Management of FHB in Barley: lessons from the Upper Midwest

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University of Minnesota
USA wheat production areas - shown by class -
USA wheat production areas - shown by class -

1993, 94, 95, 97, 2001 & 05

1996

2003 & 2009
Probable Causes of the Increase in Fusarium Head Blight

- weather patterns favoring disease development
- susceptible wheat and barley cultivars and expanded corn production
- reduced tillage practices adopted for soil conservation
Precipitation patterns
Red River Valley, MN

Month
J F M A M J J A S O N D
'61-90 '93-96

Precipitation (mm)
Fusarium Head Blight

Predominance of *F. graminearum* as causal fungus in FHB

The increase of FHB has been associated with increased corn production
FHB Pathogens

- *Fusarium graminearum* (*Gibberella zeae*), *F. culmorum*, *F. poae*, *F. avenaceum*, *F. equiseti*, *F. acuminatum*, *F. sporotrichioides* and others...

Broad host range
Fusarium species recovered from residues

**Wheat and barley:**  *F. graminearum (G. zeae)*, *F. avenaceum*, *F. equiseti*, *F. acuminatum*, *F. trincinctum*, *F. sambucinum*, *F. semitectum*, *F. poae* (barley), *F. culmorum* (wheat), *F. sporotrichioides*, *F. subglutinans*, *F. oxysporum*, *F. solani*

**Corn:**  *F. verticilliioides*, *F. subglutinans*, *F. graminearum*, *F. proliferatum*, *F. oxysporum*, *F. equiseti*, *F. solani*

**Gramineous weeds:**  *F. equiseti*, *F. avenaceum*, *F. poae*, *F. oxysporum*, *F. solani*, *F. sambucinum*, *F. graminearum*, *F. subglutinans*

**Sunflower:**  *F. oxysporum*, *F. solani*, *F. equiseti*, *F. acuminatum*, *F. semitectum*, *F. poae*, *F. graminearum*

Broader host range as a saprophyte
Disease cycle of *Fusarium graminearum*
Disease cycle of *Fusarium graminearum*

- **Infected Debris**
- **Perithecia / Sporodochia**
- **Macroconidia**
- **Ascospores**

45 days
Disease cycle of *Fusarium graminearum*

- **45 days**
  - Infected Debris
  - Macroconidia
  - Perithecia / Sporodochia

- **320 days**
  - Ascospores
Fusarium Head Blight

Sporadic epidemics reported since wheat and barley production established in the USA

From a historical perspective, FHB was most effectively controlled from the end of WWII to the mid-1980’s - the era of the moldboard plow -
CHEMICAL CONTROL
Chemical Control

- **Seed treatments** - seedling blight
- **Heading applications** - 50-60% reductions in severity
  - Early to mid 1990’s: mancozeb (protectant) and systemic MBC fungicides (benomyl)
  - Late 1990’s: Tilt (propiconazole), Folicur (tebuconazole), Quadris (azoxystrobylurin)
  - 2000’s: Caramba (metconazole), Proline (prothioconazole), Prosaro (prothioconazole & tebuconazole)

- **Application technology**
  - Nozzle type and direction
Chemical Control

- **Seed treatments** - seedling blight

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- **Application technology**
  - Nozzle type and direction

Associated with Increased DON
# Fungicides - Best Recommendations

<table>
<thead>
<tr>
<th>Fungicide</th>
<th>Product names</th>
<th>Rate/A fl oz/A</th>
<th>Head Scab efficacy</th>
<th>Preharvest interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metconazole</td>
<td>Caramba</td>
<td>10.0 – 17.0</td>
<td>G² (VG)³</td>
<td>30 days</td>
</tr>
<tr>
<td>Propiconazole</td>
<td>Tilt, PropiMax, others</td>
<td>4.0</td>
<td>p²</td>
<td>40 days</td>
</tr>
<tr>
<td>Prothioconazole</td>
<td>Proline</td>
<td>5.0 – 5.7</td>
<td>G² (VG)³</td>
<td>30 days (32 for barley)</td>
</tr>
<tr>
<td>Prothioconazole + Tebuconazole</td>
<td>Prosaro</td>
<td>6.5</td>
<td>VG²</td>
<td>30 days</td>
</tr>
<tr>
<td>Tebuconazole</td>
<td>Folicur, Embrace, Onset, Orius, Monsoon, TebuStar, Tergol, Toledo, others</td>
<td>4.0</td>
<td>F²</td>
<td>30 days</td>
</tr>
</tbody>
</table>

Scabsmart: [www.scabsmart.org](http://www.scabsmart.org)
Table 1. Effect of timing of application of Folicur (4 fl oz/acre) on field severity of FHB in greenhouse, 1999.

<table>
<thead>
<tr>
<th>Application Growth Stage (Feekes)*</th>
<th>FHB Field Severity (Field Severity = Incidence x Head Severity)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grandin HRS</td>
</tr>
<tr>
<td>10.3</td>
<td>1.6</td>
</tr>
<tr>
<td>10.51**</td>
<td>0.5</td>
</tr>
<tr>
<td>10.54</td>
<td>7.0</td>
</tr>
<tr>
<td>Untreated</td>
<td>7.0</td>
</tr>
</tbody>
</table>

* Feekes growth stage 10.3 = 50% head emergence; 10.51 = early flowering; 10.54 = kernel water ripe
** Barley sprayed at Feekes 10.5 = head fully emerged

Scabsmart: www.scabsmart.org
Fungicide Spray Angle and Direction

Hofman, McMullen et al.
FUSARIUM HEAD BLIGHT Prediction Center

Introduction
Model Basics
User Guide
Fusarium
Developers
Login

US Commentary last update 2012-08-02 Tom Aezer,

Some tips for using the application: Follow the steps to map the risk for state, model, and date. - Click the query button near the bottom left and then click on the risk map to get risk at any location. - After selecting a state, make sure that a Weather Stations layer is checked on, and then click a station to get risk for that station.

1. Choose a State
   State: United States

2. Choose a Model
   Wheat: Spring Winter

3. Weather Forecast Mode
   Forecast (hrs): 0 24 48 72
   Assessment Date: 09/21/2013
   Weather Stations: FAA AgNet Inactive (for model)

Legend
   Blight Risk: High Medium Low No Data
   Weather Stations: FAA AgNet Inactive (for model)
   Risk Map Opacity Query
Chemical Control - Best Practices
Barley

- **Recommended Fungicides:** Caramba, Proline and Prosaro. Use a good adjuvant
- **Timing:** Early Heading Applications (Feekes 10.3-10.5)
- **Ground Applications:** twin directional nozzles, Increase spray volume to improve coverage
- **Air Applications:** evening or early morning to utilize dew as additional water, small droplet size
BIOLOGICAL CONTROL
Biological Control Agents

Bacteria (*Bacillus* and *Lysobacter* spp.) and several yeasts have been examined in greenhouse and field tests.

Consistent FHB suppression and DON reduction in greenhouse but not in the field....
Biological Control Agents Tested

*Bacillus spp.* - these are attractive candidates because of their ability to produce endospores and potential to express a number of biocontrol mechanisms

- *Bacillus subtilis* Trigocor 1448 (da Luz *et al.* 2003)
- *Bacillus sp.* 1BA (Draper *et al.* 2001)
- *Bacillus subtilis* var. *amyloliquefaciens* FZB24 - a.i. in Taegro (Novozymes Biologicals) - shown to control a range of pathogens - not tested for FHB

*C3 Lysobacter enzymogenes*

*Cryptococcus flavescens* OH182.9 / *C. aureus* OH 71.4 - yeasts

*BCA* strains tested either alone or in combination with Prosaro
Effect of BCA’s on FHB and DON

None of the BCA strains alone had a consistent effect on the disease parameters measured in the field.

Prosaro, applied alone or in combination with a BCA, was effective in reducing FHB measurements in multiple trials.

Prosaro reduced DON levels in most trials - TrigoCor 1448 and the two yeasts appear to also reduce DON in some trials.

No single strain appeared superior across environments.

May be some synergy of BCA’s applied with fungicides - esp. for durability of protection or for applications after heading.
Understanding why BCA’s fail in the field

TrigoCor strain of *Bacillus subtilis* shows potential in the greenhouse BUT... is inconsistent in the field

Populations on wheat florets appear to be able to survive at levels (>10^6) which suggests they should be able to actively protect plants

The production and persistence of antifungal metabolites (lipopeptides) appears to be important in disease control and the concentrations of these might be critical

Kawamoto *et al.*
Proc. USWBSI Forum 2008
CULTURAL CONTROL
Residue Decomposition
Fusarium Head Blight

Less debris decomposition in cold winter regions leads to greater inoculum pressure
Residue decomposition and survival of *Fusarium* in residues

Field trial - Crookston, MN
- wheat residue - harvested October 1997
- placement - chisel plow at 0, 10, 20 cm depths & moldboard plow at 20 cm
- collected - April 1998 till July 2000

Pereyra, Dill-Macky and Sims
Plant Disease 2004
Residue Decomposition

![Graph showing the decomposition of residue dry matter over time for different soil preparation methods.]

- **Chisel - surface**
- **Chisel - 10 cm**
- **Chisel - 20 cm**
- **Moldboard - 20 cm**

*Graph labels:*
- **Y-axis:** Residue dry matter (%)
- **X-axis:** Time (months)

*Graph timeline:*
- 24-Oct-97 to 20-Oct-99
Colonization of Residue

Nodes colonized by G. zeae (%)

Time (months)

- Chisel - surface
- Chisel - 10 cm
- Chisel - 20 cm
- Moldboard - 20 cm
Fusarium spp. - succession on residues

Colonization of residue (%)

Species and Sampling date

G. zeae  F. equ.  F. spo.  F. oxy.  F. sol.  Other
Recovered *F. graminearum* isolates were capable of producing perithecia and viable ascospores.
Wheat and barley residues support *Fusarium* survival and inoculum as long as they are ‘recoverable’ - in MN residues may impact FHB for up to three subsequent cropping seasons.

Burying residues will eliminate the threat from residues and speed residue decomposition - BUT residues returned to the soil surface will still support inoculum production.

*F. graminearum* appears to be one of the earlier colonizers of residues - pathogenic phase may give it a competitive advantage as a saprophyte.
Previous Crops and Tillage
Previous crops and tillage study

Field trial - Morris, MN
- previous crops - corn, wheat and soybean
- tillages - moldboard plow, chisel plow and no-till
- followed with a crop of ‘Norm’ wheat (FHB susceptible)

Dill-Macky and Jones
Plant Disease 2000
Replications: 5
Plot size: 9 m x 6 m
Location/years: 6
(3 yr, dryland and irrigated)
<table>
<thead>
<tr>
<th></th>
<th>Corn</th>
<th>Wheat</th>
<th>Soy</th>
<th>Avg.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MP</strong></td>
<td>12 bc</td>
<td>9 ab</td>
<td>5 a</td>
<td>9 r</td>
</tr>
<tr>
<td><strong>CP</strong></td>
<td>42 e</td>
<td>34 d</td>
<td>17 c</td>
<td>31 s</td>
</tr>
<tr>
<td><strong>NT</strong></td>
<td>67 f</td>
<td>83 g</td>
<td>46 e</td>
<td>65 t</td>
</tr>
<tr>
<td><strong>Avg.</strong></td>
<td>41 y</td>
<td>42 y</td>
<td>23 z</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Corn</td>
<td>Wheat</td>
<td>Soy</td>
<td>Avg.</td>
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<tr>
<td>-------</td>
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<td>-------</td>
<td>-------</td>
<td>------</td>
</tr>
<tr>
<td><strong>MP</strong></td>
<td>17 b-e</td>
<td>16 a-d</td>
<td>14 a-c</td>
<td>16 r</td>
</tr>
<tr>
<td><strong>CP</strong></td>
<td>26 f</td>
<td>19 c-e</td>
<td>16 a-e</td>
<td>20 s</td>
</tr>
<tr>
<td><strong>NT</strong></td>
<td>26 f</td>
<td>20 de</td>
<td>17 b-e</td>
<td>21 s</td>
</tr>
<tr>
<td><strong>Avg.</strong></td>
<td>23 z</td>
<td>18 y</td>
<td>16 x</td>
<td></td>
</tr>
</tbody>
</table>

**Disease severity (%)**
<table>
<thead>
<tr>
<th></th>
<th>Corn</th>
<th>Wheat</th>
<th>Soy</th>
<th>Avg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>MP</td>
<td>9.7 c-f</td>
<td>7.9 a-e</td>
<td>6.5 a-c</td>
<td>8.1 r</td>
</tr>
<tr>
<td>CP</td>
<td>15.0 g</td>
<td>9.2 b-f</td>
<td>7.4 a-e</td>
<td>10.6 s</td>
</tr>
<tr>
<td>NT</td>
<td>15.6 g</td>
<td>10.7 d-f</td>
<td>6.9 a-d</td>
<td>11.1 s</td>
</tr>
<tr>
<td>Avg.</td>
<td>13.5 z</td>
<td>9.2 y</td>
<td>6.9 x</td>
<td></td>
</tr>
</tbody>
</table>
Previous Crop Residues and Tillage

Wheat and barley residues likely as good a host as corn - BUT corn residues persist longer as they are larger and resist breakdown - Bt-corn may exacerbate this!

In field inoculum impacts FHB - BUT likely will only have impact on epidemics when exogenous inoculum is limiting - which might not be often

No-till might actually be better than some reduced tillage practices (chisel plowing) residue-moisture interactions
Corn microplot experiments:
Consequences of having corn residues in a wheat field?

Naturally overwintered, local corn stalks

Lab-inoculated corn stalks

Wheat Microplot Experiment at Weaver Farm, Steuben CO. NY

© G.C. Bergstrom
Pilot corn debris microplot experiments in commercial wheat fields in New York in 2007-08
Spikes above natural corn debris and above clonal inoculum one-tenth or one-hundredth strength showed higher infection and DON than control, but not statistically significant differing.
Twenty-one corn debris microplot experiments in winter wheat fields in five states (2009-2010)

Gary Bergtrom, Carl Bradley, David Schmale, Laura Sweets, Stephen Wegulo

Plus nine satellite experiments in Michigan, Vermont, Ontario, and Quebec

Collaborators:
Ann Hazelrigg, Martin Nagelkirk, Albert Tenuta, Pierre Filion, Sylvie Rioux
Corn residue resulted in a significantly higher level of DON in only 8 out of 31 fields with microplots:
1- Michigan
5- New York
2- Ontario
Previous Crop Residues and Tillage

Spores liberated from within-field debris may provide a significant fraction of inoculum for a given field though often less than 30% (most important in FHB-limiting environments)

Regional, atmospheric spore populations generally provide more inoculum than within-field sources (especially under FHB-conducive environments)

Inoculum (debris) management strategies in individual fields may result in incremental reductions of FHB & DON, and thus contribute to integrated management
Residue Management
Influencing the survival of *Fusarium* in wheat residues

**Field trials - Crookston, Ulen & Humboldt, MN**
- wheat residue - crop harvested
- residue flamed 1-5 days post planting (wheat and barley) using a propane-powered alfalfa burner
  - light (1.3 m/s) and severe (0.5 m/s)
- wheat residues, soil samples and wheat and barley plants were collected over the season for analysis

Dill-Macky and Salas
*Plant Disease* 2004
## Effect of flaming residues

<table>
<thead>
<tr>
<th></th>
<th>Nodes (no./m²)</th>
<th>F.g. survival (%)</th>
<th>F.g. in soil (cfu/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>62 a</td>
<td>33 a</td>
<td>693 a</td>
</tr>
<tr>
<td>Light</td>
<td>46 b</td>
<td>13 b</td>
<td>598 b</td>
</tr>
<tr>
<td>Severe</td>
<td>36 c</td>
<td>9 b</td>
<td>522 b</td>
</tr>
</tbody>
</table>
Impact of flaming on *Fusarium* survival in residues

![Graph showing the impact of flaming on *Fusarium* survival in residues across different sites (Crookston, Ulen, Humboldt). The x-axis represents the site, and the y-axis represents the survival percentage of *Fusarium* in nodes. The graph compares the control and burned conditions, with green bars representing control and orange bars representing burned. The survival percentage ranges from 0 to 30% for Crookston and Ulen, with a notable increase in survival for Humboldt.](image-url)
Targeting *Fusarium* in residues

Residues need not be entirely destroyed to reduce the colonization by pathogens, including *F. graminearum*.

Flaming residues is an impractical solution for FHB - BUT demonstrates proof of concept that treating residues to reduce *Fusarium* pathogens may provide a measure of control esp. when sources of exogenous inoculum are limiting.

*F. graminearum*, and other pathogens of wheat and barley, are not evenly distributed in the canopy (data not shown) - the distribution may provide clues as to the source(s) of inoculum.
Effect of host resistance on FHB

Field trials - Rosemount, MN
- wheat residues
  - susceptible - Wheaton, Norm
  - mod. susceptible - 2375, Ingot
  - mod. resistant - Backup, Alsen
- chisel plowed after harvest
- planted to ‘Wheaton’ wheat in spring
- \( F.g \) isolated from i) residues, ii) air in canopy at early dough - Komada plates, iii) plants at hard dough

Dill-Macky and Salas
Plant Disease 2004
Effect of 2003 wheat cultivar selection on the airborne *Fusarium* inoculum in 2004 crop

![Chart showing the effect of wheat cultivars on airborne Fusarium inoculum in 2004 crop. The chart compares the inoculum levels of different cultivars at two stages: Anthesis and Early Dough. The chart includes cultivars such as Wheaton, Norm, Ingot, 2375, BacUp, and Alsen.]

Salas and Dill-Macky
Phytopathology 2005
Effect of host resistance on *Fusarium* survival

Resistance to FHB in wheat influences the colonization of residues as measured by their ability to support *Fusarium* survival and inoculum production.

FHB resistance can provide benefits in future cropping seasons by reducing future inoculum - differences likely to be more evident in commercial fields than small plots used in research.
Residues are problematic as they harbor the initial inoculum from which epidemics may develop

increased corn acreage
esp. Bt-corn
other host & nonhost residues
Residues Management Strategies for FHB in Barley

Avoid growing barley in proximity to cereal debris
  Crop Rotation: follow non-host crops
  Use underseeded crops as a barrier to splash dispersal

Remove or destroy cereal debris
  Tillage: bury debris by plowing, burning or harvesting residue
  Chopping, splitting, or other size reduction

Treat debris to reduce *Fusarium* survival/sporulation
  Green manures, organic acids, C/N sources, soil, clay, lime, microbial inoculants

Reduce *Fusarium* content in debris
  Plant resistant cereals
An argument for cultural control practices in the management of FHB

Very susceptible cultivars have been eliminated from production in FHB prone regions.

Resistance has been improved - BUT it is unrealistic to anticipate that barley or wheat cultivars immune to FHB will be developed or that the best resistance(s) available will be sufficient to eliminate the risk of FHB.

Improved levels of resistance will however:

i) reduce the risk of FHB in the growing season AND

ii) reduce the risk of future epidemics by reducing the level of *Fusarium* in crop residues.
An argument for cultural control practices in the management of FHB

Chemical control is needed in the management of FHB.

Improved application technologies and the development of forecasting systems have improved our ability to use fungicides as control measures.

High inoculum pressure and weather conditions favorable for disease can still overwhelm best management practices.
- research possibilities for cultural control of FHB -

Eliminating *Fusarium* inoculum from residues - chemical control directed to the residues, interfering with *Fusarium* sporulation

Promoting residue decomposition - shredding (Bt-corn), soil amendments that increase decomposition rates

Formulating biological control agents for greater efficacy

Promoting *Fusarium*-antagonists - green manures, soil amendments or applications of fungicides or BCA’s directed to reducing *Fusarium* in residues

Any solution must be able to be effectively integrated into the production system for cereal crops
What is the contribution of cultural control to integrated management of FHB/DON?

No single answer for all environments and cropping systems.
Scab Smart provides information on key management information for each small grain class affected by this disease in the US. Scab Smart is intended as a quick guide to the integrated strategies that result in optimum reduction in Fusarium Head Blight (FHB=Scab) and the primary associated mycotoxin (DON). Click on the following links to learn about strategies for your grain class or use the top drop-down menus for faster navigating:

- Variety Resistance
- Scab Forecasting
- Fungicides
- Crop Rotation
- Other Management Strategies: Residue Management, Planting Date, Harvest Practices, Seed Treatment

All information provided is based on successful strategies identified by extensive research supported by the US Wheat and Barley Scab Initiative with funding provided by USDA-ARS.

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