in FHB, has been demonstrated to produce high levels of *Fusarium* infestation of seed, whether of 'normal' appearance or FDK type. Such seed showed greatly reduced levels of germination (Wong et al. 1992).

Further studies using infested Manitoba seed from 1993 were done by Gilbert and Tekauz (1995), who determined the effect of cleaning on grade, germination, and plant emergence in several wheat cultivars, and, of fungicide treatment on seed performance and plant vigour. Cleaning led to raised-grades by reducing the levels of FDK, but the effects were cultivar dependent. Emergence of infested seed was reduced by as much as 60%, but seed treatment boosted germination and emergence to near uninfested 'control' levels. While the latter result is encouraging, seed treatment is an input with a cost attached. It should be noted that FDK kernels are dead and will not germinate irrespective of fungicide use.

Gilbert and Tekauz (1996) also studied the effects of temperature and duration of storage on the performance of Fusarium-infested seed. In wheat, higher storage temperature enhanced , whereas prolonged storage at cold temperature reduced germination of infested seed. This was largely due to degree of *Fusarium* survival. Cold winter temperatures typical of the prairies may allow *Fusarium* to survive readily on stored seed. Subsequently this could result in poor seed performance following planting. Producers using seed obtained from fields where FHB was present should test its germination prior to planting (preferably in spring) and apply a seed treatment fungicide if warranted.

8. Cultivar Development

As already noted, adapted wheat lines combining improved resistance to *Fusarium* with the remainder of the agronomic, disease and quality attributes required for successful production in western Canada are under development at CRC, and elsewhere. Canadian lines have demonstrated both good resistance to *Fusarium* and good agronomics; their quality has ranged from poor to acceptable (Leisle et al. 1995; Townley-Smith et al. 1996). Some lines (entries) are currently in cooperative tests where they are performing well. If expectations are met, the first *Fusarium* resistant CPS wheat cultivar for western Canada should be registered by year 2001, followed one or two years later by a CWRS type. These first cultivars will be the vanguard for future releases in which the level of *Fusarium* resistance combined with other desirable traits will continue to improve.

In barley, breeding for resistance to *Fusarium* in is in its early stages in western Canada. Initial crosses with putative resistance sources have been made (at AAFC Brandon), but in comparison to wheat the process is at least 5 years behind. In barley FHB was not recognized as a major problem until 1994. A research team is now in place at CRC to address this problem, and results from previous work on wheat are expected to accelerate development of adapted resistant barley germplasm.

Other breeding programs in western Canada (AAFC Swift Current - wheat, Crop Development Centre, University of Saskatchewan - barley) are beginning to address the *Fusarium* problem. In all programs DNA technology is being used to facilitate and expedite detection of resistance genes, to 'mark' them in hybrid genotypes, and to attempt to introgress novel resistance from non-cultivated *Triticum, Hordeum,* and other promising sources.

9. Performance of Registered Cultivars

While no registered Canadian wheat or barley cultivars have good resistance to *Fusarium,* previous observations indicated certain cultivars to be less susceptible. One of the first to be so recognized was the bread cv. Katepwa; a number of more newly-registered bread wheat cultivars derived from Katepwa appear to have retained this level of resistance. By contrast, Roblin was found to be particularly susceptible, as were most durums and wheats of CPS type. Results from trials done in Manitoba in 1995 and 1996 in which 14 to 18 wheat and 12 to 14 barley cultivars were tested at several field locations, as well as in the inoculated Fusarium Nursery at Glenlea, identified a few cultivars that were consistently superior, and others that were more susceptible (Tekauz and Gilbert 1996a, 1996b). Among the least susceptible were wheat cvs. AC Barrie, AC Cora and Katepwa, and barley cvs. Argyle, AC Oxbow, CDC Silky and Tankard. Performance of registered wheat cultivars to FHB (based on the above and other trials) has been tabled in the annual Manitoba Seed Guide (1996 and 1997 editions) prepared by Manitoba Agriculture and the Manitoba Co-operator. Information on barley likely will be included for 1998. A further year of testing of registered cultivars is planned.

Cultivars of wheat with Katepwa levels of resistance can be expected to sustain less damaged in mild or moderate FHB epidemics. During severe epidemics, such as those in 1993 and 1994, differences among cultivars were less evident and all were damaged extensively. Considerably improved levels of resistance are required if cultivars are to perform optimally during FHB epidemics.

IO. Prospects for 1997 and beyond

In Manitoba, FHB is now endemic and will damage wheat and barley crops whenever conditions favour the disease. In the Red River Valley, where heavy clay soils drain slowly following rain, resulting in prolonged high humidity, FHB will occur even when conditions are ‘normal’. When precipitation is excessive in July and early August, or abundant during wheat flowering, severe epidemics of FHB can be expected. In central and western Manitoba where lighter loam and sandy soils predominate, FHB will likely be a problem only in wet years, as in 1996. A similar scenario likely holds true for eastern Saskatchewan. In Saskatchewan, the hitherto much lower levels of F. *gramineanrm,* compared to Manitoba, provide an additional buffer to a widespread and severe outbreak of FHB. However, continued wet conditions such as those of 1996, could result in further buildup of inoculum. The potential movement of F. *graminearum* west from Manitoba, based on precipitation forecasts, has been mapped by Clear et al. (1994) and Symons et al. (1997).

In the short term, producers can control FHB using cultural means such as crop rotation and straw and stubble management to reduce *Fusarium* inoculum. Cultivar selection may also help minimize losses, as will staggered planting or use of cultivars of differing maturities to avoid general infection during specific rain events. These strategies may not have much effect when epidemics are severe.

Foliar fungicides have been tested for control of FHB but North American results have been inconsistent; the multi-applications tested would likely be uneconomic. In any event, no product is registered for this use in Canada, and to be effective this would have to applied at a date beyond that currently indicated for control of foliar diseases, such as tan spot and Septoria. A IO-point FHB risk assessment check list, developed for Manitoba producers, addresses control options and is appended; most points are relevant for Saskatchewan as well.

Shortly after year 2000 the availability of *Fusarium* resistant cultivars will provide producers with the best option to minimize yield and quality losses due to FHB. This development should assure the continued competitiveness of the industry throughout western Canada.

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ARE YOU AT RISK FROM FUSARIUM HEAD BLIGHT IN 1997?

(a IO-point check list)

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Greater Risk	**Lesser Risk**
The more points in this column that apply, the greater the risk.	*The more points in this column that apply, the lesser the risk.*
1. You farm in the Red River Valley of Manitoba.	1. You farm outside the Red River Valley.
2. Your soil is a heavy clay and drains slowly.	2. Your soil is a lighter clay loam, loam, or sandy loam and drains readily.
3. You are a zero-till producer.	3. You practice conventional tillage.
4. You grow wheat or barley every year on your farm.	4. You don't grow wheat or barley every year on your farm.
5. You don't rotate away from cereal crops in individual fields, or you practice a corn/wheat rotation.	5. You rotate between cereal and pulse or oilseed crops with a minimum one-year interval.
6. You had FHB on your farm in 1.996.	6. You did not have FHB in 1996.
7. You grow CPS, durum, or Extra Strong wheat.	*7. You* grow HRS wheat (but see list overleaf).
8. You grow the more susceptible varieties of HRS wheat and barley.	8. You grow the less susceptible varieties of wheat and barley.
9. You seeded only one variety over a short time period.	9. You seeded 2 or more varieties of different maturities, or the same variety but over a 2-4 week period.
IO. The growing season has been wetter than normal, particularly at the heading/flowering stage, with prolonged periods of high humidity.	10. The growing season has been drier than normal, or you had no rain at your farm during the heading/flowering period.