Predictive Accuracy of a Fusarium Head Blight Epidemic Risk Forecasting System Deployed in Minnesota

Charla R. Hollingsworth, Assistant Professor, Northwest Research & Outreach Center and Department of Plant Pathology, University of Minnesota, Crookston 56716; John J. Mewes, Chief Scientist, Meridian Environmental Technology, Inc., Grand Forks, ND 58203; Christopher D. Motteberg, Research Assistant, and W. Galen Thompson, Research Fellow, Northwest Research & Outreach Center, University of Minnesota, Crookston 56716

Corresponding author: Charla R. Hollingsworth. holli030@umn.edu


Abstract

Minnesota small grains production sustained an estimated $1.8 billion in crop losses from Fusarium head blight (FHB) between 1993 and 2001. Crop losses continue to increase with another $86 million added during 2005. A forecasting model, designed to predict the risk that FHB epidemics may or may not occur, is deployed statewide. Users of the online system are made aware when local weather conditions promote or reduce the likelihood that a FHB epidemic will occur. The model serves as a decision-making tool prior to fungicide application. During 2004-2005, disease index data were collected from a total of 8 experiment sites and 5 spring wheat cultivars. In 2004, index means were low, ranging from 0.8% to 6.8%. However, the system predicted low and high risks for FHB epidemics. During 2005, index means ranged from 2.6% to 13.9%. Epidemic risk predictions were estimated as low and moderate. The system predicted non-epidemics with 60% and 66% accuracies in 2004 and 2005, respectively. Epidemics were predicted 50% of the time during 2005. Increased predictive accuracy is expected during 2006 as information on spring wheat cultivar resistance levels have been added to the model.

Introduction

Fusarium head blight (FHB) of small grains [caused by Fusarium graminearum Schwabe, teleomorph Gibberella zeae (Schwein.) Petch] has been a sporadic production issue in the US since it was reported during the 1890s in Delaware, Indiana, Iowa, Nebraska, Ohio, and Pennsylvania (6). Immediately after the turn of the 20th Century, crop losses caused by FHB were documented in Europe, Japan, and 31 grain-producing states in the US (6). More recently, crops in the upper Midwest have been particularly hard hit. Since the early 1990s, hard red spring wheat and spring barley yield and quality losses have been common in Minnesota.

Researchers describe the recent FHB-related crop losses and economic instabilities in the agricultural sector in depth (4). Direct losses are borne primarily by growers, while indirect losses occur when growers spend less money in their local communities and elsewhere (5). Between 1993 and 2001, FHB caused an estimated $1.8 billion in direct and indirect losses in Minnesota (5). During 2005 alone, losses in hard red spring wheat are estimated at $86 million. Moreover, the economic viability of small grains production remains uncertain in an area of the US historically known for producing quality spring wheat and barley.

Until recently, disease management strategies consisted of growing a spring wheat cultivar with resistance, crop rotation, residue management, and fungicide application. A newly-developed tool, funded primarily by the US Wheat and Barley Scab Initiative, has been added to the disease management...
toolbox. During the 1990s, a cooperative multi-state effort among land grant university researchers from Indiana, Kansas, Missouri, North Dakota, Ohio, Pennsylvania, and South Dakota (1) produced models designed to predict the risk that FHB epidemics may, or may not occur. Currently, researchers from these 7 states and others share weather data, crop growth stage information, and FHB disease ratings from replicated experiments with researchers at Pennsylvania State University to further hone the accuracy of FHB risk predictions. The FHB risk forecasting system is used as a decision-making tool prior to fungicide application. Producers access the information in advance of seeing FHB symptoms to determine whether costs associated with additional inputs (e.g., fungicide and application) are warranted to minimize disease-related crop losses.

FHB Epidemic Risk Forecasting System

The epidemic risk forecasting model was deployed online for the first time in Minnesota immediately prior to the 2004 growing season. Simple categorical risk designations (e.g., low, moderate, high) allow producers to manage their crops based on their own production style and personal aversion to risk. Epidemic risk predictions are the result of weather data inputs. Observed, hourly weather data collected during the 7-day interval before flowering (Feekes 10.51 growth stage) are used to estimate the risk that a FHB epidemic will occur. Weather information used by the model includes hourly relative humidity, hours that air temperatures range from 9° to 30°C, and hours of rainfall exceeding 0.03 cm. The deployed model was modified between the 2004 and 2005 growing seasons (2). Changes included the addition of an interaction term high relative humidity (e.g., > 90%) and air temperatures favorable (e.g., 9° to 30°C) for FHB development. Maximum FHB risk prediction limits were incorporated into the 2005 model to prevent overestimation of disease during prolonged wet periods (Erick De Wolf, personal communication).

The epidemic risk forecasting model estimates the risk that an epidemic will occur greater than or equal to a 10% disease index (a.k.a., field severity) damage threshold (3). Disease index is calculated by multiplying mean FHB severity (mean percent symptomatic spikelets per spike) by mean FHB incidence (mean percent heads with blight) and dividing the product by 100. Disease index quantifies how widespread and severe FHB is within a field and establishes a baseline economic damage threshold.

During 2004, the epidemic risk forecasting system assigned a low risk when the calculated prediction was ≤ 40%, a moderate risk when 41% through 47%, and a high risk when > 48%. During 2005, risk categories were changed to ≤ 46% for a low risk, 46% through 64% for a moderate risk, and > 64% for a high risk of a FHB epidemic. The model is estimated to accurately predict FHB epidemics and non-epidemics at about 80% of the time (2).

Deployment of the FHB Epidemic Risk Forecasting Model in Minnesota

The FHB epidemic risk prediction model is deployed online at mawg.cropdisease.com and is available for use without fee. The website is maintained by a private company, Meridian Environmental Technology, Inc. (Meridian) in association with the University of Minnesota, and relies exclusively on commodity funding support.

The FHB epidemic risk model requires observed weather information as an input. Meridian was selected as the host for the website in part because of a unique weather database it maintains. This database consists of hourly analyses of weather conditions across the United States on a high resolution grid. The analyses are constructed using computer models to integrate surface observations [such as those collected by the National Weather Service (NWS), Federal Aviation Administration (FAA), and the State of Minnesota] with remotely-sensed data retrieved from weather radars and satellites. In general, surface observations serve as a basis for the analyses while remotely-sensed weather information is used to estimate smaller-scale variations in areas between weather observing stations. Data from more than 82 NWS and FAA
weather stations, 93 weather stations from the Minnesota Department of Transportation, Road Weather Information System (RWIS), 9 stations from the North Dakota Agricultural Weather Network (NDAWN), and no less than 6 NEXt Generation Weather RADar (NEXRAD) weather radars, contribute to the weather analyses and disease forecasting efforts in Minnesota (Fig. 1).

The end result of this analysis process is a national, 4-km resolution composite of precipitation, temperature, wind, and humidity data that is updated hourly. This database is stored online and can be accessed to provide nearly field-level estimates of past weather conditions. These weather estimates are provided as inputs to the FHB epidemic risk model, the output of which is turned into both map and field-specific presentations of FHB epidemic risk. A statewide map presentation serves as the opening page to the website (Fig. 2). Users can get a localized risk map (Fig. 3) by simply clicking on the desired location within the statewide map. The localized risk map provides more detailed landmark information, including public land survey section boundaries to aid in selecting specific field locations. After selecting a location on this localized map and inputting a crop flowering date, the website provides the user with a field-specific FHB epidemic risk (Fig. 4). The epidemic risk forecasting system updates its predictions every 3 hours, for a total of eight times daily.
Fig. 2. Users select the crop flowering date, and click on the "Go" button. Areas in Minnesota with higher (red) and lower (green) risks for a Fusarium head blight epidemic are noted at a glance.

Fig. 3. A localized risk map is generated by clicking on the desired location in the statewide map. This risk map provides more detailed landmark information, including public land survey section boundaries and major roadways.
Assessing and Reporting Fusarium Head Blight Disease Index Levels

During 2004, five hard red spring wheat on-farm disease management experiments were conducted within commercial production fields in the Red River Valley of Minnesota. During 2005, experiments were again established near the same five locations. Unfortunately, little information was collected from the two northerly sites due to frequent severe weather and flooding. Data from those experiments are not reported here. Each year, experiments included nontreated control, foliar, or head-applied fungicide application treatments in randomized, complete-block designs with four replications. This paper reports FHB index values from plots that received no fungicide (nontreated control).

During 2004, experiments were planted into grower-cooperator fields located near Hallock (April 26), Strathcona (May 3), Oklee (April 21), Perley (April 16), and Fergus Falls (April 19). Experiments conducted during 2005 were planted near Oklee (April 22), Perley (April 18), and Fergus Falls, MN (April 20). All experiments were planted into seedbeds having broadleaf crop residue present (e.g., soybean, sunflower), except one. During 2004, the most southerly test site, located near Fergus Falls in west-central Minnesota, was planted into barley residue from a 2003 crop.

Five hard red spring wheat cultivars with a range of FHB-resistance levels were tested at each location. Of those tested, Alsen has the highest level of resistance to FHB (moderately resistant), Knudson and Walworth are rated as moderately susceptible to moderately resistant, Reeder is rated as moderately susceptible, and Oxen is rated as moderately susceptible to susceptible.

Experiment sites were visited weekly and crop growth stages were recorded. Wheat spikes (50 per plot) were collected when FHB symptoms became apparent during kernel development growth stages (approximately Feekes 11.2 growth stage). Spikes were placed in self-sealing plastic bags and maintained in cold storage (approximately -23°C). Disease symptoms were rated within 1 month of spike collections. Fusarium head blight severity data were recorded based on a visual scale where each spikelet accounted for approximately 7% of the total spike (5). Index figures were calculated from severity and incidence data. Risk predictions of FHB from the model were averaged from a 3-day period when plants were flowering. During 2004, flowering dates were similar among cultivars at test sites (Hallock, July 11 to 13; Strathcona, July 18 to 20; Oklee, July 6 to 8; Perley, July 1 to 3; Fergus Falls, July 1 to 3). During 2005, growth stages varied slightly across cultivars. At the Oklee test site, all cultivars...
flowered June 27 to 29, except Knudson (e.g., 30 June to 2 July); at the Perley and Fergus Falls sites, Alsen, Oxen, and Walworth flowered June 23 to 25, while Knudson and Reeder flowered June 26 to 28.

Accuracy of FHB Epidemic Risk Forecasts in Minnesota: 2004

Fusarium head blight disease development was localized and sporadic throughout the Red River Valley. In general, few economic crop losses were caused by the disease. Index level means ranged from a low of 0.4% on Alsen at Strathcona to a high of 10.4% on Oxen at Fergus Falls. Index means by location were less than the 10% economic injury threshold (Table 1). Low epidemic risk probabilities were estimated for the Oklee, Perley, and Fergus Falls test cases, while high risk probabilities were predicted for the Hallock and Strathcona cases.

Table 1. Mean FHB disease indices of 5 hard red spring wheat cultivars at a total of 8 experiment locations during 2004-05.

<table>
<thead>
<tr>
<th>Location</th>
<th>% FHB indices* cultivar during 2004 (2005)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Alsen</td>
</tr>
<tr>
<td>Hallock</td>
<td>2.48</td>
</tr>
<tr>
<td>Strathcona</td>
<td>0.39</td>
</tr>
<tr>
<td>Oklee</td>
<td>1.89</td>
</tr>
<tr>
<td></td>
<td>(6.91)</td>
</tr>
<tr>
<td>Perley</td>
<td>1.86</td>
</tr>
<tr>
<td></td>
<td>(5.26)</td>
</tr>
<tr>
<td>Fergus Falls</td>
<td>4.16</td>
</tr>
<tr>
<td></td>
<td>(2.56)</td>
</tr>
<tr>
<td>Mean</td>
<td>2.15</td>
</tr>
<tr>
<td></td>
<td>(4.91)</td>
</tr>
</tbody>
</table>

* FHB index percentages calculated from FHB severity and incidence data [(FHB severity × FHB incidence)/100].

FHB disease symptoms were most severe on cultivars at the Fergus Falls site, but the epidemic risk prediction was low. Increased disease pressure was likely due to the presence of in-field barley residue. An application of fungicide (tebuconazole at 0.3 liter/ha) on Oxen at Feekes growth stage 10.51 was beneficial as it reduced the index level to below the economic injury threshold (e.g., 10.4% nontreated control to 5.4%; data not shown). An application of a fungicide at the Hallock and Strathcona experiment sites where high risk was predicted would have resulted in increased input costs in the absence of economic injury to the crop.

The system predicted a high risk for an epidemic in 40% of cases (2 of 5), but none occurred. Conversely, it predicted a low risk for an epidemic in 60% of cases (3 of 5), and epidemics did not occur. During 2004, the FHB epidemic risk forecasting system predicted non-epidemics in Minnesota with an estimated 60% accuracy.

Accuracy of FHB Epidemic Risk Forecasts in Minnesota: 2005

Fusarium head blight was widespread throughout the Red River Valley. Index level means ranged from a low of 2.1% on Walworth at Fergus Falls to a high of 19.3% on Oxen at Oklee. Index means by location exceeded the economic injury threshold at Oklee (Table 1). Low epidemic risk probabilities were estimated for the Oklee (June 27 to 29), Perley, and Fergus Falls test cases, while a moderate risk was predicted for the Oklee (June 30 to July 2) case.

FHB disease symptoms were most severe on cultivars at the Oklee site, but the epidemic risk predication was low. Index levels exceeded the economic
damage threshold for all three cultivars flowering during the June 27 to 29 interval. A moderate risk for epidemic was estimated a few days later at Oklee when Knudson was flowering and its index level exceeded the injury threshold. An application of fungicide (tebuconazole at 0.3 liter/ha) resulted in reduced index levels for all 4 cultivars (e.g., Oxen, 19.3% to 16.9%; Reeder, 17.1% to 16.5%; Walworth, 14.7% to 9.2%; Knudson, 11.4% to 5.3%; data not shown). Disease symptoms were less severe at the Perley and Fergus Falls sites, where mean indices did not exceed the damage threshold. The index mean for Oxen at the Perley site was slightly greater than the damage threshold, but the estimated risk for an epidemic was low. An application of fungicide on the cultivar resulted in a reduced index level (e.g., 11.0% to 10.2%; data not shown).

The system predicted a low risk for an epidemic in 75% of cases (3 of 4), and one epidemic occurred. It predicted a moderate risk for an epidemic in 25% (1 of 4) of cases, and one epidemic occurred. The FHB epidemic risk forecasting system predicted non-epidemics in Minnesota with an estimated 66% accuracy (2 of 3) and epidemics with an estimated 50% accuracy (1 of 2).

**Conclusion**

Annual monitoring and ground-truthing of the FHB epidemic risk forecasting system is necessary to obtain system feedback and accuracy estimates regarding model performance in Minnesota.

A modified FHB epidemic risk forecasting model was released in April for use during the 2006 growing season by researchers at Pennsylvania State University. The model is expected to have greater epidemic risk prediction accuracies compared to earlier iterations since it incorporates disease-resistance levels of spring wheat cultivars into predictions. Two-year data from Minnesota supports this modification. Alsen, a moderately resistant cultivar, had low FHB index levels during 2004-2005, but Oxen, a susceptible to moderately susceptible cultivar, had economically damaging levels of disease during the same time period.

Epidemic risk accuracy on spring wheat can likely be enhanced by inputting crop residue information into the model, much like what has been done for winter wheat. Planting susceptible crops into corn and small grains crop residues increases the probability of FHB disease injury. During 2004, disease index levels were most severe at the Fergus Falls site, which was likely caused from in-field barley residue.

Increasing the accuracy of the FHB epidemic risk forecasting system is a critical step in establishing its long-term support from producers and commodity organizations. Like any new crop production tool, the model is being discussed, evaluated, and even scrutinized, in coffee shops and farmer cooperatives. Researchers must continue to improve the forecasting model to achieve real-world applicability if the tool is to succeed.

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**Literature Cited**
