PROGRESS IN ASSESSING THE IMPACT OF FUSARIUM HEAD BLIGHT ON OAT IN WESTERN CANADA AND SCREENING OF *AVENA* GERMPLASM FOR RESISTANCE

A. TEKAUZ[1] *- J.W. MITCHELL FETCH*[1] *- B.G. ROSSNAGEL*[2] *- M.E. SAVARD*[3]

[1] Cereal Research Centre, Agriculture and Agri-Food Canada, 195 Dafoe Road, Winnipeg MB, R3T 2M9, Canada, e-mail: atekauz@agr.cg.ca
[2] University of Saskatchewan, Crop Development Centre, Saskatoon, Saskatchewan, Canada
[3] Eastern Cereal and Oilseed Research Centre, Ottawa, Ontario, Canada

Abstract: Fusarium head blight (FHB) of oat in western Canada was determined to be caused by a complex of Fusarium species, the composition and proportions of which varied considerably among years, and between Manitoba and Saskatchewan, the two main oat production regions (provinces) in western Canada. The levels of deoxynivalenol (DON), associated with Fusarium graminearum infection, were considerably higher in oat than in wheat and especially in barley, when levels of DON were compared to those of F. graminearum on seed, suggesting that oat may stimulate production of the mycotoxin by this causal species during the infection process, compared to that in other cereals. Testing of oat cultivars and lines for reaction to FHB indicated that while differences existed, these were relatively small. 'Naked' oats, in general, were more resistant. Several of the exotic oat accessions tested appeared to have superior levels of resistance and these are being used as parents in crosses to improve resistance in adapted, high quality oats.

Keywords: oat*, Fusarium graminearum*, *Fusarium poae*, deoxynivalenol, mycotoxins, resistance

Introduction

Fusarium head blight (FHB) continues to be a disease of world-wide importance in cereals due to its damaging effects on crop yields and quality and in particular, its potential to contaminate grain with mycotoxins. The mycotoxins, of which deoxynivalenol (DON) is the most common, compromise the grains= uses for food and feed and constitute a hazard to human and animal health. In Canada, epidemics of FHB have occurred sporadically since the 1920s, but these became more regular since the 1980 epidemic in winter wheat in Ontario (Sutton 1982), and the epidemic of 1993 in spring wheat in Manitoba (Gilbert et al. 1994) and adjacent U.S. states (McMullen et al. 1997). FHB was observed in commercial fields of barley in 1994 and was detected early in this millennium in oat (Tekauz et al. 1995, 2003). The disease is now widespread in the eastern prairies (Manitoba and south-eastern Saskatchewan) and is found annually in most commercial cereal crops in this region.

In 2007, oat production in Canada totalled 4.7 M tonnes, almost all of which (4.3 M tonnes) was produced in western Canada. Most food oats and some feed oats produced in the eastern prairies are shipped south to the United States. Food oats are processed and form a main ingredient of certain breakfast cereals, energy snack bars, and other food products. Some of these products have a health claim on their packaging re. "lowering cholesterol, managing blood pressure and promoting healthy arteries", due to the high beta-glucan content in oats. This health advantage for consumers is desirable and coveted by industry, and requires that specific grain quality parameters be met. Diseases adversely effect oil and beta-glucan content, as well as seed size, and need to be managed effectively to maintain yield and quality potential. The potential for contamination of grain with mycotoxin(s), resulting from infection by *Fusarium*/FHB, is a new and worrisome factor that could jeopardizes oats' standing as a healthy grain.

This paper outlines the progress made in our laboratory during the past few years

 DOI: 10.1556/CRC.36.2008.Suppl.B.8

on various aspects of FHB in oat, including regional disease prevalence, causal species and their significance, mycotoxin levels, oat cultivar reactions, and sources of resistance. A previous status report on FHB in oat in western Canada was published in 2004 (Tekauz et al. 2004).

Materials and methods

Causal species and regional trends

Systematic surveys of commercial oat fields were undertaken from 2002 to 2007 to document FHB occurrence and severity and to collect affected spikes (panicles) for identification of the causal *Fusarium* species. The number of fields monitored varied from 9 to 55 depending on the year and region (the provinces of Manitoba or Saskatchewan). The results have been summarized and published annually in the electronic journal Canadian Plant Disease Survey (www.cps-scp.ca/cpds.htm). Disease occurrence and severity was assessed by sampling three clumps of 100+ spikes per field for incidence and visual severity. To assess the causal components, putatively infected panicles were hand-threshed, the seed surface-sterilized with NaOCl, and 100 kernels per sample plated onto potato dextrose agar or other diagnostic medium, to isolate, identify and quantify the *Fusarium* species present.

Mycotoxin levels

>Variety Performance Trials= (VPTs), to assess the performance of registered oat cultivars (and those of spring wheat and barley for comparison) to FHB, were grown from 2002 to 2005 at 11 field locations in southern Manitoba. The four-row plots, 1 x 3 m in size, were seeded in May, replicated three times, and inoculated with *F. graminearum*-infested corn kernel inoculum spread on the soil surface at 40g/m^2 prior to heading. No supplementary moisture was applied. At maturity, one of the central rows was harvested, the panicles threshed, and the seed tested for levels of total and individual *Fusarium* species (as a percent, based on 100 kernels plated on potato dextrose agar), and for deoxynivalenol (DON) content in ppm, using ELISA (based on a 1.0g sub-sample from 20 g of ground seed). A total of 54 oat cultivars (plus 31 of wheat, 14 of barley) were tested during the four years.

Cultivar reactions and resistant sources

To minimize damage and mycotoxin contamination, suitable sources of FHB resistance need to be identified and used in oat breeding programs to develop cultivars suitable for production in FHB-affected environments. In addition, the resistance status of advanced breeding lines needs to be determined to select the best performers, as does the resistance status of cultivars already being grown commercially. The latter would enable extension personnel to make sound recommendations to growers for the selection of cultivars best suited to their production regions.

Testing is ongoing and is being accomplished through the evaluation of registered cultivars, advanced breeding lines, and exotic oat accessions in a mist-irrigated artificially-inoculated (*F. graminearum*-infested corn kernels spread on the soil surface at 40g / m^2, applied twice) FHB Disease Nursery. This screening nursery was first established in 2003 at Portage la Prairie, Manitoba. Plots are harvested at maturity and the seed subsequently tested for *Fusarium* spp. levels and DON contamination, as described above.

Results

Causal species and regional trends

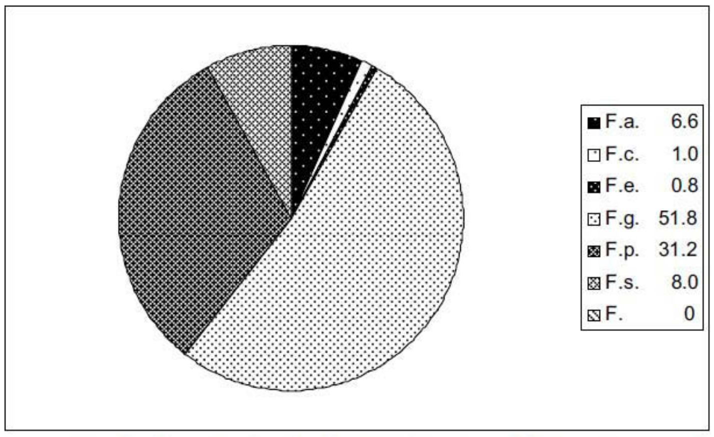
Invariably, FHB could not be detected at levels other than 'trace', i.e. an FHB Index of <1.0%, in commercial field of oat surveyed over several years. 'Blight' symptoms, if present, were usually seen on only a single seeds per panicle, and even in these, it was not evident whether the symptoms were due to FHB or other causes, e.g. sterility. As such, the panicles of oat collected for subsequent laboratory sampling, were essentially collected at random, and not on the basis of the presence of disease. Several *Fusarium* species were isolated routinely from putatively affected panicles of oat, but these differed in their relative proportion from year to year (Table 1). In southern Manitoba from 2002 to 2007, levels of each of the major *Fusarium* species varied considerably, with specific years appearing to favour infection by *F. avenaceum* (2005), *F. graminearum* (2003, 2004, 2007), *F. poae* (2002, 2006) or *F. sporotrichioides* (2002, 2004). Overall, *F. graminearum* was the most common species isolated, followed closely by *F. poae.*

The proportion of species also differed between two broad survey regions, southern Manitoba and Saskatchewan, the main oat production areas (provinces) in Canada (Figures 1 and 2). Comparing available 5-year and 4-year mean levels in Manitoba and Saskatchewan, respectively, *F. graminearum* made up about half of the total *Fusarium* spp. and *F. poae* near a third in Manitoba. The *Fusarium* species composition in Saskatchewan was very different, with *F. avenaceum* being the most common, again followed by *F. poae* which made up about a third, but here significantly, no *F. graminearum* was found.

Table 1. Proportion of *Fusarium* species isolated from commercial fields of oat in southern Manitoba, Canada, putatively affected by FHB, 2002-2007.

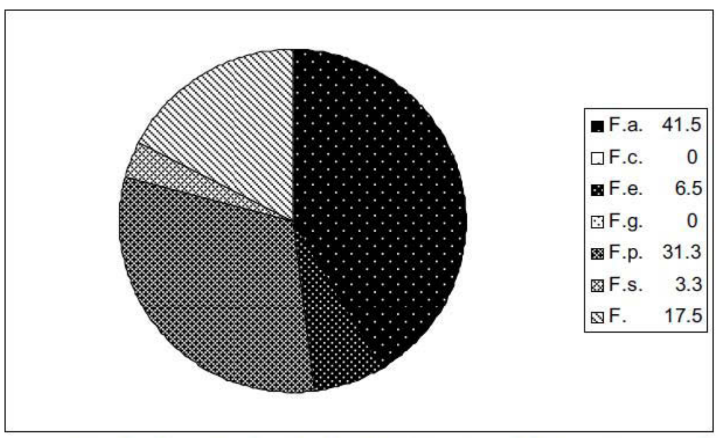
Crop year	*F. avenaceum*	*F. gramineaurm*	*F. poae*	*F. sporotrichioides*	Other *F.* spp.
2002	5.5[a]	32.3	37.3	23.4	1.5
2003	2.3	65.9	20.5	6.8	4.5
2004	2.3	50.3	19.2	28.2	0
2005	23.5	32.7	29.6	12.2	2.0
2006	2.1	7.2	82.5	6.7	1.5
2007	5.8	61.4	18.3	9.4	5.1
Mean	**6.9**	**41.6**	**34.6**	**14.5**	**2.4**

[a]Percent of the total *Fusarium* spp. present



Fa = *F. avenaceum*; Fc = F. *culmorum*; Fe = *F. equiseti*; Fg = *F. graminearum*; Fp = *F. poae*; Fs = *F. sporotrichioides*

Figure 1. Percentage of individual *Fusarium* species isolated from oat in Manitoba, Canada, 2003-2007.



Fa = *F. avenaceum*; Fc = F. *culmorum*; Fe = *F. equiseti*; Fg = *F. graminearum*; Fp = *F. poae*; Fs = *F. sporotrichioides*

Figure 2. Percentage of individual *Fusarium* species isolated from oat in Saskatchewan, Canada, 2004-2007.

Mycotoxin levels

The *Fusarium* species isolated from harvested seed of cultivars of oat, and those of wheat and barley, grown in the VPT trials in southern Manitoba (data for 2005 averaged over three sites shown as an example in Table 2) were similar to those observed annually for commercial fields surveyed in the region, namely that in oat, *F. poae* has a major causal role in the FHB syndrome. This was observed at 8 of 11 VPT trial sites (2002-2005), when levels of *F. poae* on seed were considerably higher than those of *F. graminearum*, the principal species isolated from seed of both spring wheat and barley in the same trials. *Fusarium poae* was also a sizeable component on seed of barley, but not on spring wheat.

The predominance of *F. poae* in oat occurred despite the addition of *F. graminearum*-infested corn kernels as inoculum in the field trials.

Table 2. Percent *Fusarium* spp. on seed of oat, wheat and barley from VPT trial in southern Manitoba in 2005.

Crop	Total *Fusarium*	Fa	Fc	Fe	Fg	Fp	Fs
Oat	25.9	3.4	0	0.2	4.2	15.8	2.0
Wheat	22.0	4.6	0	0.2	13.4	3.0	0.9
Barley	36.0	5.0	0	1.5	17.7	8.9	2.8

Fa = *F. avenaceum*; Fc = F. *culmorum*; Fe = *F. equiseti*; Fg = *F. graminearum*; Fp = *F. poae*; Fs = *F. sporotrichioides*

Fusarium graminearum and DON levels at the VPT trial sites in each of 2002 to 2005 varied depending on annual environmental conditions. Altogether, the values for *F. graminearum* and DON, averaged over the cultivars tested, ranged from 0.3–18.8% and 0.6–3.2 ppm in oat, 4.9–55.1% and 0.6 – 13.0 ppm in wheat, and 2.0–51.0% and 0.3 – 4.6 ppm in barley. In each of 2002 to 2005, and at all test sites, the ratios of DON to *F. graminearum* (DON/Fg) were highest in oat, followed by wheat and then barley (Figure 3). These data suggest that oat is particularly sensitive to DON accumulation, as each one percent of *F. graminearum* seed infection resulted in an average accumulation of 0.31 ppm of DON, compared to a DON accumulation of 0.14 ppm in wheat and 0.07 ppm in barley. Testing for mycotoxins other than DON was not done.

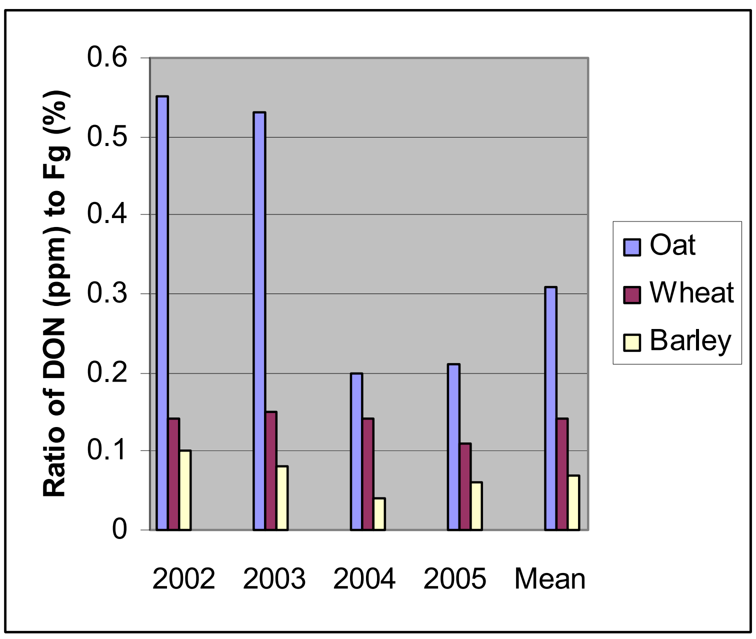


Figure 3. Ratio of DON to *Fusarium graminearum* in oat, wheat and barley cultivars at 11 trial sites over four years, 2002-2005.

Cultivar reactions and resistant sources

Testing of Canadian registered oat cultivars in the VPT trials and the FHB Nursery at Portage la Prairie (Figs. 4, 5) over several years indicated that their reactions to FHB, based on *Fusarium* levels on seed or DON in the grain, varied somewhat, but did so over a relatively small range. This was also the case for total *Fusarium* or *F. graminearum* in advanced breeding lines entered in the Western Cooperative Oat Registration Trial (WCORT), where lines submitted for registration consideration are tested over two years, along with check cultivars (AC Ronald, Leggett, AC Morgan, CDC Dancer) (Fig. 4). Entry OT 3028 had the lowest levels of both total *Fusarium* and *F. graminearum*, and a relatively low level of DON in the most recent WCORT test (2006-2007), indicating that a degree of resistance may be present in this adapted breeding line. Promising levels of resistance, based on low DON levels, were also demonstrated in a number of the 'exotic' accessions tested, including several that appear to originate from South America (Fig. 5). The locally registered 'naked' oat cultivar, Boudrias and the hulled cv. Leggett also had relatively lower levels of FHB. The inclusion of wheat and barley 'checks' in the FHB Nursery demonstrated, that in general, oats accumulate lower levels of DON than either the susceptible (Roblin, Superb, CDC Yorkton), or intermediately (MR-MS) resistant (AC Barrie, 5602HR, AC Metcalfe) cultivars of these crops. However, DON levels in oats can be quite high, >5 ppm, indicating that an improvement in resistance is needed.

Discussion

Previous reports have noted that FHB is not normally evident in a standing oat crop, and therefore that visual estimation for disease presence and severity is not possible. Other means, such as determining *Fusarium* levels on seed and/or mycotoxin contamination of grain must be used (Tekauz et al. 2004). Based on sampling of commercial fields over several years, FHB on oat in western Canada was associated with several *Fusarium* spp., primarily *F. avenaceum*, *F. graminearum* and *F. poae*, and to a lesser extent, *F. sporotrichioides*. These species had previously been isolated from harvested grain samples of oat following the 1993 and 1994 FHB epidemics in southern Manitoba (Clear et al. 1996). In our studies, the relative proportion of the major species varied considerably from year to year and between the two broad production regions sampled. The difference in *Fusarium* species in FHB-affected oats from Manitoba, compared to those from Saskatchewan, was most pronounced for *F. graminearum*. Similar disparate results were found in relative *Fusarium* species proportions and composition obtained from spring wheat, winter wheat, durum, and barley in the two provinces, with *F. graminearum* predominating in Manitoba but being almost absent in Saskatchewan (Tekauz et al., unpublished).

The high levels of *F. poae* found in oat grown in the VPT trials and in commercial fields surveyed suggest that this species is particularly adapted to this host. However, while *F. graminearum* levels were often lower than those of other *Fusarium* spp. in oat, levels of the mycotoxin DON in the grain were considerably higher (2-4 x) than expected based on previous experience with wheat and barley. Possibly, a stimulation or 'over-production' of DON by *F. graminearum* occurs when oat is the host 'substrate', compared to when this species infects wheat or barley. Other factors may also be at play, such as reduced breakdown of the initially-produced DON in oat, compared to other cereal crops. The combination of elevated DON levels relative to infection levels by *F. graminearum*, and the possible occurrence of other mycotoxins due to the regular presence of high levels of *F. poae* and/or other toxigenic species (i.e. *F. avenaceum*, *F. sporotrichioides*) suggest that oats grown in western Canada may accumulate a suite of mycotoxins when FHB is prevalent in the crop. Toxins such as moniliformin, T-2 and HT-2 have been detected in barley inoculated with *F. avenaceum* and *F. sporotrichioides* in Manitoba (Abramson et al. 2002, 2004), and may also be produced as a part of the disease syndrome in oat. Clear et al. (2000) found low levels of DON in Manitoba and Saskatchewan harvested oat grain samples from 1995-97, but did not detect any other mycotoxins. However, the disease may not have been as prevalent or widespread then, as it is now. While it is known that levels of DON in oat can be reduced substantially during commercial processing (Tekauz et al. 2004), it is not known whether other mycotoxins follow a similar pattern. Therefore further research, and monitoring for multiple mycotoxins, is warranted in oat, to adequately assess any health risks associated with utilization of raw oats and/or processed oat products.

Differences in oat reactions to FHB were demonstrated among the cultivars and accessions tested to date. However, based on our results, at present there does not appear to be a 'silver bullet' source of resistance available. Testing of additional germplasm is ongoing, including material from crosses of cultivated oats with *A sterilis* (kindly supplied to our laboratory by Dr. Helge Skinnes). These and/or other sources of effective resistance should result in the development of FHB-resistant, high quality, adapted oat cultivars at some point in the future.

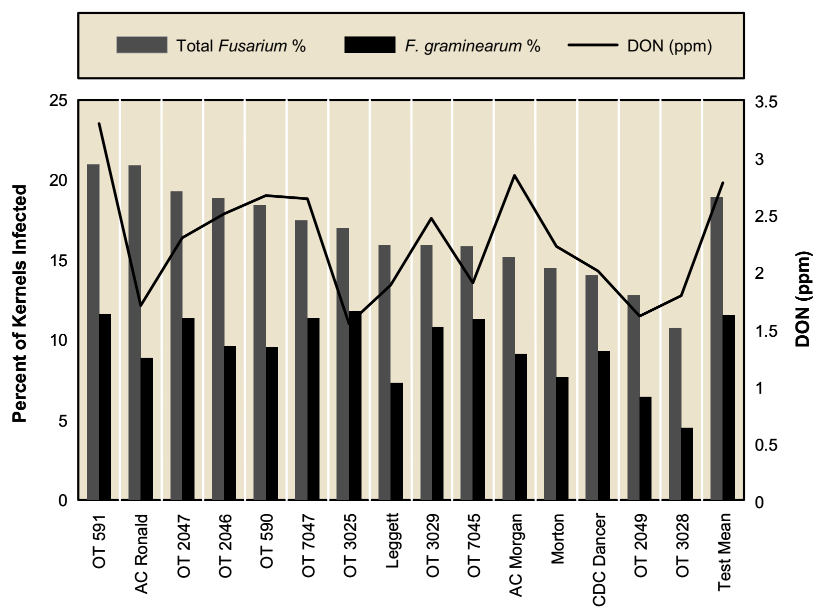


Figure 4. Average reactions of selected Western Cooperative Oat Registration Test entries and checks to *Fusarium* in the 2006 and 2007 Portage la Prairie, Manitoba, Canada, FHB Nurseries.

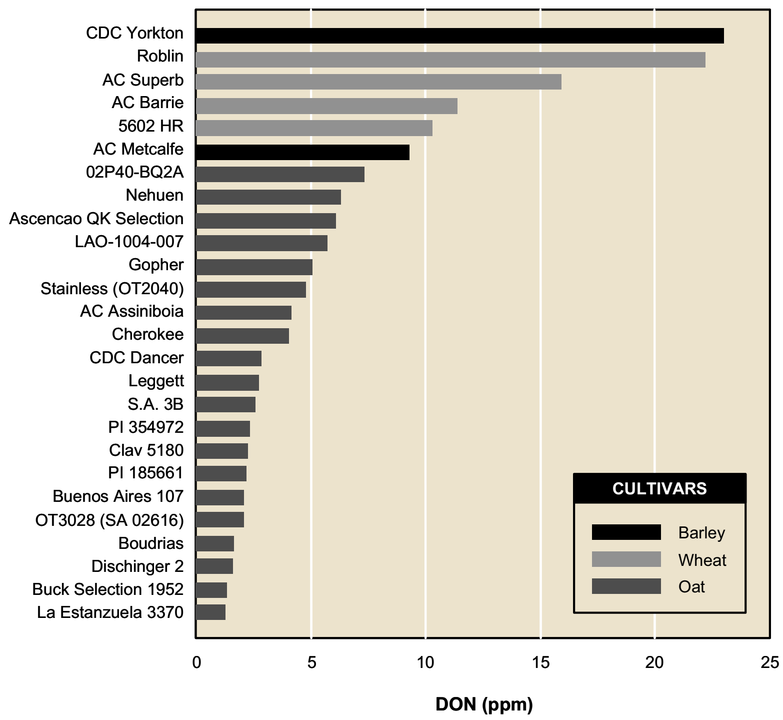


Figure 5. DON levels in selected accessions and check cultivars of oat (AC Assiniboia, CDC Dancer, Leggett, Boudrias), wheat and barley grown in the 2007 FHB Nursery at Portage la Prairie, Manitoba, Canada

References

Abramson, D., McCallum, B., Smith, D.M., Tekauz, A. 2002. Moniliformin in barley inoculated with *Fusarium avenaceum*. Food Additives and Contaminants **19**:765-769.

Abramson, D., McCallum, B., Tekauz, A., Smith, D.M. 2004. HT-2 and T-2 toxins in barley inoculated with *Fusarium sporotrichioides*. Can. J. Plant Sci. **84**:1189-1192.

Clear, R.M., Patrick, S.K., Platford, R.G., Dejardins, M. 1996. Occurrence and distribution of *Fusarium* species in barley and oat seed from Manitoba in 1993 and 1994. Can. J. Plant Pathol. **18**:409-414.

Clear, R.M., Patrick, S.K., Gaba, D. 2000. Prevalence of fungi and fusariotoxins on oat seed from western Canada, 1995-1997. Can. J. Plant Pathol. **22**:310-314.

Gilbert, J., Tekauz, A., Mueller, E., Kromer, U. 1994. Occurrence of fusarium head blight in Manitoba in 1993. Can. Plant Dis. Surv. **74**:77-78.

McMullen, M., Jones, R., Gallenberg, D. 1997. Scab of wheat and barley: a re-emerging disease of devastating impact. Plant Dis. **81**:1340-1348.

Sutton, J.C. 1982. Epidemiology of wheat head blight and maize ear rot caused by *Fusarium graminearum*. Can. J. Plant Pathol. **4**:195-209.

Tekauz, A., Gilbert, J., Mueller, E., Kaethler, R., Kromer, U. 1995. Foliar and head diseases of barley in Manitoba in 1994. Can Plant Dis. Surv. **75**:113-114.

Tekauz, A., Mueller, E., Stulzer, M., Beyene, M., Ghazvini, H., Schultz, D., Reverchon, F. 2003. Fusarium head blight of oat in Manitoba in 2002. Can. J. Plant Pathol. 82:50-51.

Tekauz, A., McCallum, B., Ames, N., Mitchell Fetch, J. 2004. Fusarium head blight of oat – current status in western Canada. Can. J. Plant Pathol. **26**:473-479.