Global Occurrence and Economic Consequences of Stripe Rust in Wheat

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University of Minnesota, CSIRO, and CIMMYT

Advancing Pest and Disease Modeling Workshop
February, 2015
Policy Questions regarding Crop Diseases

- Geographic Extents
- Share of Crop Production Susceptible
- Associated Crop Losses
- Economically Justified Investment
Wheat Rust Diseases

Disease Cycle

Primary Host

Alternate Host

Wheat

Berberis spp.

Disease Cycle:

- Uredinia
- Telia
- Aecia
- Pycnia

Wind Dispersal

Puccinia Pathway

Source: USDA CDL
Wheat Rust Diseases

**Extent**
- Occurring almost all wheat growing countries
- Spreading across continents

**Frequency**
- Increasing frequency in the last decade

**Impact**
- Stem Rust Ug99
- Stripe Rust Yr9 and Yr27

Photo source: CIMMYT
AGRICULTURE

Right-Sizing Stem-Rust Research

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Is increased support needed for wheat disease research to avert crop losses from current and future strains?

Climate suitability of stem rust

- Suitable
- Persists
Stem Rust Losses in the U.S.

Average 2.25% per year

Average 0.26% per year

Effective Resistance Breeding

Author’s calculation based on USDA CDL data
Stem Rust:
Global Assessment Summary

- A sustained investment of $51.1 million per year (2010 prices) in stem rust research could be justified economically.
Stripe Rust Losses in the U.S. (by year)

Author’s calculation based on USDA CDL data
Stripe Rust Losses in the U.S. (by state)

<table>
<thead>
<tr>
<th>Year</th>
<th>Region Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-2000</td>
<td>Mainly the Pacific Northwest (PNW) region</td>
</tr>
<tr>
<td>Post-2000</td>
<td>PNW and central states</td>
</tr>
</tbody>
</table>

Author’s calculation based on USDA CDL data
Expanding Geography of Stripe Rust

Data source: 2013 BGRI-HarvestChoice Survey
Stripe Rust

• **Expanding Geography**
  • US: epidemics expand from PNW (pre-2000) to Central States (post-2000) ([Chen 2005](#))
  • CWANA: Yr9 and Yr27 driven epidemics since 1980s ([Solh et al. 2012](#))
  • South Africa: first report of stripe rust during 1996 ([Pretorius et al. 1997](#))
  • Australia: annual $40-90 million spent on fungicides ([Wellings 2007](#))

• **Aggressiveness / Increased Fitness**
  • Isolates collected since 2000 are better adapted at warmer temperatures ([Milus et al. 2009](#))
  • Other factors contributed to increased aggressiveness ([Loladze et al. 2014](#))
Research Method

- Stripe Rust Global Occurrence Model
- Stripe Rust Loss Data
- Simulation
- Probabilistic Consequences of Wheat Stripe Rust
CLIMEX Model of Pests and Diseases

- **Known Distribution**: Location, Frequency, Severity
- **Climate Data**: Temperature, Moisture, Stress, Latency
- **Species Parameters**: Temperature, Moisture, Stress, Latency

CLIMEX Pest Model
CLIMEX Pest Model

**Species Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture Index</td>
<td>0.2, 0.7, 1.5, 2.5</td>
</tr>
<tr>
<td>Temperature Index</td>
<td>DV0, DV1, DV2, DV3</td>
</tr>
<tr>
<td>Light Index</td>
<td>VD</td>
</tr>
<tr>
<td>Dispanose Index</td>
<td>DTCS, TCHS, DTCSA, TCHS</td>
</tr>
<tr>
<td>Cold Stress</td>
<td>0</td>
</tr>
<tr>
<td>Heat Stress</td>
<td>0</td>
</tr>
<tr>
<td>Wet Stress</td>
<td>0.2, 0.005</td>
</tr>
<tr>
<td>Dry Stress</td>
<td>0.2, 0.3</td>
</tr>
</tbody>
</table>

**Climate Data**

- **Locations**: World
- **Climate Change Scenario**: No Climate Change
- **Irrigation**: Not Set
- **Species**: Puccinia striiformis

**Model Output**

- Run on: Feb 14 2015, 18:16
- Parameter File: C:\GYmax\Models\CLIMEX\Compare Locations (1 species).gmp
- Run Type: Multiple (World)
- Description: CLIMEX - Compare Locations (1 species) Puccinia striiformis Run on Feb 14 2015 18:16 World

Map showing model output with regions shaded based on conditions.
Modeled global climate suitability for stripe rust (Beta)

<table>
<thead>
<tr>
<th></th>
<th>Seasonably vulnerable</th>
<th>Persistently vulnerable</th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>89.5</td>
<td>56.7</td>
</tr>
</tbody>
</table>

- **Suitable**
- **Persists**
- **Reported**
Sub-Saharan Africa (Beta)

- Suitable
- Persists
- Reported
Europe, North Africa and the Middle East (Beta)
Asia (Beta)

Suitable
Persist
Reported
Stochastic Structure of U.S. Losses Attributed to Stripe Rust

1961-1984: significant yield losses
1985-1999: use of resistant cultivars and fungicide
Since 2000: new stripe rust pathotypes

Average 0.54% per year

Average 1.5% per year

Average 0.15% per year
Research Method

Stripe Rust Global Occurrence Model

Stripe Rust Loss Data

Simulation

Probabilistic Consequences of Wheat Stripe Rust
15 Epidemiological Zones

- Following Saari and Prescott (1985), 15 Epidemiological Zones
  - Epidemic in each epidemiological zone occurs independently
- HavestChoices Spatial Allocation Model (SpAM)
  - 10 arc minute resolution: Output / Area / Yield
Estimate R&D benefits

Disease Free Yield

Losses

Observed Yield (Susceptible Wheat)

R&D Benefits

Observed Yield (Resistant Wheat)

Present Value of Cost \times (1 + 10\%)^T = \text{Future Value of Benefits}
Monte Carlo Simulation

Step 1
- Observed yield
- Disease Free Yield

Step 2
- Counterfactual yield assuming two scenarios:
  - Low losses: with resistant varieties
  - High losses: without resistant varieties

Step 3
- Value of losses avoided
### Probabilistic Losses Attributable to Stripe Rust

<table>
<thead>
<tr>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Volume (million tonnes)</td>
<td>Value (million $US)</td>
</tr>
<tr>
<td>90</td>
<td>≥ 0.65</td>
<td>≥ 172</td>
</tr>
<tr>
<td>50</td>
<td>≥ 0.79</td>
<td>≥ 209</td>
</tr>
<tr>
<td>20</td>
<td>≥ 0.88</td>
<td>≥ 235</td>
</tr>
<tr>
<td>5</td>
<td>≥ 0.98</td>
<td>≥ 262</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Benchmarked relative to 1985-1999 U.S. losses*
# Research Investments Attributable to Rust

**Economic justification:**
Developing effective resistance through R&D investment is more beneficial than exposing susceptible wheat to rust epidemics

<table>
<thead>
<tr>
<th>Reference Period</th>
<th>Stripe Rust</th>
<th>Stem Rust</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000-2050</td>
<td>$38.6 million (2010 prices)</td>
<td>$51.1 million</td>
</tr>
<tr>
<td>Annual Spending (Economically Justifiable)**</td>
<td>Preliminary Data: Do Not Quote (18 cents)</td>
<td>(23 cents)</td>
</tr>
<tr>
<td>Per Hectare*</td>
<td>(18 cents)</td>
<td>(23 cents)</td>
</tr>
</tbody>
</table>

*In comparison, U.S. wheat farmers spent $27.69 per hectare on seed in 2010

**Actual stem rust R&D spending is estimated less than half the amount, and stripe rust spending is even less than stem rust
Summary

• Rapid spread of stripe rust epidemics
  • Spatial expansion: almost 90 percent of the world’s wheat production is susceptible to stripe rust
  • Frequency increase
  • Losses severe

• Our (beta) assessment suggests that around $39 million per year be spent to alleviate global losses from stripe rust
  • About three quarters the corresponding stem rust research investment
  • Difference
    • Stem Rust: projected losses
    • Stripe Rust: observed losses

Preliminary Data: Do Not Quote
Future Work: Leaf Rust

Leaf Rust in the U.S.

% Loss

Author’s calculation based on USDA CDL data
Thanks