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Foliar diseases of barley: Don't rely on a Single Strategy from the Disease Management Toolbox

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Summary
One of the main constraints to successful barley production results from foliar diseases, which destroy green leaf area and thus restrict the barley plant's ability to set yield and fill grain. Although a range of strategies are available to control foliar and other cereal diseases, rarely does the use of a single "silver bullet" solution provide complete protection. The main barley foliar diseases in western Canada are scald, (*Rhynchosporium secalis*), netted (*Drechslera teres* (Sacc.) Shoemaker) and spotted (*Drechslera teres* f. *maculata* Smedeg.) forms of net blotch, and spot blotch (*Cochliobolus sativus* (Ito & Kuribayashi) Drechs. ex Dastur). Scald, net blotch and spot blotch each have unique life cycles, and as a consequence producers need to consider a combination of strategies to provide effective and consistent long-term protection from these foliar diseases. This paper provides an overview of the holistic management of common foliar diseases of barley in western Canada, using a diverse set of management tools, and applying a growing season perspective.

Introduction
The common foliar diseases of barley (*Hordeum vulgare* L.) in western Canada are scald, (*Rhynchosporium secalis*, Figure 1), netted (*Drechslera teres* (Sacc.) Shoemaker, Figure 2) and spotted (*Drechslera teres* f. *maculata* Smedeg., Figure 3) forms of net blotch, and spot blotch (*Cochliobolus sativus* (Ito & Kuribayashi) Drechs. ex Dastur, Figure 4). These diseases are major constraints to maintaining yield and quality in western Canada and elsewhere, and the harm exerted can be especially acute when susceptible varieties are grown. Because the pathogens are composed of several to many strains or pathotypes[1,2,3,4,5,6,7], and new ones evolve rapidly in response to variety changes and/or production modifications, even 'resistant' varieties may become vulnerable and become diseased. Yield losses of up to 20% as a result of these diseases have been reported previously[8,9,10,11] and similar losses have been demonstrated in cv. Harrington barley grown under foliar disease pressure in western Canada[12,13]. Such studies have also demonstrated the usefulness of foliar fungicides in enhancing yields, thousand kernel weight, and kernel plumpness in affected crops.

While several strategies including genetics, chemicals, and cultural modifications are available to control foliar and other cereal diseases, rarely does the use of a single one of these provide complete protection. Since a "silver bullet" scenario does not exist, producers need to consider a combination of strategies from their disease management toolbox to provide effective and consistent long-term protection from foliar diseases. It can be difficult to consider all of the potential interactions that will occur among the various crop/disease approaches that a producer will use. Our objective here is to focus on holistic management of the common foliar diseases of barley in western Canada, using a diverse set of management tools, and applying a growing season perspective. Where available, we will support our approach with research results, and will also indicate where disease management strategies may interact with weed and crop production management.

Figure 1: Typical symptoms of scald of barley. Photo credit: T.K. Turkington

Figure 2: Typical symptoms of netted net blotch of barley. Photo credit: T.K. Turkington

Figure 3: Typical symptoms of spotted net blotch of barley. Photo credit: T.K. Turkington

Figure 4. Typical symptoms of spot blotch of barley. Photo credit: T.K. Turkington.

Management considerations prior to and at seeding

Planning. Information from previous growing seasons, such as what diseases commonly appear in a particular production region, is a powerful tool to help determine the strategies that can be used. As an example, if a severe leaf spot problem occurred the previous year, consideration should be given to growing a different crop or using a different field where the risk of the disease occurring is lower.

Field location, topography and wind-direction, can also be important considerations. This is particularly so for net blotch and spot blotch, because *P. teres* and *C. sativus* are wind-borne[2]. Locating a barley field downwind from another that has had a history of net blotch will invariably exacerbate the risk of disease. This may be less of an issue for *R. secalis* given that the pathogen is only dispersed by rain-splash over short distances, i.e. <2 m[5,2,14,15,16].

Seeding - quality seed, seed placement, seed treatment, and seeding date. The use of good quality, pathogen-free, non-damaged seed with good germination and vigour, is another important cornerstone of an effective and holistic disease management program. Quality seed helps avoid early-season disease problems, and reduces or eliminates the risk of introducing a seed-borne pathogen to new areas (fields or regions). Effective management of seed-borne pathogens at early crop growth stages is particularly relevant when a susceptible variety is being grown, or when environmental conditions are conducive to disease development and spread during the growing season.

In contrast to stubble- and straw-borne pathogen inoculum, the lack of references and information in the scientific literature regarding seed-borne inoculum of *R. secalis*, *P. teres*, and *C. sativus* suggests that it is not regarded as a major contributor to the overall leaf disease epidemics on barley in western Canada. However, seed-borne inoculum can be an important source of disease elsewhere, as in the case for net blotch in England, India, and New Zealand[17,18,19,16,20]. While seed-borne inoculum may not result in appreciable early-season disease, barley foliar diseases are polycyclic in nature and can complete and repeat their life cycles in 7-14 days[2], thus having the potential to build up, spread, and reach damaging levels.

Research from Alberta showed that during the three-year period from 1995 to 1997, between 71 and 97% of barley grain samples tested had detectable levels of *P. teres*, with percent seed infestation that ranged from 7.1 to 22.6%[21]. Maximum infestation levels by the same pathogen in single grain samples were high in each year, ranging from 81 to 89%. Such levels would certainly have an effect on subsequent seed germination and emergence, if seed treatment were not used and/or and early-season conditions favoured the pathogen(s) over the crop plant.

For best results, seeding with quality seed should be combined with shallow seed placement, which further reduces the risk of 'seedling blights' and early season root and foliar damage. Poor quality seed will result in slow germination and emergence when seeded deep, prolonging the exposure of the seed and young plants to pathogens. Deep seeding also results in additional energy being expended by the plant to reach the soil surface, weakening it and making it more vulnerable to attack by soil- or surface-borne pathogens. Poor germination and emergence can subsequently result in sparse stands in which competition by weed species further weakens the crop and reduces its yield and quality potential. When emergence is slowed or reduced, additional tiller development may occur, resulting in delayed and/or uneven maturity[22,23]. Seed treatment with a registered fungicide is another viable strategy to address potential early-season disease problems[2,5,24]. Treating seed assists plants in getting a good start even under less than optimal conditions, and promotes even stand establishment. Seed treatment is particularly appropriate under continuous barley production and/or if a more susceptible variety is grown.

Field experiments showed that seeding date may affect severity of scald in central Alberta. This research has led to the recommendation that early seeding of scald susceptible barley cultivars should be avoided in scald-infested fields. Scald susceptible cultivars may be seeded late for swath grazing to reduce the risk of scald development[25].

Crop residue management. Destruction of infested barley residues is often suggested as a means to eliminate potential sources of primary inoculum that initiate leaf spot epidemics. With the widespread adoption of conservation tillage practices, there are concerns that the practice of leaving more crop residue on the soil surface may increase the risk of barley leaf spot epidemics. Research from a number of trials in Canada and elsewhere have indicated that the adoption of conservation tillage has not led to a dramatic increase in barley leaf spot diseases and a negative impact on crop yields compared to conventional tillage[26,27,28,29,2,30]. Although, a United Kingdom study by Jordan and Allen[31] demonstrated a decrease in net blotch on winter barley under conventional ploughing compared to direct drilling (zero tillage), in western Canada the most common form of conventional tillage is the use of a heavy duty cultivator (chisel plough), while ploughing is less common[32]. In western Canada, typical conventional tillage practices leave between 50-80% residue cover after each tillage operation, depending on the tillage implement used (Anon. 2003), and these residues could still act as a significant source of pathogen inoculum. Although ploughing leaves behind a smaller amount of residue[33], subsequent tillage operations related to seedbed preparation could still bring infested crop residues to the soil surface. Overall, crop production factors such as environmental variation among individual fields, regions and years, crop rotation, seed-borne inoculum, and choice of cultivar (level of disease resistance) will likely have a larger impact on the risk of disease development compared with the type of tillage system that is used[34,35,36]. Although burning has also been advocated as a method of destroying sources of primary inoculum, recent research has indicated that the use of fire for barley leaf disease management is ineffective, while burning of residues can lead to reduced soil quality[37,38].

Crop Rotation. Diversification of crops in a rotation helps to break-up the life cycles of many disease-causing organisms. It also provides the opportunity for an overall rise in crop productivity and more effective management of insect and weed species. Cook and Veseth[39] indicate that "rotation allows time for natural enemies to destroy the pathogens of one crop while one or preferably two unrelated crops are grown". They also suggest that rotation acts as natural "soil fumigation", where the collective activity of "antibiotic, predatory, and competitive organisms" helps to eliminate plant pathogens from soil and infested crop residues. However, economic considerations tempt producers to restrict rotations.

Variety choice. Regardless of rotation and field location, producers should choose to grow varieties that have the best disease resistance package available, with the understanding that such varieties should also meet agronomic and marketing requirements. This information is included in the annually updated provincial Seed Guides; information in these guides indicates that disease resistance levels vary widely among registered varieties[40,41,42]. Weighing and prioritizing varietal attributes (grain yield, quality, maturity, disease performance, etc.) relevant to a particular situation is no easy task. Fortunately, barley breeding programs in western Canada are releasing ever-improved varieties that incorporate as many of the agronomic, quality, and disease attributes as possible.

Research in Alberta has shown that growing a different barley variety annually, even without rotation, can reduce foliar disease severity and improve yields[43]. This is particularly effective if the barley varieties originate from different breeding programs, as their genetics for disease resistance and other traits are more likely to differ. Growing the same variety each year provides the scald and net blotch pathogens, in particular, with a greater chance to adapt and overcome any resistance present, resulting in enhanced damage and reduced yield.

Fertility. Fertility is most often associated with overall crop productivity relating to yield and quality, but it can also impact disease severity[28,24]. A balanced fertility program will meet the macro- and micro-nutrient needs of the crop and promote healthy root systems and more vigorous growth. In contrast, a nutrient deficient crop will demonstrate slower, poorer growth. Optimal fertility may not guarantee that a disease will not develop, but a vigorous-growing crop will likely be better able to tolerate disease. In contrast, a nutrient-deficient crop is likely to be more vulnerable and suffer greater damage and loss.

Although balanced fertility is important, excessive fertilization (especially with nitrogen) will promote development of a lush, dense canopy with a micro-environment conducive to the development of foliar diseases. When the priority is to maximize yields via heavy fertilization, producers should select resistant varieties if available, and/or apply a registered foliar fungicide to counter the enhanced likelihood of disease.

Management considerations during the growing season

Resources - information, field scouting and disease control. A disease management tool that is often overlooked is the availability and utilization of information, targeted not only to producers, but also to the industry and research personnel. Effective disease management relies on accurate identification of diseases and their causal agents. Diseases have unique life cycles and developmental requirements, and may be best controlled by specific means. Producers should avail themselves of the information from their local agricultural office or provincial extension department, industry professionals, government or university researchers, or appropriate sites on the internet. In addition, various publications relating to plant diseases are available through bookstores, and professional societies. One useful publication that includes disease descriptions and colour images and relates to barley and other cereal and field crops is 'Diseases of Field Crops in Canada, 2nd Edition', published by the Canadian Phytopathological Society (CPS) and available at some university bookstores or directly from CPS at www.cps-scp.ca/publications.html. The American Phytopathological Society (APS) offers a large selection of publications related to plant diseases through their APS Press Bookstore at http://www.apsnet.org/apsstore/Pages/default.aspx. Both society websites offer links to other pathology-related sites. All provincial agricultural governments maintain internet sites that offer a wide variety of extension materials relating to plant diseases and their management - to read or download. In western Canada, these include the sites by Manitoba Agriculture, Food and Rural Initiatives, http://www.gov.mb.ca/agriculture/crops/diseases/index.html, Saskatchewan Ministry of Agriculture, http://www.agriculture.gov.sk.ca/Default.aspx?DN=65976d1a-8c66-4510-a96d-874a2b2b47a6, and Alberta Agriculture and Rural Development, http://www.agric.gov.ab.ca/app21/infopage?cat1=Diseases%2FInsects%2FPests&cat2=Crop Diseases.

Another management strategy that can be under-utilized is field scouting. Systematic inspection of a growing crop to assess its status is crucial to effective overall production management. This not only includes scouting for the presence of diseases, but also to check for populations of insects and weed species. This information is useful to help with scheduling of management practices in the current growing season, as well as in the development of a management plan for subsequent years. Field scouting will provide information on what diseases are present at key stages of crop development and what impact these might be having or are likely to have. This knowledge should form the basis for decision-making regarding fungicide application (or the application of insecticides and herbicides). Producers have the option of scouting by themselves or hiring a professional field scout. The latter can provide advice regarding a variety of disease and other management strategies. In general, scouting, if done effectively, should identify potential problems, and combined with readily-available weather information, be indicative of whether an in-crop application of fungicide is warranted.

Disease forecasting systems designed to assist in decision-making by producers regarding the use of fungicides are becoming more common. These are largely web-based and may be quite general in nature, or require that considerable detail, i.e. planting date, crop variety, inputs, etc., be inputted. These can be found on the provincial web-sites noted above, or as stand-alone entities. In western Canada, they have been developed for fusarium head blight of cereals (http://www.gov.mb.ca/agriculture/crops/fhb/index.html). None have been developed specifically for barley foliar diseases, but individual crop protection companies may have proprietary decision guides available to offer to producers. Life sciences/chemical company representatives and their retailers may also be a useful source of decision support information.

When the disease risk is high enough, fungicide application is warranted and can benefit barley producers. Usually, this input is most economical for seed growers and malting barley producers; it may not be an economic benefit for feed barley producers. Feed barley varieties have a somewhat better leaf disease resistance 'package', including resistance to scald, which no malting varieties currently possess and thus may exhibit a lesser response to fungicide application. However, the level of resistance varies among varieties. For example, resistance to netted net blotch is poor, while resistance to spotted net blotch is good, and scald resistance lacking in a number of feed varieties [40](Agriculture and Rural Development 2011). Provincial Seed Guides should be checked for this varietal information, which, when combined with effective scouting to identify the problem, will go a long way to assist in making a viable fungicide application decision. Research has demonstrated the usefulness of in-crop fungicides in reducing disease damage, increasing grain or silage yields, and maintaining quality when moderate to severe disease epidemics occur[12,13,44]. Proper timing of fungicide application is crucial if optimal control is to be achieved. Research has indicated that fungicide applications at the flag leaf stage (direct protection of the leaves in the upper barley canopy) is crucial to ensuring improved grain yield and kernel weights[45,46,47].

Conclusions

Clearly, implementing an effective, economic, and lasting barley leaf disease management strategy is not a simple issue. There are many factors for producers to consider, some risks, and a number of potential solutions. However, as outlined here there are a variety of resources available to assist in developing and implementing such a plan, which, when combined with good crop management, should result in a platform for sustainable barley production. The diversity and integration of approaches available, not only for management of diseases but also in consideration of insects and weed species, should provide for a flexible, responsive, and holistic crop management production system.

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