DIAGNOSING PLANT DISEASES

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1. Introduction

Each year farmers, crop scouts, industry agronomists, and chemical company representatives can be faced with the challenge of correctly diagnosing crop production problems. Producers typically want to know what is causing the observed poor crop performance, what can be done to alleviate it, and the potential impact. Crop production problems fall into two broad categories: biotic or abiotic factors. Biotic factors generally relate to stresses imposed on the crop by insects, weeds, diseases, or seed quality factors such as poor germination or vigour. In contrast, abiotic factors relate to stresses imposed by poor growing conditions, fertility issues, seedbed preparation and seeding concerns, and crop input injury issues. However, these categories are not mutually exclusive with abiotic stresses often increasing the susceptibility of plants to the effects of biotic factors such as plant diseases. The goal of this exercise is to provide two diagnostic scenarios to assist participants with the correct identification of disease issues affecting barley at the seedling stage and later during flag leaf emergence. The exercise will help participants to differentiate disease issues from other abiotic and biotic factors that may affect crop growth and to identify potential solutions.

2. Early season seedling scenario

2.1. Introduction

Plant disease concerns that occur early in the growing season can often be among the most difficult to diagnose. In general, at this stage of crop development the focus is typically on issues affecting seed germination, crop emergence, stand establishment, and general crop appearance. Plant diseases such as seed rots, damping off, and seedling blights are the main diseases that can be associated with early season issues. It is important to recognize that these common names may be used interchangeably and often

describe any symptom from seed decay to seedling death. It may be useful to think of early season disease issues in terms of the seedling disease complex, which consists of seed rot (various agents), damping off (Pythium spp.), seedling blight (Rhizoctonia solani and Fusarium spp.), and wirestem (Rhizoctonia solani). Symptoms caused by these diseases can be similar and it is very difficult to identify the causal agent in field, which necessitates the need for collecting plant samples and running them through a diagnostic laboratory.

Plant diseases that affect seed germination, seedling growth, emergence, and stand establishment may be confused with symptoms due to: insufficient soil moisture, excessive soil temperatures, or extended periods of cool/moist conditions, poor seedbed preparation, lack of effective seed-to-soil contact, nutrient deficiencies, seed row fertilizer injury, seed quality issues, and herbicide residues issues. In general, the seedling disease complex principally influences seed germination and early season plant development. Soon after planting seed death may result from the activities of pathogens such as the Pythium spp. However, seed death will often reflect other issues surrounding overall seed health and mechanical seed damage. The extent and rate of germination and seedling growth may also be compromised by the seedling disease complex. Pre-emergence damping-off results if the plant is killed prior to emergence, while post emergence damping-off occurs when the plant is killed shortly after emergence. If the plant survives through to the early seedling stage of development, the seedling disease complex can have an impact on root development, tillering, and leaf size. Should extensive necrosis (discolouration or rotting) of the seedling root system and plant base occur there can be stunting and discolouration (e.g. yellowing) of the above-ground parts of the plant and ultimately plant death when disease severity is high.

Ultimately the end result of early season plant disease development is the production of a poor stand that is unthrifty and non-uniform. A poor start to the growing season can then set the stage for other problems in terms of lack of effective weed management due to an uncompetitive crop stand. Uneven crop growth and second crop flushes can delay crop maturity as well as leading to complications associated with time of swathing and harvest. For some diseases such as the cereal smuts, net and spot blotch in barley and ascochyta in chickpeas, pathogen-infected seed can act as a source of disease for further disease development during the course of the growing season.

3. Mid season cereal leaf disease scenario

3.1. Introduction

Crop production issues that appear during the middle of the season can be relatively easy to diagnose. Typically these issues will affect the plant's ability to photosynthesize or its ability to absorb water and nutrients. For diseases that mainly affect the crop canopy, timely scouting will be critical as a correct diagnosis can be used to limit their impact by scheduling an in-crop fungicide application. For some issues there may be little that can be done in-crop, but the information obtained from accurate diagnosis of the issue can be used to estimate potential yield loss for some diseases and to plan for the next growing season. For example, extensive cereal leaf disease development on the upper leaves of a cereal canopy will greatly diminish the potential benefit of fungicide application; however, this information can be used to estimate potential yield loss and to plan for the next growing season. Options such as incorporating crop rotation and choosing a cereal variety with disease resistance can be considered for the next growing season. Accurate diagnosis can also be used to identify or rule out product performance or non-disease issues that may be related to fertility problems, herbicide residues, and poor growing conditions.

3.2. Assessing barley leaf disease risk

Field scouting in early to mid June will be crucial to identify any emerging leaf disease problems. Although fungicide application is not recommended at this stage the appearance of symptoms serves to illustrate the potential for leaf disease development and the need for continued field scouting. There may be a tendency to trivialize the occurrence of a small amount of leaf disease observed during weed scouting activities in June. However, barley leaf spot diseases are polycyclic in nature and as a consequence have the potential to build up to damaging levels in relatively short periods of time. Under favourable conditions, the causal agents of these diseases can complete and repeat their life cycles every 7–14 days depending on the particular pathogen and prevailing weather conditions. Even a very small amount of disease observed in June could develop into a problem, especially when a highly susceptible variety is grown, and there is potential for favourable weather conditions to promote rapid disease development during the growing season.

As mentioned previously, field scouting will be crucial to identify any emerging problems. However, confusion between true disease symptoms and leaf discolouration due to nitrogen deficiencies, heat/moisture stress, etc. can lead to unnecessary fungicide application. Producers are encouraged to review the new third edition of "Diseases of Field Crops in Canada", which is a publication from the Canadian Phytopathological Society and can be ordered via their website (http://www.cps-scp.ca/publications.htm). This publication as well as other information from provincial and industry sources will help producers, crop scouts and industry agronomists to correctly identify disease problems during the growing season. Internet search engines such as GOOGLE

(http://www.google.ca/) can also be used to search for a wide array of websites related to plant diseases and their management.

In general, the risk of leaf disease in barley increases with frequent showers, high relative humidity, and/or heavy dews when growing a susceptible variety with a high yield potential. In barley, fungicide application tends to be most economical for seed growers and malt barley producers. Most feed barley varieties tend to have better leaf disease resistance packages, and as a consequence their response to fungicide may be limited compared with more susceptible varieties. Protection of the upper leaves, especially the two leaves immediately below the barley head will be important when a foliar fungicide is applied for disease management. Keep in mind that fungicide application is mainly effective at preventing the pathogen from infecting the host plant. If extensive development of leaf disease has already occurred on the upper leaves of the canopy (>10–20% of the area of the flag leaf and penultimate leaf affected), the ability of fungicides to eradicate well-established infections is limited at best.

Assessment of the prevalence and severity of leaf disease is very important as the crop is coming into the flag leaf stage. The appearance of moderate levels of disease on leaves in the lower and middle parts of the barley canopy will indicate a potential risk for infection of the upper canopy leaves, which are important for yield and grain filling. If scouting at the flag leaf emergence stage indicates the presence of moderate leaf disease levels in the lower and middle canopy of a susceptible variety coupled with the occurrence of favourable weather conditions, fungicide application to protect upper canopy leaves may be warranted. However, it will be important to also consider the potential cost and benefit of fungicide application as part of any spray decision.

4. Characteristics of early season barley seedling disease issues and mid season leaf disease symptoms versus abiotic and other biotic issues

Table 1. Characteristics of early season barley seedling disease issues and mid season leaf disease symptoms.

Characteristic	*Seedling disease complex/leaf diseases*
Typical seedling symptoms	**Seed rots** - Softening, brownish to blackish discolouration, and/or disintegration of the seed, generally before germination **Damping off** - Destruction of seedlings close to soil surface - Results in rapid lethal decline before or shortly after emergence - Sudden wilting and death of seedling - Sudden collapse and death before or after emergence - Seedlings typically fail to emerge or die shortly after emergence **Seedling blight** - General and rapid killing of the plant or plant parts - Early infection before or just after emergence - Small brown or reddish-brown spots or blotches on developing root and shoot (hypocotyl) tissues - Spots enlarge as the season progresses with further spread to the base of stems and to root tissues **Wirestem** - Typically found with other crops, e.g. canola - Symptoms first appear water-soaked - Develop into sunken reddish-brown lesions - Infections typically remain firm and "dry" - More of a "pinching off" along the hypocotyls - May extend up to the cotyledons and down to the roots General seedling blight damage - is confined to the host crop, although closely related crop and weed species may be affected by the same pathogens (e.g. *Pythium*, *Rhizoctonia* spp., *Fusarium* spp.)
Typical leaf symptoms	**Scald** - Typical infections first appear as water-soaked areas, which initially have a grayish-green appearance and are oval in shape - As the affected areas mature, typical lesions are oval in shape with a tan- or light gray-colored interior surrounded by a brownish margin

Characteristic	*Seedling disease complex/leaf diseases*
	- Under conducive conditions individual lesions will grow together and can eventually destroy an entire leaf **Net blotch** - There are two forms of net blotch commonly found in western Canada, which can be separated based on symptoms - Initial symptoms of both forms of net blotch are similar, i.e. small spots or lesions first appear on host tissues - Small circular or oval lesions of the "net-form" of net blotch will eventually expand into long narrow lesions that develop along leaf veins with interconnections between the narrow lesions producing a netted appearance - In comparison, lesions of the "spot-form" of net blotch do not elongate and remain as small oval brownish lesions on leaves and other plant tissues - Both forms of net blotch can be found in Alberta with the "net-form" being more common than the "spot-form" **Spot blotch** - Initial infection by the spot blotch fungus results in small brownish spots on leaf blades and sheaths - As these spots or lesions enlarge they are typically oval in shape, brown to dark brown in colour with distinct margins - Individual lesions may be up to 1.0 cm in length - Small brown to dark brown spots and discolouration may be observed on head tissues and individual seeds - Although they are similar in colour, spot blotch lesions do not have the typical long, narrow appearance of the "net-form" of net blotch lesions - However, spot blotch may be confused with the "spot-form" of net blotch, which is characterized by small circular to oval, dark brown spots **General symptoms** - Chlorosis or yellowing of the leaf may occur around individual lesions - Leaf diseases typically do not result in yellowing, bronzing, or premature ripening of the entire leaf - However, more extensive yellowing/bronzing/premature ripening may occur with very severe leaf disease symptoms
Nature of affected areas or plant tissues	**There is a typical progression of symptoms** - Initial symptom development may be limited, but as the pathogen population increases and/or the severity of disease increases, symptoms become more severe and there is transfer from older to younger tissues

Characteristic	*Seedling disease complex/leaf diseases*
	Gradual spreading of affected areas - Mainly for above-ground diseases and their symptoms - The transition from diseased to healthy areas of the field may be less clearly defined
Causal agents	**For some diseases there may be signs of pathogen growth and development** - e.g. fungal hyphae, bacterial ooze, specialized fruiting or resting structures
Pattern of symptoms in the field	**Symptoms due to plant diseases tend to exhibit a random pattern in the field** - However, caution should be used as some diseases (e.g. root rots or seedling blight) may be associated with low spots or areas of field where fertility issues occur - For some diseases, symptoms may be more prevalent around field edges resulting from pathogens moving in from adjacent fields or headlands, or due to an influence on crop growth and canopy microclimate resulting from snow banks, and/or shelter from trees around field margins - A uniform distribution of disease across an individual field may indicate a seed-borne disease or where there is a well-established residue-borne disease or diseases, such as rust, which originate from outside the field - Distinct strips or patterns of increased disease damage may be associated with fungicide application equipment problems - Low spots or areas of the field may show more damage due to better moisture conditions combined with denser crop canopies

Table 2. Characteristics of early season and mid season abiotic and other biotic issues.

Characteristic	*Abiotic factors*	*Other biotic issues (mainly insects)*
Typical seedling symptoms	**Large range of symptoms** - Typically do not include the discolouration as described for seed rots, damping off, seedling blight or wire stem - Although initial symptoms may show no discolouration, eventual secondary invasion (after 2-4 weeks) by	**Insects** - Signs of damage due to chewing, piercing, scraping or tunnelling - Secondary invasion by saprophytic organisms (fungi, bacteria) may cause brownish or blackish discolouration **Seed damage, poor quality seed** - Mechanical damage of seed or poor germination/vigour may prevent seed germination or result in reduced seedling growth

Characteristic	*Abiotic factors*	*Other biotic issues (mainly insects)*
	saprophytic organisms may cause blackish or brownish discolouration - Note that frost damage may cause blackish discolouration - Pinching off of stem at or near the soil surface may be caused by other factors: - High winds - Heat canker - Frost canker - Dry soil conditions - Damage is not necessarily restricted to the host crop	- Initial symptoms (yellowing and premature ripening) may show no discolouration, but eventual (after 1-2 weeks) secondary invasion by saprophytic organisms may cause blackish or brownish discolouration - Damage is mainly restricted to the host crop or preferred range of host species
Typical leaf symptoms	**Large range of symptoms** - Typically do not include the discolouration as described for scald, net blotch, or spot blotch - General leaf yellowing or bronzing and plant stunting may occur due to a variety of abiotic issues - Eventual secondary invasion (after 1-2 weeks), especially of prematurely ripened or senesced plant tissues by saprophytic organisms may cause blackish or brownish discolouration - Damage is not necessarily restricted to the host crop	**Insects** - Signs of damage due to chewing, piercing, scraping or tunnelling - May be localized yellowing or premature ripening associated with the insect damage - Eventual secondary invasion (after 1-2 weeks) of insect-damaged tissues by saprophytic organisms may cause blackish or brownish discolouration

Characteristic	*Abiotic factors*	*Other biotic issues (mainly insects)*
Nature of affected areas or plant tissues	**Symptoms may appear suddenly and typically there is no progression of symptoms** - Severity and distribution of symptoms remains constant (i.e. not spreading), suggesting abiotic issues (non-living factors) - Typically there is a clear delineation between healthy and affected areas of the field - No transmission from affected to unaffected tissues	**There is a typical progression of symptoms** - Initial symptom development may be limited, but as insect populations and feeding activity increases, symptoms become more severe **Gradual spreading of affected areas** - Mainly for above-ground insects and the symptom they induce, but slow spread may be associated with soil-borne insect pests
Causal agents	**Typically it is not possible to directly observe an abiotic agent** - In direct evidence can be obtained from field activity records, weather records, knowledge of field topography, old home or well sites, previous chemical spills, herbicide application history, herbicide bioassay, soil test results, knowledge of soil characteristics	**Various developmental stages of insect pests may be present, including overwintering structures** - Waste products (frass, honeydew, etc.) may be produced by some insect pests
Pattern of symptoms in the field	**Uniform patterns in the field or patterns associated with field topography or other field/soil characteristics** - Areas of poor plant development and plant tissue discolouration/	**Symptoms due to insect pests tend to exhibit a random pattern in the field** - However, caution should be used as some insect pests that are soil-borne pests or have limited mobility may be show distinct areas of damage or may be associated with knolls, low spots or other field

Characteristic	*Abiotic factors*	*Other biotic issues (mainly insects)*
	senescence may be associated with water runs/drainage patterns, low spots, areas with fertility issues, poor soil quality, seed-to-soil contact issues, etc. - Symptoms may exhibit distinct patterns or strips associated with machinery malfunctions, spray injury, soil issues associated with previous chemical spills or old well, farm, or access sites	characteristics - For some insects, symptoms of damage may be more prevalent around edges due to insects moving in from adjacent fields, headlands, or other overwintering sites - A uniform distribution of insect damage across an individual field may indicate a highly mobile insect pest that has moved in from outside the field over short or long distances - Distinct strips or patterns of increased insect damage may be associated with insecticide application problems due to equipment malfunctions, etc.

Further Information

It is beyond the scope of the present paper to cover all potential issues that may affect your crop during the early and mid season development stages. We have tried to highlight some general concepts and recommendations regarding the diagnosis of plant diseases and differentiating these from other issues that may affect the crop during the growing season. In addition, to this paper there is a wide selection of information available from various sources including extension staff, industry representatives, diagnostic laboratory personnel, and even your friendly neighbourhood plant pathologist. Some of the following websites may also be useful in terms of field scouting and the diagnosis of plant disease problems:

Canadian Phytopathological Society - http://www.cps-scp.sca/index.html

American Phytopathological Society - http://www.apsnet.org

http://www.apsnet.org/education/IntroPlantPath/Topics/plantdisease/top.htm

http://scarab.msu.montana.edu/Diagnostics/

http://www.agf.gov.bc.ca/cropprot/sample_tips.htm

http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/prm2365?opendocument

http://www.gov.mb.ca/agriculture/crops/cropproduction/gaa01d02.html

http://www.omafra.gov.on.ca/english/crops/pub811/1fscout.htm

http://www.cahe.nmsu.edu/pubs/_h/h-158.html

http://muextension.missouri.edu/explore/agguides/crops/g04050.htm