Cereal rust risk: “The answer, my friend, is blowin’ in the wind”* (*“Blowin’ in the Wind”, from the album “The Freewheelin’ Bob Dylan” by Bob Dylan)

An introduction to cereal rust risk and wind trajectories from the USA

Prairie Crop Disease Monitoring Network

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Disclaimer

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Summary

Cereal rusts present a unique challenge for Western Canadian cereal producers. In contrast to cereal leaf spot diseases and fusarium head blight, most cereal rusts do not typically overwinter in Western Canada. As a consequence crop rotation and volunteer control in subsequent crops are not as relevant. In general, rusts of wheat, barley and oat will survive on cereal and grass hosts in the southern USA and northern Mexico, although stripe and stem rust can also survive in the Pacific Northwest (PNW) and California. Urediniospores are blown northward by wind currents, affecting successive northerly winter and spring cereal crops. Depending on availability, a resistant variety can be grown and this decision can be made the previous fall or winter. However, growing susceptible varieties requires routine crop scouting and timely fungicide spray decisions, which can be difficult during a busy growing season. Agriculture and Agri-Food Canada (AAFC) and Environment and Climate Change Canada (ECCC) have been working together to study the potential of trajectories for monitoring insect movements since the late 1990s. Trajectory models are used to deliver an early-warning system for the origin and destination of migratory invasive species, such as diamondback moth. In addition, plant pathologists have shown that trajectories can assist with the prediction of plant disease risks and are utilizing these same data. An introduction will be presented regarding efforts to identify wind trajectory events that may bring rust urediniospores into Western Canada from epidemic areas in the central and PNW regions of the USA. Identification of potential wind trajectory events as well as an assessment of epidemic severities for source locations and prairie weather conditions, are used to assess the need for prompt targeted crop scouting for at-risk regions of the Canadian Prairies.

Introduction

Cereal rusts represent a unique challenge for Western Canadian cereal producers. In contrast to cereal leaf spot diseases and fusarium head blight, most cereal rusts do not typically overwinter in Western Canada. Thus, crop rotation does not reduce the risk of rust outbreaks and as a consequence effective management of cereal rusts depends on either growing resistant varieties (if available) or timely application of in-crop fungicide application for susceptible varieties. The choice of which variety to grow is a relatively easy decision, and can be made during the previous fall and winter. However, the decision to spray a fungicide can be difficult to make, especially during a busy growing season. Whether to spray a fungicide will depend on the when disease appears in the crop and its level, weather conditions, the variety being grown, crop yield potential, and commodity price. The ultimate goal of using a foliar fungicide is to protect green leaf area in the upper cereal canopy since these leaves contribute most to yield and grain filling.

Routine scouting will be a key strategy to determine whether there is a risk of rust in any individual crop and if fungicide is needed to protect upper cereal canopy leaves. When considering a fungicide application for cereal rust management it is critical to know when and where to start scouting for initial signs of rust.

Agriculture and Agri-Food Canada (AAFC) and Environment and Climate Change Canada (ECCC) have been working together to study the potential of trajectories for monitoring insect movements since the late 1990s. Trajectory models are used to deliver an early-warning system for the origin and destination of migratory invasive species, such as diamondback moth. In addition, plant pathologists have shown that trajectories can assist with the prediction of plant disease infestations and are utilizing these same data. AAFC receives two types of model output from ECCC: reverse trajectories and forward trajectories. Given the importance of long distance transport of cereal rust spores via wind currents from the USA, the Prairie Crop Disease Monitoring Network is identifying wind trajectory events that can bring rust spores into Western Canada from epidemic areas in the south central USA and the PNW.

Source, dispersal and risk of cereal rusts

In general, cereal rusts, especially for wheat, barley and oat will overwinter on cereal and grass hosts in the southern USA and northern Mexico, although stripe and stem rust can also overwinter in the Pacific Northwest (PNW) and California (Bailey et al. 2003; Chen 2005; Menzies and Gilbert 2003; Prairie Oat Growers Association 2020; Saskatchewan Ministry of Agriculture 2023; Simons 1985; Upadhaya et al. 2022; Wiese 1987; Xi et al. 2015). Rust spores (also known as urediniospores) are blown northward by wind currents, affecting successive northerly winter and spring cereal crops (Agrios 1988; Chen 2005; Menzies and Gilbert 2003). In the Prairie region, rust spores will typically arrive in mid to late June. Several scientific reviews provide more detail on long distance transport of cereal rust fungi and other plant pathogens (Aylor 1990, 2003; Brown and Hovmøller 2002; Chen 2005; Eversmeyer and Kramer 2000; Nagarajan and Singh 1990).

Spread of cereal rusts into Western Canada from locations in the USA will depend on the following factors:

- Disease severity and pathotypes at the point of origin
- Release and turbulent transfer of spores into upper atmosphere air parcels
- Movement and direction of air parcels
- Spore survival during long distance transport
- Deposition of spores over at-risk locations in Western Canada
- Crop growth stage for at-risk locations
- Prevailing weather conditions for at-risk locations

Rust spore liberation from symptoms on infected cereal leaves is favoured by increased wind speeds and sudden wind gusts, while vertical movement into upper air parcels is favoured by convective wind currents resulting from surface heating and cooling during the 24 hour night/day cycle (Aylor 1990; Nagarajan and Singh 1990). Burleigh et al. (1967) found that the aerial concentration of rust spores increased when disease levels were increased in wheat crops below the collection points. Cereal rust spores can be found at altitudes of up to 3000 m and may travel several hundred kilometres before being deposited (Eversmeyer et al. 1984; Stakman 1923, 1934; Stakman and Christensen 1946). Deposition of cereal rust spores over at-risk locations appears to primarily result from the "scrubbing action" of rainfall, where even light precipitation events may remove spores from the air (Nagarajan and Singh 1990; Rowell and Romig 1966). Successful infection of Prairie cereal crops and potential impact are then influenced by local weather conditions, host resistance, and crop growth stage (Chen 2005; Eversmeyer and Kramer 2000; Menzies and Gilbert 2003; Wiese 1987; Xi et al. 2015).

One confounding issue when assessing the risk of stripe rust is that the pathogen that causes this disease may also potentially overwinter in the Western Prairie region on winter wheat, especially during mild winters (Aboukhaddour and Amundsen 2018; Conner et al. 1988; Kumar et al. 2013; Xi et al. 2006, 2015). Traditionally, inoculum of *Puccinia striiformis* infecting crops in Alberta has been thought to originate from cereal fields in the Pacific Northwest (Oregon, Washington and NW Idaho) (Chen 2005). However, Conner et al. (1988) observed that overwintering of *P. striiformis* in winter wheat in southern Alberta resulted in stripe rust epidemics on soft white spring wheat. Increased winter warming in Canada may contribute to higher over-wintering survival of insect pests and cereal rusts in the Prairie region, which may elevate the impact of these pest issues (Chen 2005; Conner et al. 1988; Kumar et al. 2013; Olfert et al. 2016b; Xi et al. 2015). Warmer, longer growing seasons may impact reproduction, phenology, and rates of herbivory (insect consumption of plants) (Bale et al. 2002; Olfert et al. 2017). Furthermore, climate change impacts were shown to impact biological control agents (Olfert et al. 2016a). Cold winter temperatures typically kill the stripe rust pathogen in infected winter wheat tissues. However, with milder winters the stripe rust pathogen may readily overwinter as dormant mycelia in infected winter wheat plants, leading to early epidemic development from local overwintering sources of inoculum (Kumar et al. 2013; Xi et al. 2015). Moreover, spring wheat may be at a much greater risk of stripe rust, where rust overwinters and builds on winter wheat crops before moving to adjacent spring wheat fields. Research at Lacombe, AB suggests that planting spring wheat close to winter wheat may increase the risk of stripe rust, where the rust builds on the winter wheat before moving to the adjacent spring wheat fields (Xi et al. 2012). In addition, planting winter wheat close to spring wheat fields where significant stripe rust is present may increase late summer to early fall exposure of winter wheat to stripe rust inoculum. Each spring and fall plant pathologists from Lacombe, Alberta (Sajid Rehman, and formerly Kequan Xi and Krishan Kumar); Lethbridge, Alberta (Reem Aboukhaddour); and Brooks, Alberta (Mike Harding) monitor winter wheat crops for fall development of stripe rust followed by overwintering and early spring disease development.

Trajectories based on forecast and diagnostic wind fields

The 3D trajectory model (D'Amours and Pagé 2001) has been used to forecast potential movement of diamondback moth into western Canada (Braun et al. 2002; Dosdall et al. 2001; Hopkinson 1999). Currently, air parcel trajectories are being constructed from wind fields at discrete intervals and solved numerically to identify potential wind trajectory events that may carry rust spores from epidemic areas in the USA. The trajectories utilise wind fields of the

Global Environmental Multiscale model, which have a horizontal resolution of 33 km and 58 vertical levels over North America. The model is being run at three levels corresponding to starting points (forward – prognostic trajectories) or end points (backward – diagnostic trajectories) at approximately 500 m, 1500 m, and 2500 m above ground level and follow parcels of air on curves denoting their successive positions in time. The forward trajectories are prognostic based on forecast wind fields while the backward trajectories are diagnostic and based on analyzed wind fields. By following trajectories for air parcels through time, potential wind events that may carry rust spores from source areas in the USA can be identified.

Reverse trajectories are the focus of the current cereal rust/wind trajectory updates. Backward trajectories follow a five-day time frame backward in time for air parcels moving over at-risk locations in Western Canada. Backward trajectories forecast where air parcels have come from. Locations for backward trajectories and the disease issues of concern are summarized in Table 1 and Figure 1. Backward trajectory events that passed over specific areas in the USA including the PNW, the Texas/Oklahoma region, and the Kansas/Nebraska region were the focus. Stripe rust would be the main rust issue affecting cereal crops in the PNW, while stem rust, leaf rust and stripe rust can affect crops in the Texas to Nebraska corridor (Table 1, Figure 1). In general, as the number of wind events increases the risk of rust spores being transported into the Prairie region increases.

The PNW region, an important source area where air parcels can pass over, has a significant proportion of wheat production and is where stripe rust epidemics occur (https://www.wheatworld.org/wheat-101/wheat-production-map/, https://ipad.fas.usda.gov/rssiws/al/crop_production_maps/us/USA_Wheat_Winter_Lev2_Prod_2012_2017.jpg, https://www.nass.usda.gov/Charts_and_Maps/Crops_County/ww-yi.php). Recently, there have been increasing concerns regarding stem rust, especially on barley, in this region (Upadhaya et al. 2022). Air parcels from the PNW can typically arrive into southern Alberta within a day, while for other regions from the central to western Prairies, parcels may take 2-3 days depending on location.

The corridor from Texas up through Oklahoma and into Kansas/Nebraska (including eastern Colorado) is an important source of leaf, stem and stripe rust inoculum for Prairie cereal producers, especially for the central to eastern Prairie region. The origin of wind trajectory events from Texas north to Nebraska includes regions that have a significant proportion of wheat production and where epidemics of stem rust, leaf rust and stripe rust occur. This region may also represent a source of oat crown rust. Average travel time for air parcels from the Texas to Nebraska region into Western Canada typically ranges from 2-4 days, although some events can reach at-risk locations in as little as one day.

Information on cereal rusts and on the use of fungicides for management of cereal rusts can be found at the following websites:

https://www.ars.usda.gov/midwest-area/stpaul/cereal-disease-lab/docs/cereal-rusts/cereal-rusts/

http://smallgrains.wsu.edu/disease-resources/foliar-fungal-diseases/stripe-rust/

https://smallgrains.wsu.edu/disease-resources/foliar-fungal-diseases/stem-rust/

http://hill.msuextension.org/documents/StripeRustFallarticleHillCounty.pdf

http://www.gov.mb.ca/agriculture/crops/plant-diseases/index.html (navigate to links for the various cereal rusts)

https://www.gov.mb.ca/agriculture/crops/plant-diseases/stripe-rust-puccina-pathway.html

Stripe rust 101 : what is it, why do we have it, what can be done about it - Open Government (alberta.ca)

Identifying and managing stripe rust - Alberta Grains

Prairie Cereal Rust Risk Levels - Manitoba Crop Alliance (mbcropalliance.ca)

https://cropprotectionnetwork.org/publications/an-overview-of-stripe-rust-of-wheat

https://cropprotectionnetwork.org/encyclopedia/leaf-rust-of-wheat

https://cropprotectionnetwork.org/encyclopedia/stem-rust-of-wheat

https://prairiecca.ca/articles/volume-4-10-screen.pdf

https://www.gov.mb.ca/agriculture/crops/guides-and-publications/pubs/guide-crop-protection-2024.pdf

Guide to Crop Protection | Crop Guides and Publications | Government of Saskatchewan

https://www.albertabluebook.com/

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Table 1. Locations for reverse (diagnostic) trajectory events, Western Canada, 2022.

Reverse trajectory location	Prov.	Pest issue*
ANDREW	AB	Stripe rust
BEISEKER	AB	Stripe rust
CALGARY	AB	Stripe rust
EDMONTON	AB	Stripe rust
FORT VERMILLION	AB	**, stripe rust
GRANDE PRAIRIE	AB	**, stripe rust
LACOMBE	AB	Stripe rust
LETHBRIDGE	AB	Stripe rust
MANNING	AB	**, stripe rust
MEDICINE HAT	AB	Stripe rust
OLDS	AB	Stripe rust
PROVOST	AB	Stripe rust
RYCROFT	AB	**, stripe rust
SEDGEWICK	AB	Stripe rust
VEGREVILLE	AB	Stripe rust
VULCAN	AB	Stripe rust
WANHAM	AB	**, stripe rust
FORT ST. JOHN	BC	Stripe rust
ARBORG	MB	Stem rust, leaf rust, stripe rust
BRANDON	MB	Stem rust, leaf rust, stripe rust
CARMAN	MB	Stem rust, leaf rust, stripe rust
DAUPHIN	MB	Stem rust, leaf rust, stripe rust
PORTAGE	MB	Stem rust, leaf rust, stripe rust
RUSSELL	MB	Stem rust, leaf rust, stripe rust
SELKIRK	MB	Stem rust, leaf rust, stripe rust
SWAN RIVER	MB	Stem rust, leaf rust, stripe rust
GAINSBOROUGH	SK	Stem rust, leaf rust, stripe rust
GRENFELL	SK	Stem rust, leaf rust, stripe rust
KINDERSLEY	SK	Stripe rust
MOOSE JAW	SK	Stem rust, leaf rust, stripe rust
NAICAM	SK	Stem rust, leaf rust, stripe rust
NORTH BATTLEFORD	SK	Stripe rust
REGINA	SK	Stem rust, leaf rust, stripe rust
SASKATOON	SK	Stem rust, leaf rust, stripe rust
SWIFT CURRENT	SK	Stripe rust
TISDALE	SK	Stem rust, leaf rust, stripe rust
UNITY	SK	Stripe rust
WATROUS	SK	Stem rust, leaf rust, stripe rust
WEYBURN	SK	Stem rust, leaf rust, stripe rust
YORKTON	SK	Stem rust, leaf rust, stripe rust

*Specified pest issue(s) reflect the relative importance of particular disease issues for the reverse and forward trajectory locations. Some locations were chosen based insect pest concerns, especially diamond back moth. Note increasing stem rust issues in the PNW especially on barley may represent a threat to Western Prairie regions.

** Primarily chosen based on insect concerns, but there is a risk of stripe rust.

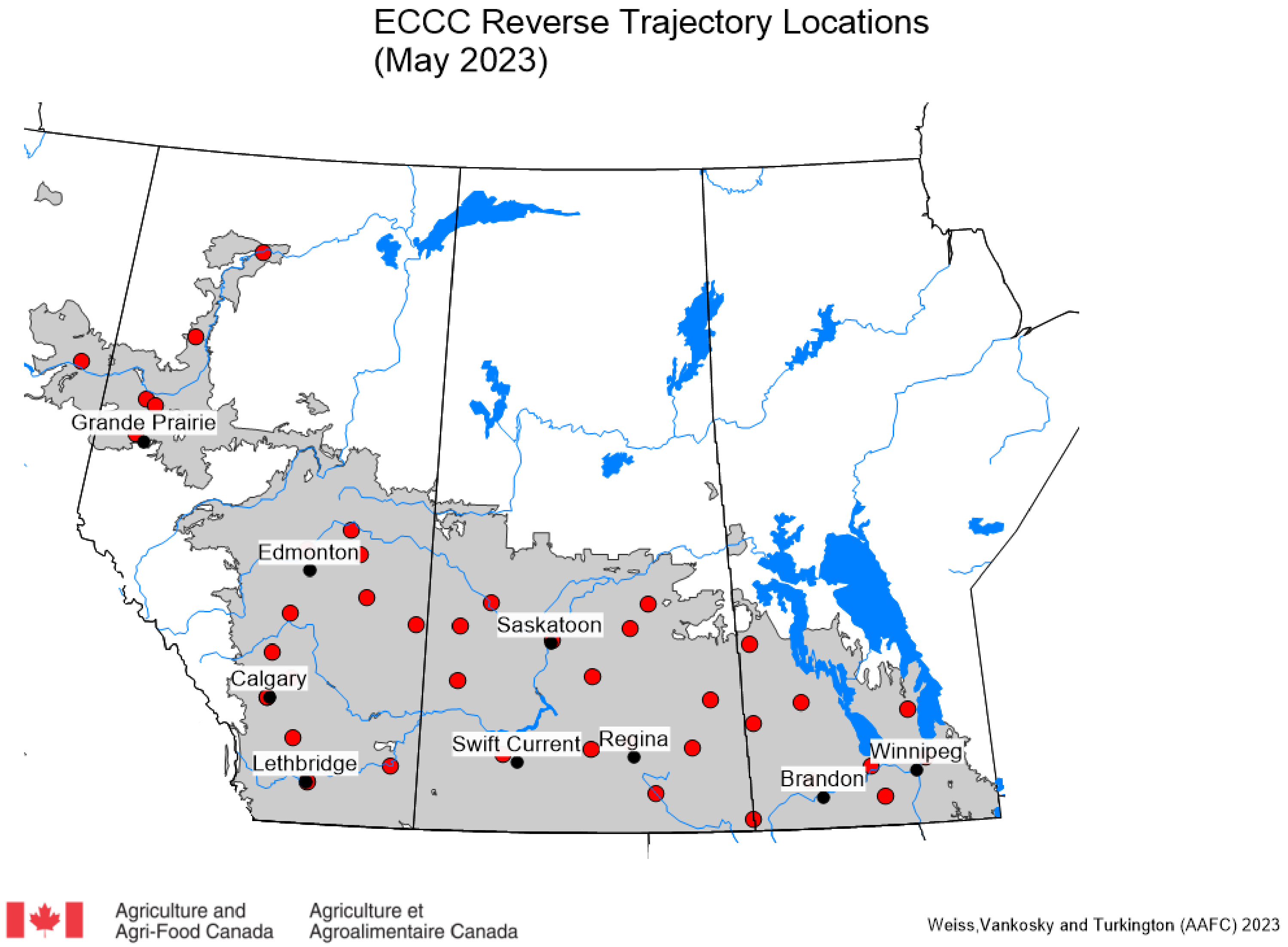

Figure 1. Locations for backward (diagnostic) trajectory events, Western Canada, 2024.