Reduced-Risk Strategy for *Fusarium* head blight in wheat

Pesticide Risk Reduction Program
Pest Management Centre, AAFC

pmc.cla.info@agr.gc.ca

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Preface

Pesticide risk reduction strategies are developed under the Pesticide Risk Reduction Program (PRRP), a joint program of Agriculture and Agri-Food Canada (AAFC) and the Pest Management Regulatory Agency (PMRA) of Health Canada. The Program’s objective is to reduce risks to the environment and to human health from pesticide use in agriculture. To achieve this, the Program works with grower groups, provincial experts and researchers to identify gaps in pest management and opportunities for pesticide risk reduction, and to develop and implement strategies to address these.

A pesticide risk reduction strategy is a detailed plan developed through consultations with stakeholders aiming to address grower needs for reduced-risk management tools and practices for a specific pest issues. The strategy document presented herein is intended to update participating stakeholders and the public at large on the activities supported by the Program in developing and implementing the strategy and the new tools and practices made available through this process.

For more information, visit the website of the Pest Management Centre.

Acknowledgement

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Executive summary

Fusarium head blight (FHB) is a serious disease affecting yield and quality of wheat and other important cereal crops across Canada. This disease was identified as a top priority issue through stakeholder consultation since 2005. This report summarizes the collaborative work and results from activities undertaken by the Pesticide Risk Reduction Program (PRRP) to support development and implementation of a reduced-risk strategy to manage FHB in wheat crops in Canada. The goal of this strategy is to reduce risks associated with fungicides used for FHB control, while helping growers to achieve viable disease management and farm profitability.

This strategy was developed through consultations and collaboration with industry stakeholders including grower groups, provincial crop specialists, researchers and government scientists across key wheat growing regions. Many of these stakeholders and subject matter experts have been actively involved in a PRRP-led working group tasked to develop the FHB strategy. As part of the strategy work, disease management issues were identified, reduced-risk solutions to address these issues were discussed and prioritized, and a plan of actions to develop and implement these solutions was developed.

To implement the FHB strategy, over the last ten years the PRRP funded 10 projects and provided regulatory assistance for biopesticide registration. Key outputs for growers include:

- improved DONcast® system with better accuracy for FHB prediction and risk assessment in wheat
- validation and demonstration of best suited FHB forecasting systems across Saskatchewan, Manitoba and Quebec wheat growing regions
- new information on cultural practices and integrated management of FHB
- development and assembly of a regulatory package for registration of a new biopesticide product for FHB control

More details about the projects and new solutions resulting from this strategy are provided in Tables 1 & 2 at the end of this document. This information has been communicated and demonstrated to growers to facilitate the uptake and proper use of the tools. It is anticipated that adoption of these new tools and practices will enable an integrated FHB management that helps growers shift away from full reliance on fungicides.

Pest management and pesticide risk reduction issues

Fusarium head blight of wheat is caused by several Fusarium species, but F. graminearum is the most predominant and aggressive one in Canada. The fungus can overwinter as spores or mycelium on seed and crop residue. Infected seed causes blight to wheat seedling upon emergence. Inoculum on crop residue serves as a main source for infection later in the season. Fusarium spores are spread by rain-splash and wind and can directly infect open wheat florets. Disease develops rapidly under warm and moist conditions and can cause widespread epidemics when these conditions coincide with flowering, when wheat is most susceptible to Fusarium. The disease can cause significant yield loss in wheat crops due to damaged and unfilled kernels.
The fungus also contaminates kernels with mycotoxins such as deoxynivalenol (DON), which lowers the grade of wheat grain, making it unfit for human and animal consumption.

Effective and sustainable FHB management is a key to viable wheat production across Canada. While *F. graminearum* is found in abundance in eastern Canada and the eastern prairies, over the last 20 years, its distribution has progressed gradually towards the western regions of the prairies. In Alberta, *F. graminearum* is listed as a regulated pest under *Agricultural Pests Act* since 1999.

A large FHB resistance breeding program has been underway within AAFC since the 1990s. Through this program, AAFC scientists, in collaboration with other Canadian researchers have made significant progress, leading to the release of a number of spring and winter wheat cultivars with improved resistance to FHB.

However, in 2005, with no fully resistant wheat varieties available commercially, FHB control relied mainly on fungicide applications. Over the course of this strategy, the number of active ingredients available for FHB control has increased from two in 2005 to six (totalling 16 products) in 2014, including the biopesticide Taegro (*Bacillus subtilis* var. *amyloliquefaciens* strain FZB24). However, all chemical active ingredients belong to only 3 fungicide/resistance groups (triazole/3, chloronitrile/M and methoxy-carbamate/11) and all resulting products are labelled for disease suppression only. Chlorothalonil is currently under regulatory review by Health Canada’s Pest Management Regulatory Agency and as a result of this re-evaluation some of its uses may be phased-out in Canada. Moreover, the repetitive use of fungicides within the same group can lead to development of pathogen resistance to certain chemistries. The need for alternatives to triazole fungicides has long been identified as a priority by the industry to improve resistance management.

**Strategy development**

Some priority pest management gaps were identified through preliminary consultations with the provinces and grower organizations held by the Program in 2005 and 2006. In response to these discussions, the Program supported several projects addressing recommended solutions. Subsequently, it became apparent that a concerted effort was needed to allow for broader stakeholder consultations, engaging expertise from various regions and specialties.

- **Working group consultations**

  An expert working group was established in early 2009 to help PRRP develop a plan of actions to address the FHB issue. The group brought together key experts and stakeholders, including grower organizations, university researchers, provincial extension and pest management specialists, federal scientists and private entities to work on risk reduction opportunities.

- **Priority issues and gaps**

  With work continuing in the public sector research plots toward the goal of developing resistant wheat varieties, the FHB WG focussed its efforts on other disease management elements which
would be required for establishing an integrated management system for FHB. Through multiple consultation sessions over the years, the working group identified reduced risk solutions to address several priority gaps outlined in the strategy, as summarized below:

- **Lack of alternative control options in the tool-box**

Despite a number of chemical options available, the economic damage from FHB has been on the rise, with the pathogen continuing to expand its geographic distribution and significantly downgrading grain quality. Growers have faced challenges with the limited chemical groups available and the attendant risk for resistance development. The industry needed access to effective alternative control options, including biopesticides and cultural options, to enable an integrated management approach and reduced reliance on fungicides. A priority action was put forward for the further development of promising biocontrol agents as well as irrigation and crop management practices that would help to suppress or avoid disease development in wheat crops.

- **Lack of reliable FHB forecasting tools**

As available FHB control products are mainly preventive and can only suppress disease, these have a narrow window of application to achieve an acceptable efficacy. They should be applied at specific stages of wheat growth (e.g. at 75% bloom) and before the onset of disease. However, not all provinces had regional FHB risk warning services delivered to growers to aid in their spray timing decisions. In Ontario, WIN (Weather INnovations Incorporated) delivered the original version of DONcast (developed in late 90s), while in Manitoba, the Ministry of Agriculture, Food and Rural Initiatives delivered daily online updates of a disease risk map based on the DeWolf model. A priority action was put forward to improve the accuracy and field specificity of existing FHB forecasting systems and validate these and other systems to enable adoption of suitable models in regions where such services were not available.

This strategy was thus centered on developing suitable and effective forecasting tools and lower risk control alternatives to replace, or minimize the use of chemical fungicides and allow for integrated disease management.

- **Action Plan**

Based on these issues and proposed solutions, an action plan was developed to implement the FHB strategy. As summarized in Table 1, this action plan included the goals, milestones and specific solutions proposed by the working group, as well as progress on research and development activities undertaken by the Program to act upon the recommended solutions and advance the implementation of this strategy.

Three goals were defined in this strategy to address the above two priority areas:

- Identify reduced risk products as alternative to current fungicides;
- Develop tools and practices for integrated FHB management;
- Transfer and promote adoption of new FHB management solutions.
Table 1. Progress and results on action plan to implement a reduced-risk strategy for Fusarium head blight management in wheat production in Canada

**Status legend:** Project addressing a milestone is complete (Completed); Work/project is currently underway (On-going); priority identified for future work (Future).

<table>
<thead>
<tr>
<th>Goal</th>
<th>Milestones</th>
<th>Status</th>
<th>Implementation Activities (please click on hyperlinks to view project details)</th>
<th>Completion period</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Identify and assess biological agents for FHB control</td>
<td>Completed</td>
<td>Project <strong>BPI07-110</strong> - Biological management of Fusarium head blight and mycotoxin contamination in wheat: AAFC researchers evaluated 20 selected strains of potential bioagents including 15 bacteria and 5 fungi from AAFC and Cornell university isolates. A strain of <em>Clonostachys rosea</em> (ACM941) was identified as the most effective and promising for future commercialization.</td>
<td>2007-2008</td>
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<td></td>
<td>Assess field efficacy of promising biocontrol(s)</td>
<td>Completed</td>
<td>Project <strong>BPI08-020</strong> - Microbial agents to control diseases of wheat in Canada and to minimize mycotoxin contamination of small grains: Scaled up field efficacy evaluations of <em>Clonostachys rosea</em> strain ACM941 and other promising candidates to control FHB. ACM941 significantly reduced FHB and DON levels in wheat and provided better prevention of post-harvest development of Gibberella zeae perithecia than the conventional control (Folicur).</td>
<td>2008-2009</td>
</tr>
<tr>
<td></td>
<td>Identify industry partner for biocontrol commercialization</td>
<td>Completed</td>
<td>A biopesticide company based in Newfoundland; licenced <em>Clonostachys rosea</em> strain ACM941 from AAFC for the purposes of commercialization. Subsequent work undertaken by the company in collaboration with Cornell University and AAFC led to optimization of the biopesticide formulation. Unfortunately, shortly after this the company experienced difficulties and had to give up the licence. In 2014, through an open competition, AAFC granted licensing rights to the Canadian company <em>Adjuvants Plus Inc.</em> to register and commercialize ACM941 as a new biopesticide. Work is underway to develop a data package for regulatory review by Health Canada’s Pest Management Regulatory Agency for commercial use in Canada.</td>
<td>2009-2011</td>
</tr>
<tr>
<td></td>
<td>Development, registration and commercialization of biocontrol agent</td>
<td>Completed</td>
<td>AAFc project <strong>BPI09-050</strong> - Formulation of C. rosea biocontrol agent for efficacy against Fusarium diseases in wheat and soybean: Project delivered formulated C. rosea strain ACM941 to AAFC researchers for field and greenhouse efficacy trials and worked towards developing and refining C. rosea as a biopesticide for FHB control.</td>
<td>2009-2011</td>
</tr>
</tbody>
</table>

Through national consultations, *C. rosea* ACM941 was selected as a priority biocontrol agent for support by PRRP in 2010-2011. The Biopesticides section of Pesticide Risk Reduction Program provides continued regulatory support to assist with the registration submission process of *C. rosea* strain ACM941 as a biofungicide.
<table>
<thead>
<tr>
<th>2. Develop tools and practices for integrated FHB management</th>
<th>AAFCC project PRR06-370 - Improving the scope and delivery of weather-based decision models for diseases in wheat: An improved site-specific ssDONcast spray advisory was developed and made available since spring 2008 through the WIN website (<a href="http://www.weatherinnovations.com">http://www.weatherinnovations.com</a>) and Bayer’s CropScience Weather Program <a href="http://www.weathercentral.ca">http://www.weathercentral.ca</a> to assist wheat growers in Ontario with field-specific predictions of DON levels in wheat grain at harvest and spray recommendations accordingly at the time of heading.</th>
<th>Completed</th>
<th>2006-2008</th>
</tr>
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<td></td>
<td>AAFCC project PRR10-040 - Validation and demonstration of existing Fusarium Head Blight disease forecasters as management decision making tools for use in wheat production in Manitoba: The disease forecast model DeWolf provided accurate predictions of FHB index value at 79% (2010) and 77% (2011) of the time across 80 and 114 surveyed wheat field sites in Manitoba, respectively. Model made available through <a href="http://weatherfarm.com">http://weatherfarm.com</a>.</td>
<td>Completed</td>
<td>2010-2012</td>
</tr>
<tr>
<td>Validate efficacy and demonstrate benefits of adopting forecasting tools</td>
<td>AAFCC project PRR10-200 - Validation and demonstration of existing Fusarium Head Blight disease forecasters as management decision making tools for use in wheat production in Saskatchewan: The disease forecast model DeWolf provided accurate predictions of FHB index value at 79% (2010) and 77% (2011) of the time across 6 and 18 surveyed wheat field sites in Saskatchewan, respectively. Model was made available through <a href="http://weatherfarm.com">http://weatherfarm.com</a>.</td>
<td>Completed</td>
<td>2010-2012</td>
</tr>
<tr>
<td></td>
<td>AAFCC project PRR11-010 Validation and demonstration of forecasting models for Fusarium head blight development in wheat under production conditions of Quebec: Among five existing forecasting models and some variations of one of these models extensively validated from 2011-2013, the model DeWolf B performed best with the highest (90%) accuracy in disease risk prediction. DeWolf B was thus deemed the most suitable for the region and was made available to growers through <a href="http://www.agrometeo.org/">http://www.agrometeo.org/</a>.</td>
<td>Completed</td>
<td>2011-2013</td>
</tr>
<tr>
<td></td>
<td>AAFCC projects PRR10-130 - On-farm field demonstration of the impact of irrigation management, timing of fungicide sprays and cropping system on Fusarium head blight control in irrigated wheat production in Southern Alberta: Project demonstrated that irrigated wheat crops showed higher FHB levels than dryland. Reduced irrigation, particularly during flowering, combined with timed fungicide sprays provided significant disease suppression without compromising yield.</td>
<td>Completed</td>
<td>2010-2013</td>
</tr>
<tr>
<td>3. Transfer and promote adoption of new FHB management solutions</td>
<td>Develop disease management systems integrating various tools and approaches, including existing wheat varieties with improved resistance to FHB such as the latest release of what was the first commercial Fusarium -Resistant winter wheat variety (AC™ Emerson) made available to Canadian farmers in fall 2014.</td>
<td>Future</td>
<td></td>
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<tr>
<td></td>
<td>A number of articles and presentations were delivered to growers through growers’ magazines and meetings under the AAFCC project PRR06-370. Alerts on this service being available to growers for signing up are regularly posted on OMAFRA’s CropPest Ontario publication and other grower associations’ websites.</td>
<td>Completed</td>
<td>2006-2008</td>
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<td></td>
<td>A factsheet &quot;Weather Time Spray Applications&quot; was presented at FarmTech 2007 in Edmonton, AB on January 24 &amp; 26, 2007.</td>
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<td></td>
<td>A number of posters and oral presentations featuring results from the biocontrol work on Fusarium head blight of wheat with Clonostachys rosea strain ACM941 have been presented at national and international meetings, including at the Canadian Workshop on Fusarium Head Blight (2007 &amp; 2009).</td>
<td></td>
<td>2007-2014</td>
</tr>
<tr>
<td>Communicate the new tools and practices to growers</td>
<td>A factsheet A New Biofungicide to Manage Fusarium Head Blight of Wheat was published and made available on PRRP website for access by stakeholders.</td>
<td>Completed</td>
<td></td>
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</table>
Several technology transfer activities have been conducted as part of projects PRR10-040, PRR10-200, PRR10-130 and PRR11-010 through media vehicles such as articles in agriculture magazines, radio, webinar forums and YouTube videos as well as through presentations at grower and industry meetings. In addition, grower cooperators have been engaged to collaborate in project allowing trials to be conducted in their fields, and field tours held at projects sites.

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<th>2010-2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Future</td>
<td>Develop and demonstrate integrated FHB management program for cereal crops incorporating, among other tools, the new biofungicide <em>Clonostachys rosea</em> strain ACM941 to achieve full benefits of this new product, when it becomes registered for use in Canada.</td>
<td></td>
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</tbody>
</table>
Strategy outcomes

The main outcomes achieved from the implementation of the FHB strategy include:

- A more accurate DONcast® system made available to growers in Ontario and parts of Quebec for better FHB prediction and more efficient fungicide sprays in wheat crops;
- DeWolf model was further validated and demonstrated to growers as a suitable tool to guide them in FHB decision making across prairie wheat regions of Manitoba and Saskatchewan;
- DeWolf (variation B) model was identified for first time as the FHB forecasting system best suited to wheat growing regions of Quebec and is now being recommended for use to growers;
- New information on integrating cultural practices such as irrigation management, tolerant varieties and crop rotation with fungicide sprays was generated and demonstrated to growers to help with FHB suppression in high disease risk areas of irrigated wheat in Southern Alberta;
- Regulatory assistance led to generation of efficacy data to fulfill registration requirements for the new biopesticide Clonostachys rosea strain ACM941 (registration submission pending).
- Publication of a number of scientific papers and a factsheet has contributed to dissemination of information and transfer of the biocontrol work to growers
- A large cohort of growers and crop advisors have become aware of resulting new tools and have been educated on sustainable FHB management through consultations, collaborative research and demonstration projects, and extensive dissemination of information.

Strategy impact: then and now

When the strategy was initiated in 2005, management solutions available for FHB were limited to two chemical fungicides, sporadic forecasting tools, and few alternative controls. Since then, a number of new compounds and wheat cultivars with improved FHB resistance have become available for use, enabling some rotation and improved resistance management.

In addition, the support by the Pesticide Risk Reduction Program through this strategy over the past 10 years has contributed in further diversifying and expanding the toolbox available for FHB control of wheat in Canada. It has led to improved forecasting tools for the major wheat growing provinces being validated and demonstrated to growers, allowing more effective disease management measures. Moreover, a new biofungicide is anticipated to be added to the toolbox. Increased opportunity for integrating these new tools and other existing solutions is likely to improve FHB management while minimizing reliance on chemicals.
As highlighted in Table 2, implementation of these new solutions has the potential to impact a large area (up to ~10 million hectares) by reducing the risk from pesticides and improving efficacy in FHB management in wheat and possibly other cereal crops affected by this disease.

**Table 2.** Potential impacts of control solutions developed through the Fusarium head blight strategy.

<table>
<thead>
<tr>
<th>Solution</th>
<th>Pesticide risk reduction mechanism</th>
<th>Crop(s)¹ the solution is applicable to</th>
<th>Total crop acreage² (000 Ha)</th>
<th>Potential acreage for adoption</th>
<th>Additional benefits/Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>New biopesticide (ACM941)</td>
<td>Reduce reliance on conventional pesticides</td>
<td>Wheat</td>
<td>10,000</td>
<td>100%</td>
<td>Enables: protection of non-target &amp; beneficial organisms; IPM systems; rotation among various modes of actions; resistance management; mitigation of REI/PHI &amp; MRL issues</td>
</tr>
<tr>
<td>Disease prediction</td>
<td>Avoid unnecessary sprays</td>
<td>Wheat</td>
<td>10,000</td>
<td>70%</td>
<td>Enables IPM systems; better decision making of improved timing application and efficacy of control products</td>
</tr>
<tr>
<td>Cultural practices</td>
<td>Avoid disease and reduce the need for using products</td>
<td>Wheat</td>
<td>10,000</td>
<td>10%</td>
<td>Reduces production cost by lowering fungicide use; suitable for conventional &amp; organic wheat production. Higher adoption potential in Southern Alberta or other regions where wheat is grown under irrigation</td>
</tr>
<tr>
<td>Factsheet/articles featuring advances on the biopesticide work</td>
<td>Increase likelihood of growers adopting biopesticides</td>
<td>Wheat</td>
<td>10,000</td>
<td>100%</td>
<td>Enables better informed and more engaged stakeholders and the possibility for a faster uptake of the tool.</td>
</tr>
</tbody>
</table>

¹Includes only crops targeted by this strategy; impact can be larger if additional crop uses will be included in the product label or the tool/practice can be applicable to other crops.

²Acreage of the indicated crop planted in Canada in 2014.