Management of Field Crops Diseases: Past, Present and Future

Bruce D. Gossen

Saskatoon Research & Development Centre, AAFC

IHARF, Balgonie SK  February 7, 2018
Disease Management – Past and Present

- Crop residue was buried.
- Windbreaks, pastures, and headlands for diversity.
- Crop rotation largely for weed management.
  - Provided interval for residue breakdown.
  - Also provided natural biological control.
- Improved herbicides facilitate short rotations, reduced tillage, few windbreaks / pastures.
- Disease management increasingly reliant on major gene resistance and fungicides.
Gossen’s Guide to Disease Management

- Disease management activities should be almost complete **BEFORE** any crop is planted.

- Plan for a diverse crop rotation
  - 3- to 4-yr, alternating cereals with dicots. Even different cultivars can be useful if they carry different sources of resistance.

- Use the best genetics for your region.
  - High yield, suitable days to harvest, good disease resistance.

- Don’t plant problems with the crop.
  - Use seed with high germination and vigour, treated & inoculated, minimal / no pathogens with seed.

- Provide isolation from last year’s heavily infected fields.

- Scout fields and apply a foliar fungicide only if required.
Cropping Systems Study

- Split-split-plot design with four replicates.
- Main plots were three levels of inputs.
  - High (HIGH) – selected to maximize yield.
  - Reduced (RED) – selected to minimize costs.
  - Organic (ORG) – no synthetic inputs.
- Subplots were levels of cropping diversity.
  - Fallow-annual grains (LOW).
  - Diversified annual grains (DAG).
  - Diversified annuals and perennials (DAP).
- Sub-sub plots were replicates.
Disease severity on barley, final years

B. Barley (flag leaf)

Severity (%)

- High
- Reduced
- Organic

2007 2008 2009 2010 2011 2012 2013

Graph showing the severity of disease on barley from 2007 to 2013, with lines representing high, reduced, and organic treatment groups.
A. Wheat (flag leaf)

B. Barley (flag leaf)

C. Field pea

D. Canola/Mustard
Wheat yield, by cycle and input

Grain Yield, kg ha\(^{-1}\)

Cycle

1996-2001
2002-2007
2008-2013
All Years

HI
RED
ORG

0
500
1000
1500
2000
2500
3000
3500
4000
Conclusions

- Start with no disease problems, don’t bring in problems, and use a reasonable rotation. Result: No major problems!

- Input level and cropping rotation had no consistent impact on foliar disease severity in moderate- to highly-diverse rotations assessed over 18 years.

- Weather conditions had a large impact on foliar disease severity among years.

- Higher profits from careful mgnt of inputs.
History of Fungicide Usage

- Initially, persistent actives with multi-site modes of action, e.g., heavy metals.

- Shift to focus on reduced-risk actives (usually non-persistent, single-site modes of action).

- Reduced sensitivity usually detected first under high selection pressure.

- Viticulture, golf courses, orchards > hort crops > intensive field crops > extensive field crops
## Fungicide Usage on the Canadian Prairies

<table>
<thead>
<tr>
<th>Province</th>
<th>Production area (M ha)</th>
<th>Fungicide applied (%)</th>
<th>↑Δ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2006</td>
<td>2011</td>
</tr>
<tr>
<td>Alberta</td>
<td>7.0</td>
<td>7</td>
<td>15</td>
</tr>
<tr>
<td>Saskatchewan</td>
<td>10.9</td>
<td>7</td>
<td>21</td>
</tr>
<tr>
<td>Manitoba</td>
<td>3.5</td>
<td>23</td>
<td>47</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>21.3</strong></td>
<td><strong>11</strong></td>
<td><strong>23</strong></td>
</tr>
<tr>
<td>Ontario</td>
<td>2.4</td>
<td>11</td>
<td>17</td>
</tr>
</tbody>
</table>
Risk of insensitivity to strobilurins was high:

- Genetically diverse pathogen.
- Air-borne sexual spores.
- Several fungicide appl. / yr.
- Insensitivity in related fungi.

N.B. Resistance reported first in SK, but then ND & AB.
## Increase of Insensitive Isolates in SK

<table>
<thead>
<tr>
<th>Year</th>
<th>Data</th>
<th>Insensitive (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004–2005</td>
<td>Headline 53 isolates Susc</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>Quadris 4 R, 49 S</td>
<td>8%</td>
</tr>
<tr>
<td>2006</td>
<td>Headline 20 R, 17 S</td>
<td>50%</td>
</tr>
<tr>
<td></td>
<td>Quadris 23 R, 14 S</td>
<td>68%</td>
</tr>
<tr>
<td></td>
<td>Control failures</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6 of 7 fields</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>1 field</td>
<td>0%</td>
</tr>
<tr>
<td>2007</td>
<td>132 R, 4 S</td>
<td>97%</td>
</tr>
<tr>
<td>2008</td>
<td>74 R, 7 S</td>
<td>92%</td>
</tr>
</tbody>
</table>
Mycosphaerella pinodes from field pea

- Pathogen at high risk of loss of sensitivity to strobilurins.
- Baseline assessment conducted using isolates collected in SK, AB, ND & WA before 2003.
- 8% of isolates from SK & AB insensitive, 0% from ND & WA.
- Populations in SK & AB at risk of loss of efficacy using strobilurins.
Fungicide insensitivity in SK 2013–2016

- 72% (46/64) isolates of *M. pinodes* insensitive.
  - Strobilurins likely no longer effective in the field.

- Crop health benefit assessment
  - No benefit on pea or chickpea.
  - Early season benefit at one site-yr on lentil.

- 24% (13/54) isolates of *A. lentis* from lentil insensitive.
  - Levels only slightly higher than baseline from 10 yr ago.

- 10% (2/22) isolates of *Colletotrichum lentis* from lentil insensitive (baseline).

- 25% (2 of 8) isolates of *A. rabiei* insensitivity
Factors Affecting Risk of Insensitivity

Pathogen
- No. of generations
- Spore production
- Spore dispersal
- Occurrence of disease
- History of resistance

Agronomic
- Alternation/Combination
- No. of different MOAs
- No. of applications
- Resistant varieties
- Cropping system
- Residue management

Fungicide
- Single/Multi-site
- Persistence
- Intrinsic activity
- Resistance factors

Overall Resistance Risk

Source: K. Polziehn
The Present

- Crop rotations are getting shorter – producers specializing.
- Fields getting larger – less habitat for natural biocontrols.
- New, long-lived pathogens becoming a problem (invasives!).
  - Few / no strong sources of resistance, rapid breakdown.
  - Fungicides ineffective or timing is problematic.
- Need new management tools!
Clubroot on Canola

- Cause: *Plasmodiophora brassicae* (Woronin).
- Attacks mainly *Brassica* spp.
- Important wherever Brassica crops are grown, e.g., China.
- Causes stunting, delayed maturity, yield loss, and plant death.
Spore conc. after Susceptible Canola

$y = 1 \times 10^7 e^{-0.76x}$

$R^2 = 0.65$

Spores g$^{-1}$ soil (log scale)

Break following a susceptible crop (years)
Temperature x pH

Disease severity index

Temperatures °C

- 0-20
- 20-40
- 40-60
- 60-80
- 80-100

pH

0
20
40
60
80
100
15
20
25
6.0
6.5
7.0
7.5
8.0
Aphanomyces root rot of pea (and lentil)
Aphanomyces disease nursery, July 2016
The Future

Niels Bohr (1885–1962)

“Prediction is very difficult, especially if it is about the future”
What won’t change?

- Many problem diseases will remain difficult to manage.
  - Fusarium head blight.
  - Clubroot on canola.
  - Soil-borne pathogens, e.g., *Aphanomyces*.

- Introduction of new pests.

- Pests change if a strong selection pressure is applied.
  - Insensitivity, loss of resistance.
Agricultural equipment has gotten bigger and bigger.

What has changed?
The future is now!

- Programs already exist that:
  - Monitor environment, diseases, crop growth stage, cultivar resistance, and nitrogen status of the crop.
  - Calculate infection probabilities.
  - Recommend specific fungicides for specific diseases.
  - Recommend spray timing.
  - Replace persistent pesticides with reduced-risk products, biopesticides and biocontrols.
Detection and Diagnostics

- DNA technologies for rapid ID of pests.
  - Barcode of Life – Will develop into on-site identification.
  - Genome sequencing
  - ELISA (enzyme-linked immunosorbent assay).
  - PCR (polymerase chain reaction).
  - LAMP (loop mediated isothermal amplification).

- Already used routinely at points of entry into a country, and soon on individual fields.
The future is now!
Remote counting of pathogens and insects

BASF display, U.K.
Internet/ cell phone connectivity is everywhere
Other approaches to plant protection

- Rhizosphere ‘microbiome’.
  - Better understanding and use of mycorrhizae & endophytes (microbes around, on, or in host plants).
- Products that induce resistance.
- RNAi = gene silencing.
Near future?

- Driverless vehicles and farm equipment.
  - Better batteries for local use of solar energy on a 24-hr basis.
  - Focused application of pesticides (hots spots, applied at night).

- Plant breeding
  - Marker-assisted selection for complex resistance (stacked genes, partial resistance, isolines).
  - Genome editing (e.g., CRISPR/Cas9).

- Better long-term weather forecasts.

- Machine learning in computers.
  - Semi- or completely autonomous to deal with ‘Big Data’.
  - Improvements in precision agriculture.
Still to come:

- **Chemical detectors**
  - A “nose” to detect the chemical signature of plant pathogens and pests at points of entry, on imported food & plant materials.
  - In the field, to detect the chemical signals that plants emit when under attack from diseases, insects and other stresses.
  - Robotics and UAVs for scouting and crop protection.

- **Small fields for greater biodiversity**
  - Smaller field equipment for intercropping, strip cropping, hedgerows and reduced compaction.
  - Benefits for soil health and natural enemies.

- **Optimize cropping rotations.**
Human operators will be required to maintain and manage this high tech gear. Will farms be run by individuals or corporations?
Acknowledgements

Thanks to:

- Funding from the Pulse and Canola Science clusters of Growing Forward I and II, the Canola Council of Canada, provincial producer associations, ADF and WGRF.

- The colleagues, post-docs, grad students and technicians who do the hands-on research!

- Dr. M.R. McDonald for many discussions of the future of disease management.
Questions?
Gossen’s Recipe for Hot Spots of Clubroot

- Identify and mark infested area.
  - Symptomatic plants / spores in soil samples.
  - Mark affected area (x2 at least!) in every direction.
  - Exclude all traffic from marked area.

- Initial treatment.
  - Fumigate and cover, or incorporate lime to pH 7.5.
  - Seed to sod-forming grass.
  - When a strong sod is established, traffic allowed.

- Evaluation and termination.
  - Use soil sampling to monitor spore conc.
  - When no longer detectable, break sod.
  - Use only clubroot-resistant cultivars.