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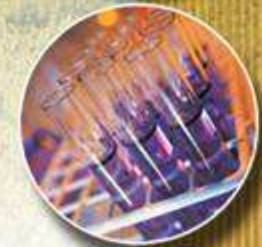

Management of Field Crops Diseases: Past, Present and Future

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IHARF, Balgonie SK   February 7, 2018

Canada

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.

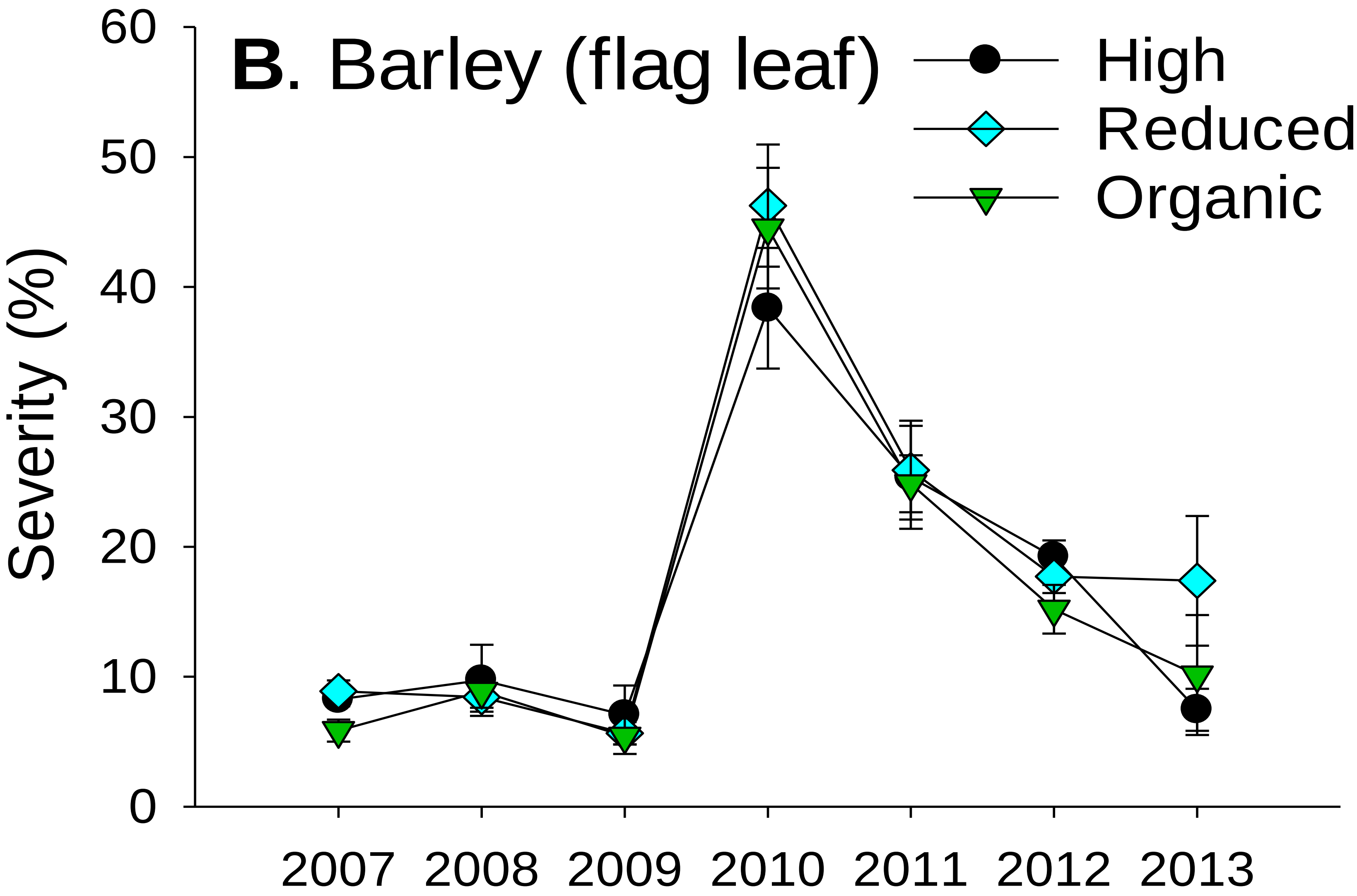
Gossen's Guide to Disease Management

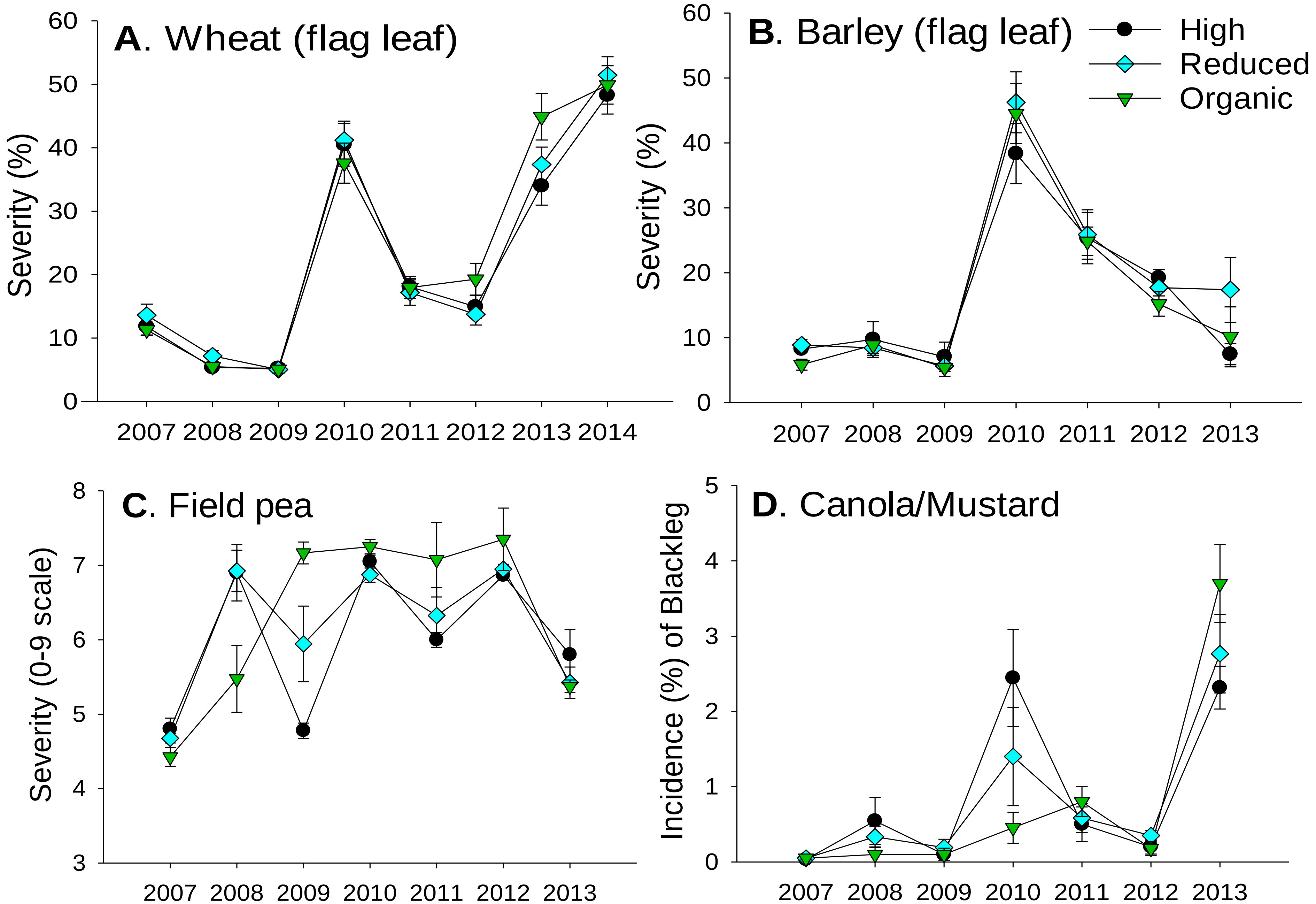
- Disease management activities should be almost complete **BEFORE** any crop is planted.
- Plan for a diverse crop rotation
  - 3- to 4-yr, alternating cereals with dicots. Even different cultivars can be useful if they carry different sources of resistance.
- Use the best genetics for your region.
  - 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

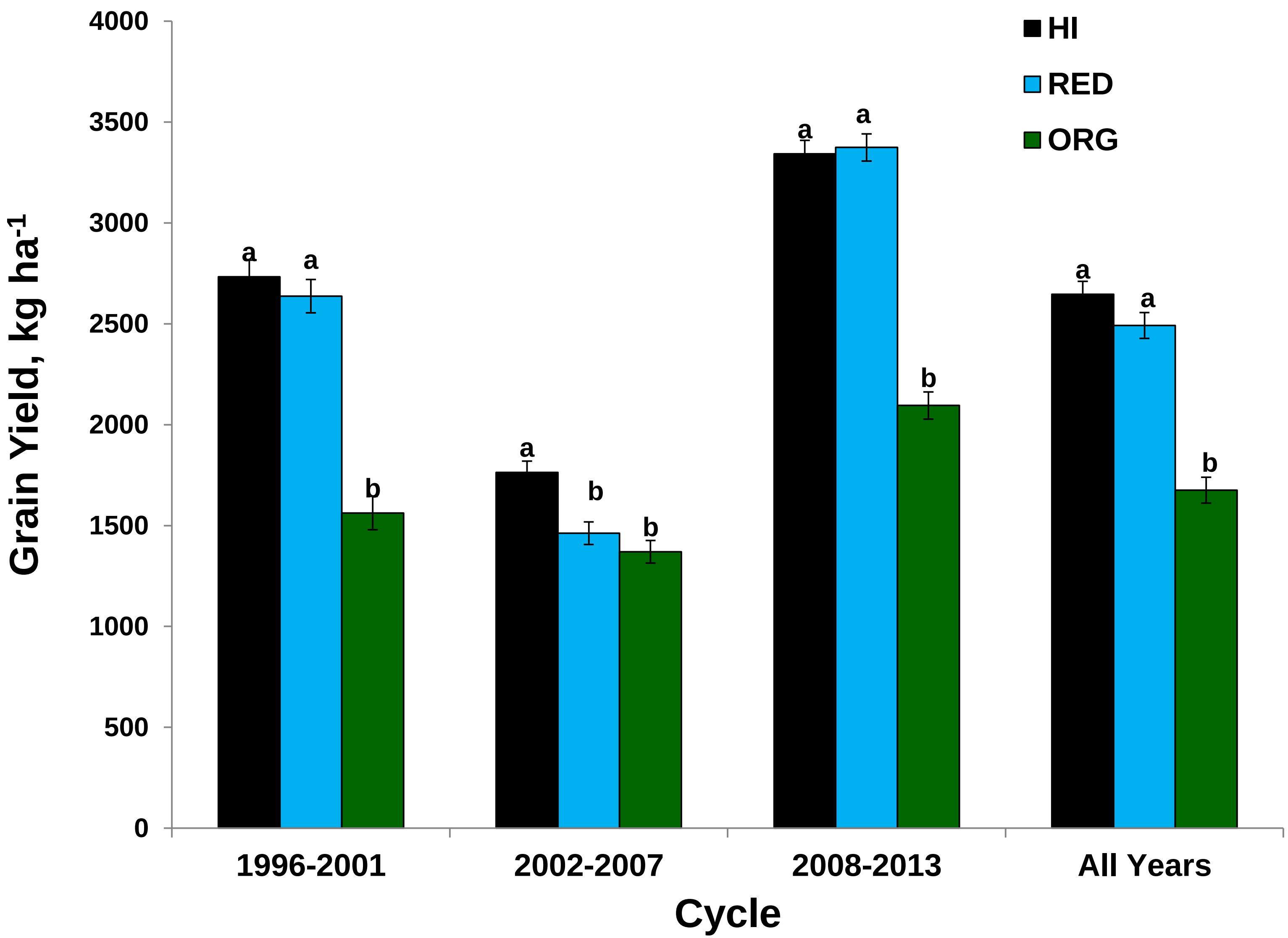
- Three 6-yr cycles, 1994–2012.
- Split-split-plot design with four replicates.
- Main plots were three levels of inputs.
  - High (HIGH) – selected to maximize yield.
  - Reduced (RED) – selected to minimize costs.
  - Organic (ORG) – no synthetic inputs.
- Subplots were levels of cropping diversity.
  - Fallow-annual grains (LOW).
  - Diversified annual grains (DAG).
  - Diversified annuals and perennials (DAP).
- Sub-sub plots were replicates.


Disease severity on barley, final years




A. Wheat (flag leaf)
Severity (%)
0
10
20
30
40
50
60
2007 2008 2009 2010 2011 2012 2013 2014
B. Barley (flag leaf)
High
Reduced
Organic
Severity (%)
2007 2008 2009 2010 2011 2012 2013
C. Field pea
Severity (0-9 scale)
3
4
5
6
7
8
2007 2008 2009 2010 2011 2012 2013
D. Canola/Mustard
Incidence (%) of Blackleg
0
1
2
3
4
5
2007 2008 2009 2010 2011 2012 2013

Wheat yield, by cycle and input



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

Province	Production area (M ha)	Fungicide applied (%)			↑Δ (%)
		2006	2011	2016	
Alberta	7.0	7	15	22	214%
Saskatchewan	10.9	7	21	33	374%
Manitoba	3.5	23	47	51	122%
Total	21.3	11	23	32	191%
Ontario	2.4	11	17	34	209%

Strobilurin Insensitivity in *Ascochyta rabiei*

Risk of insensitivity to strobilurins was high:

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

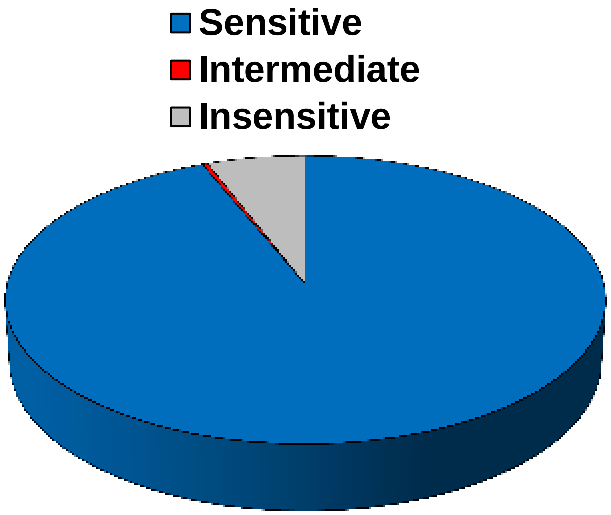
N.B. Resistance reported first in SK, but then ND & AB.

Increase of Insensitive Isolates in SK

	Insensitive (%)
2004–2005	
Headline 53 isolates Susc	0%
Quadris 4 R, 49 S	8%
2006	
Headline 20 R, 17 S	50%
Quadris 23 R, 14 S	68%
Control failures	
6 of 7 fields	100%
1 field	0%
2007 132 R, 4 S	97%
2008 74 R, 7 S	92%

Mycosphaerella pinodes from field pea

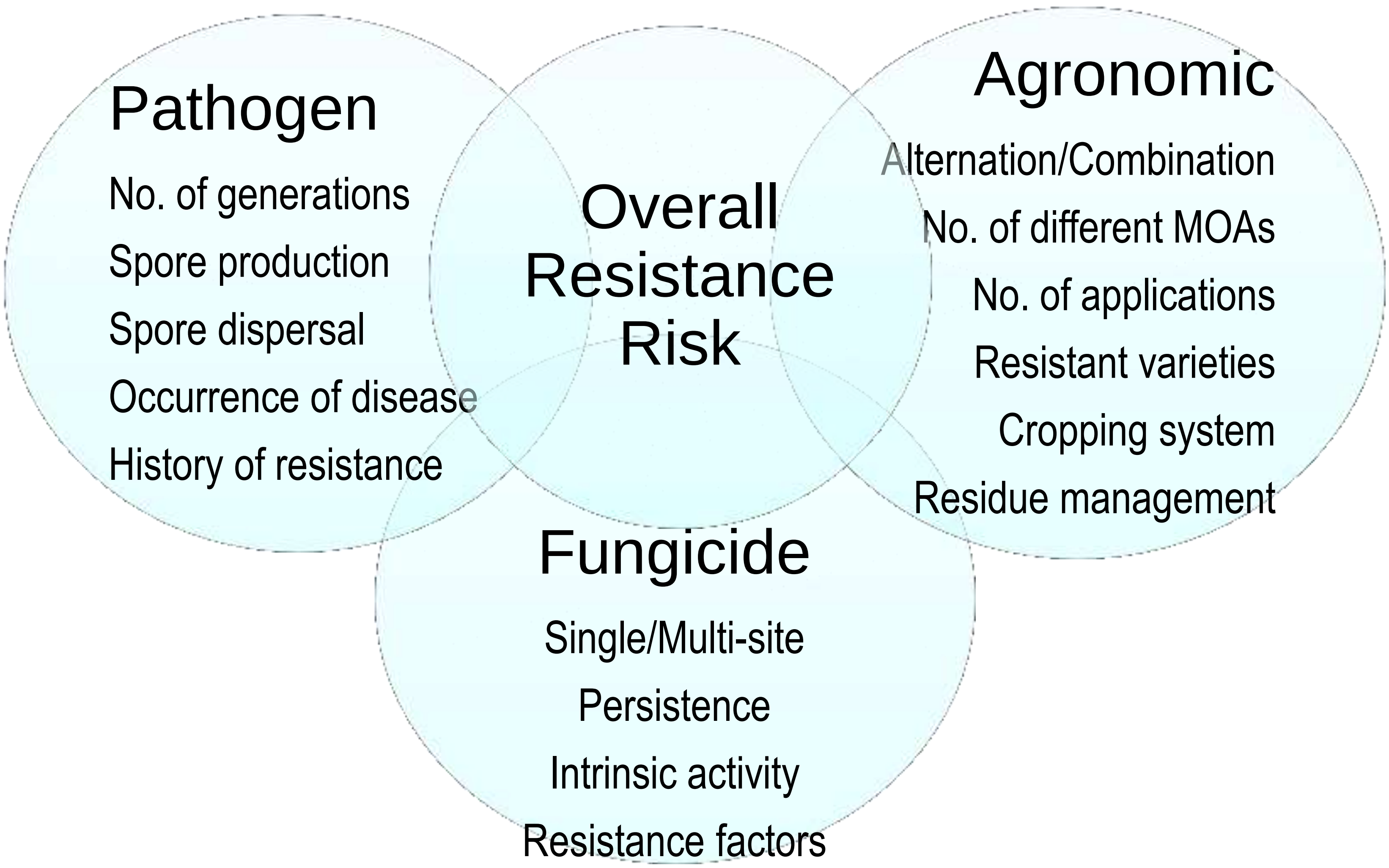
- Pathogen at high risk of loss of sensitivity to strobilurins.
- Baseline assessment conducted using isolates collected in SK, AB, ND & WA before 2003.
- Assessed > 300 isolates collected in 2010–2011.
- 8% of isolates from SK & AB insensitive, 0% from ND & WA.
- Populations in SK & AB at risk of loss 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* insensitivie

Factors Affecting Risk of Insensitivity



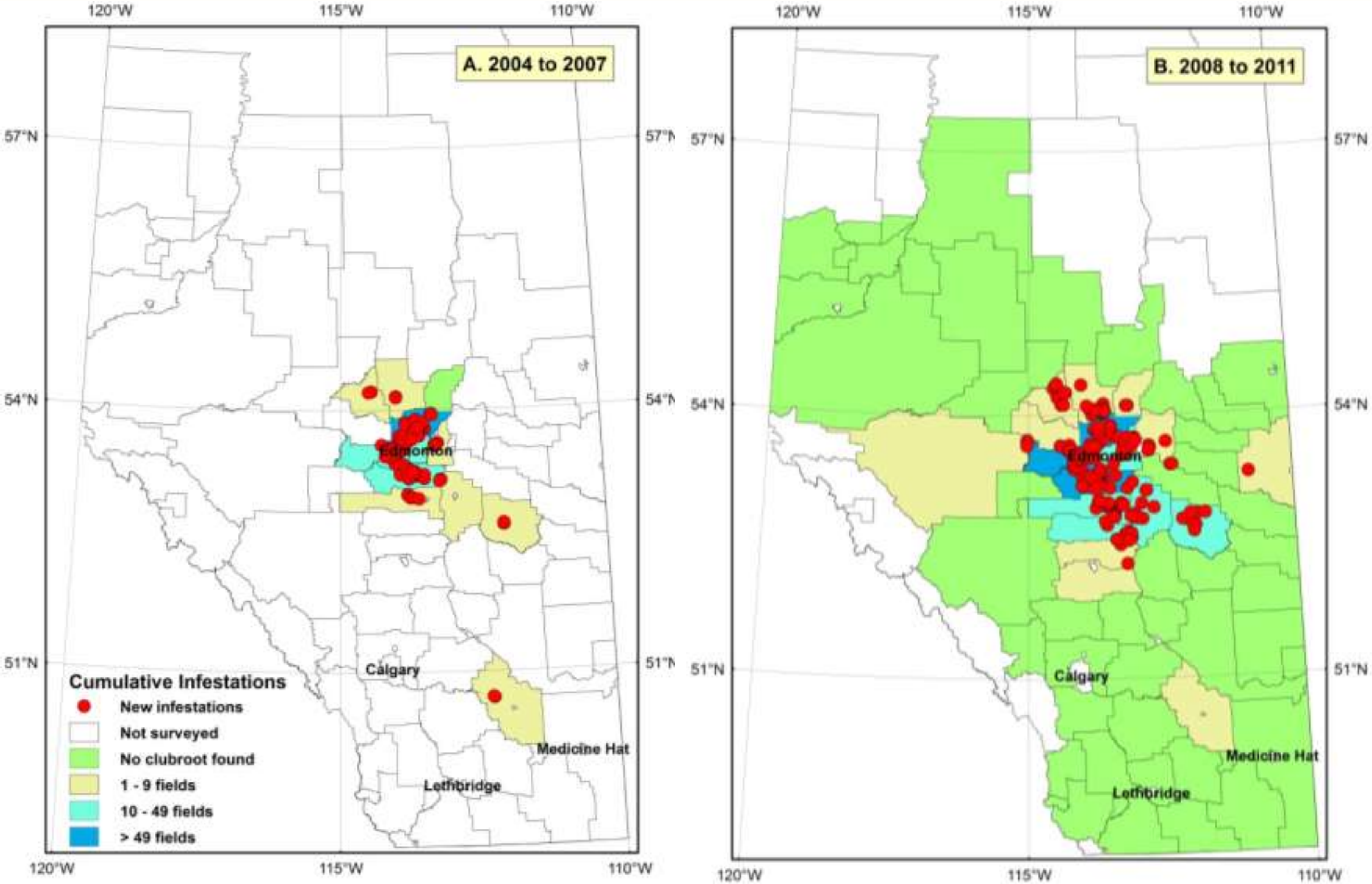
Source: K. Polziehn

The Present

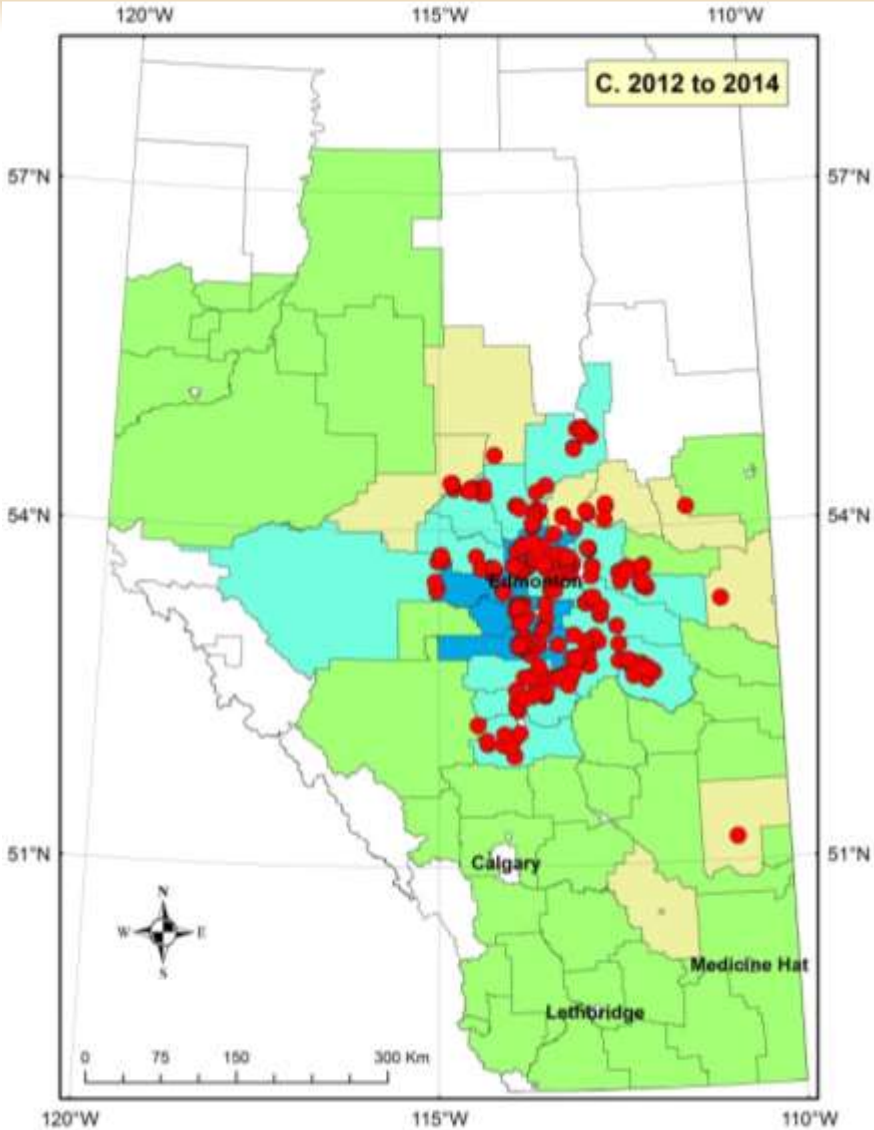
- Crop rotations are getting shorter – producers specializing.
- Fields getting larger – less habitat for natural biocontrols.
- New, long-lived pathogens becoming a problem (invasives!).
  - Few / no strong sources of resistance, rapid breakdown.
  - Fungicides ineffective or timing is problematic.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

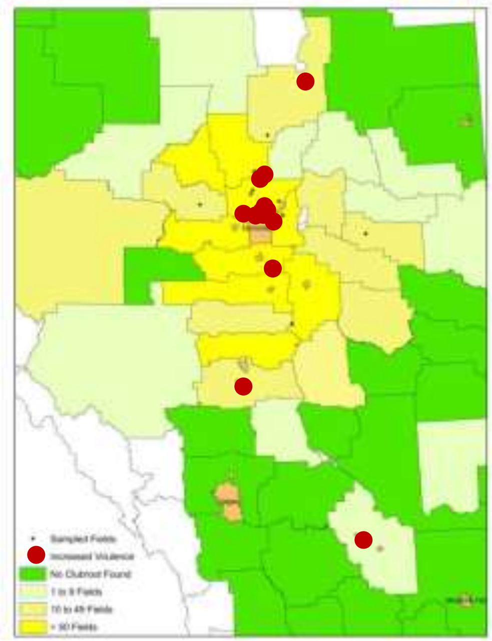
Clubroot on Canola

- 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.



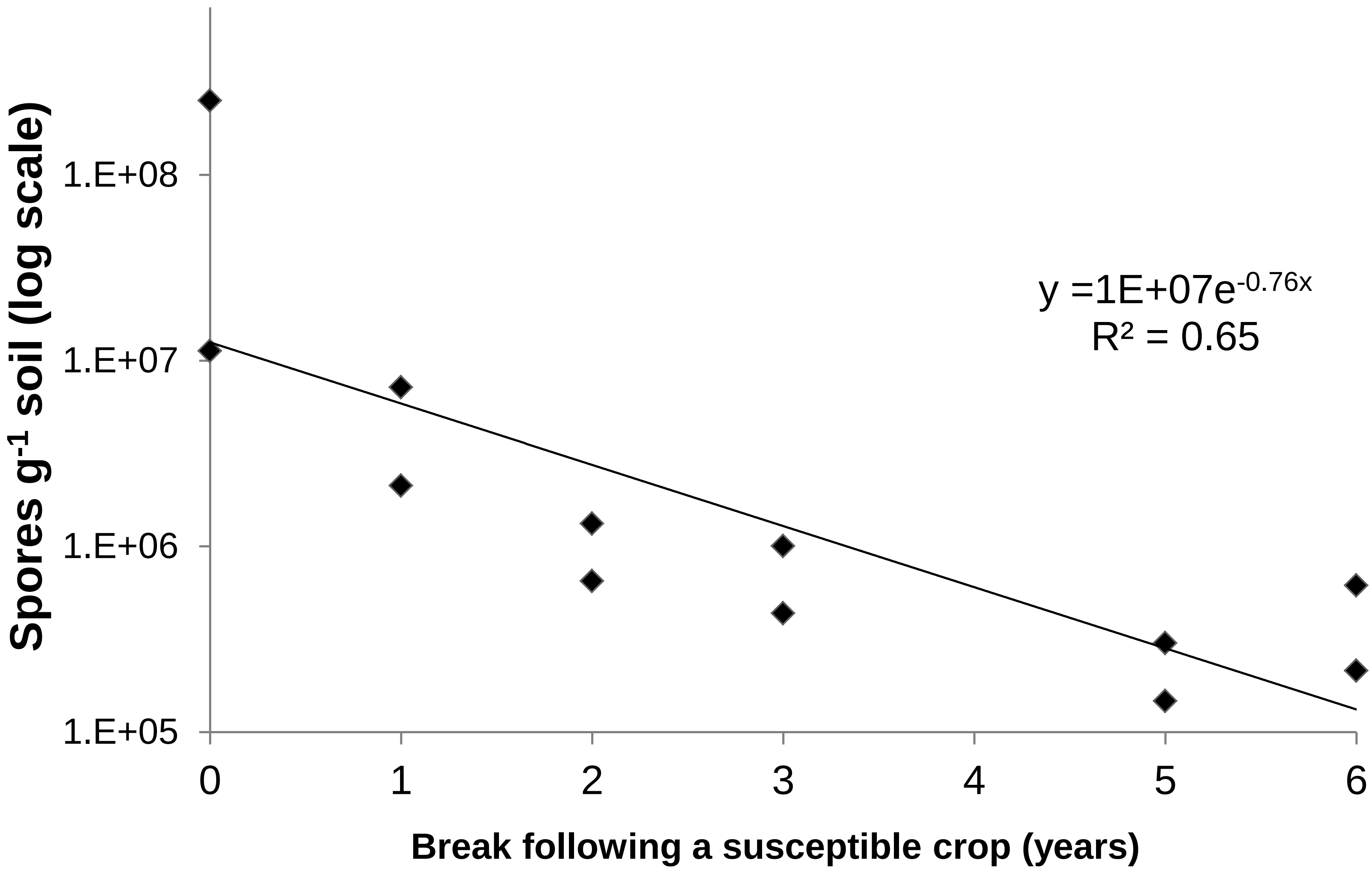
A. 2004 to 2007
B. 2008 to 2011
120°W
115°W
110°W
57°N
54°N
51°N
Edmonton
Calgary
Medicine Hat
Lethbridge
Cumulative Infestations
New infestations
Not surveyed
No clubroot found
1 - 9 fields
10 - 49 fields
> 49 fields


C. 2012 to 2014
120°W
115°W
110°W
57°N
54°N
51°N
Edmonton
Calgary
Medicine Hat
Lethbridge
N
W
E
S
0
75
150
300 Km

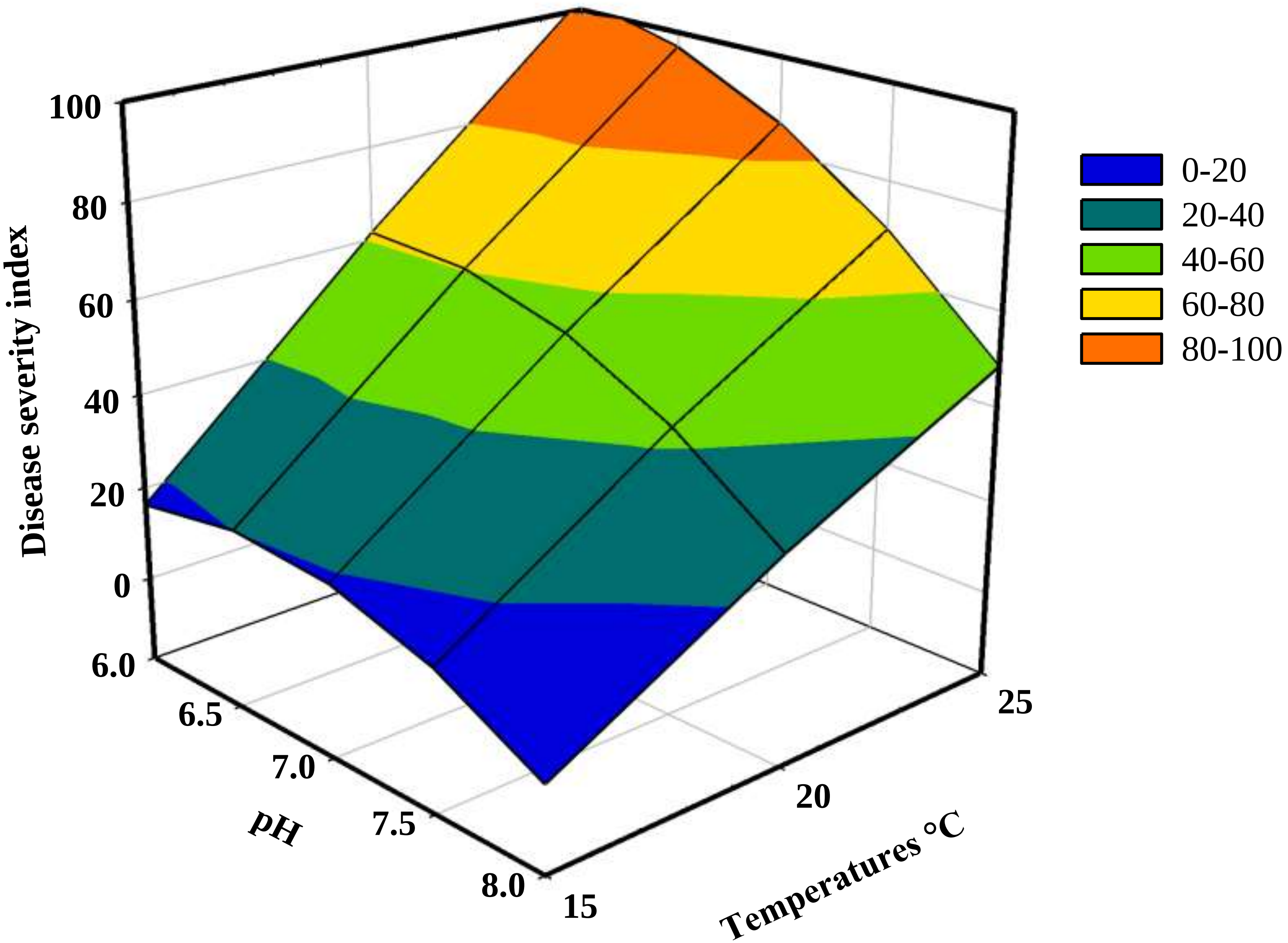

Sampled Fields
No Clubroot Found


A
12KV
30um
B
C
D

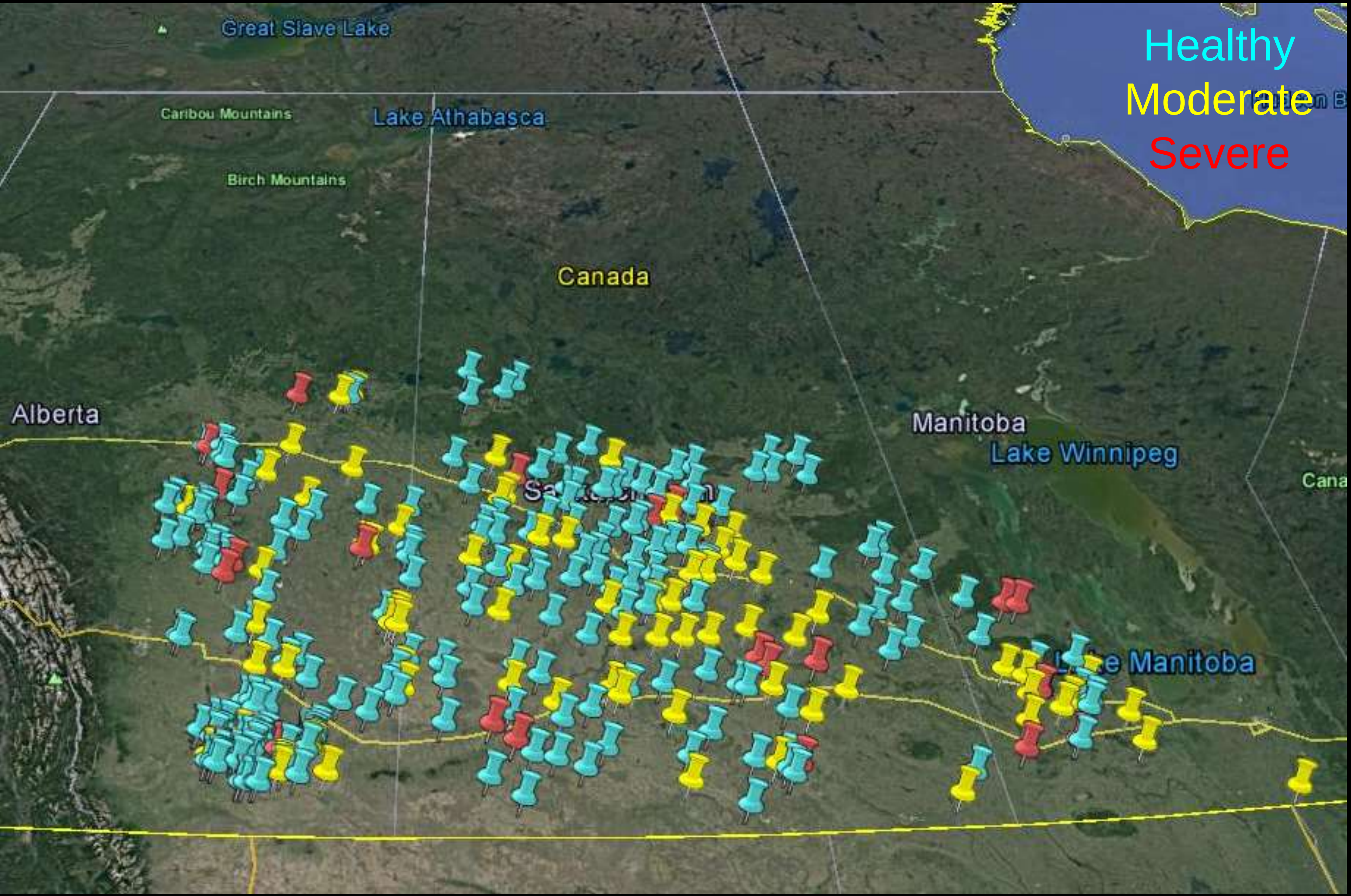
Spore conc. after Susceptible Canola



Temperature x pH



Aphanomyces root rot of pea (and lentil)


Healthy
Moderate
Severe
Great Slave Lake
Caribou Mountains
Lake Athabasca
Birch Mountains
Canada
Alberta
Manitoba
Lake Winnipeg

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.

Fusarium on maize

Clubroot on canola

What has changed?

Agricultural equipment has gotten bigger and bigger.

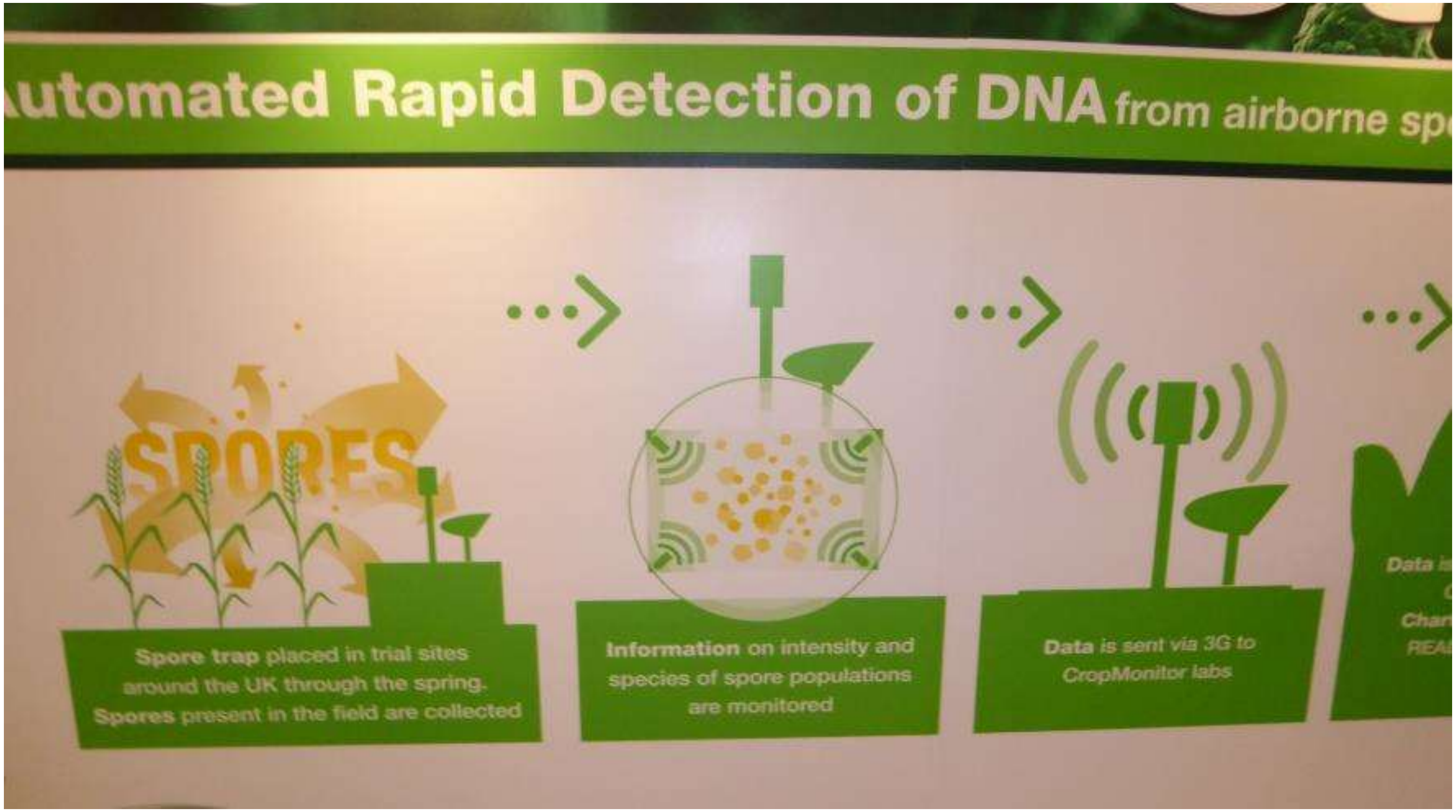
The future is now!

- 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 eveywhere

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.

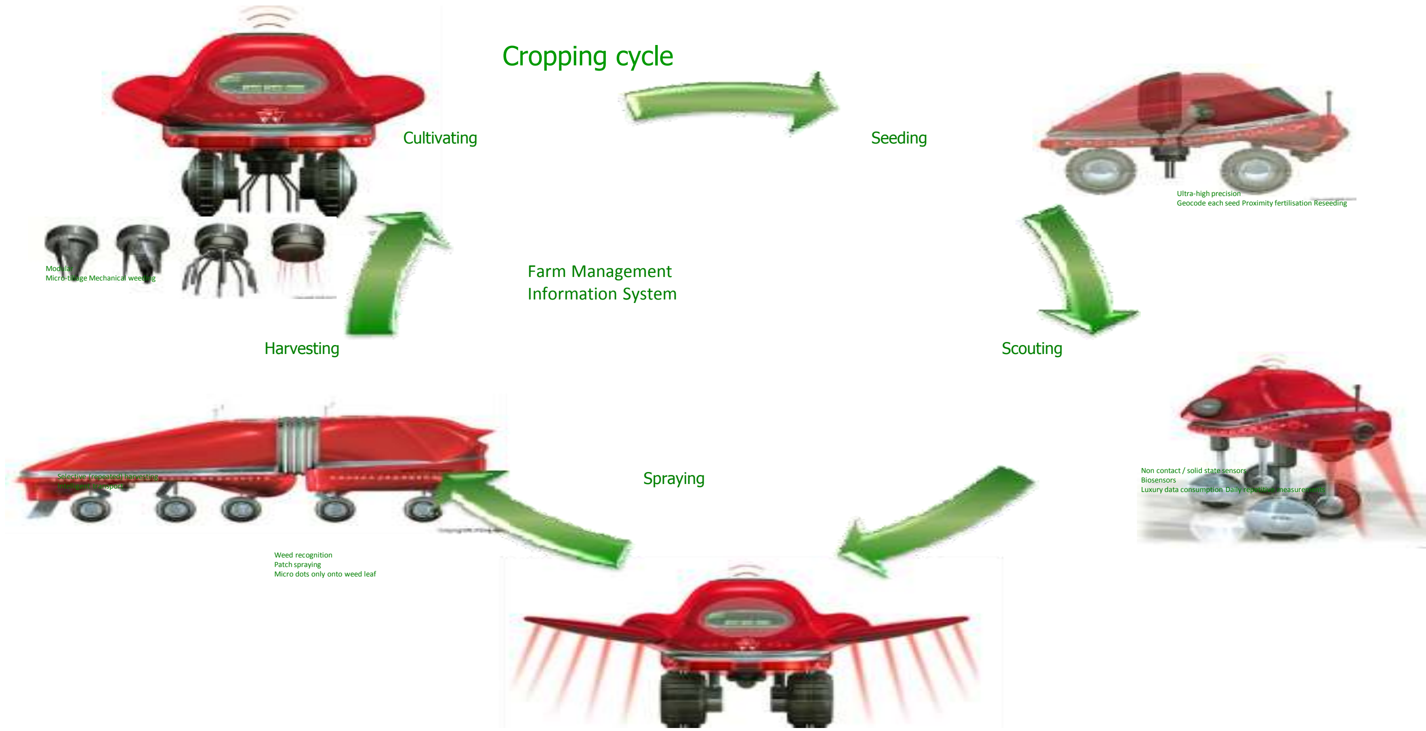
Bacillus subtilis

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.

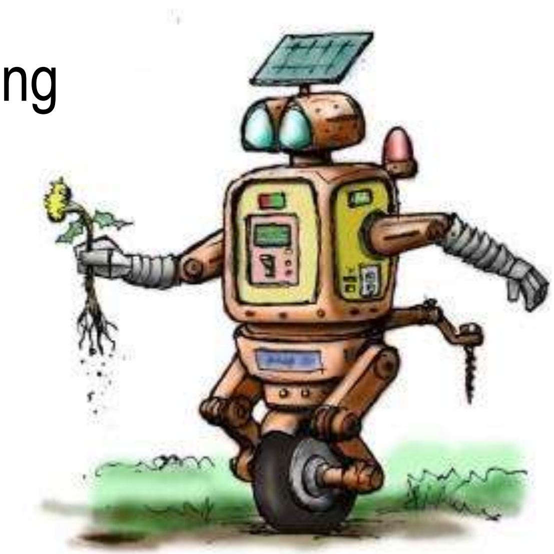
Still to come:

- 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.



Prof. Simon Blackmore – The Future of Farming

Human operators will be required to maintain and manage this high tech gear. Will farms be run by individuals or corporations?



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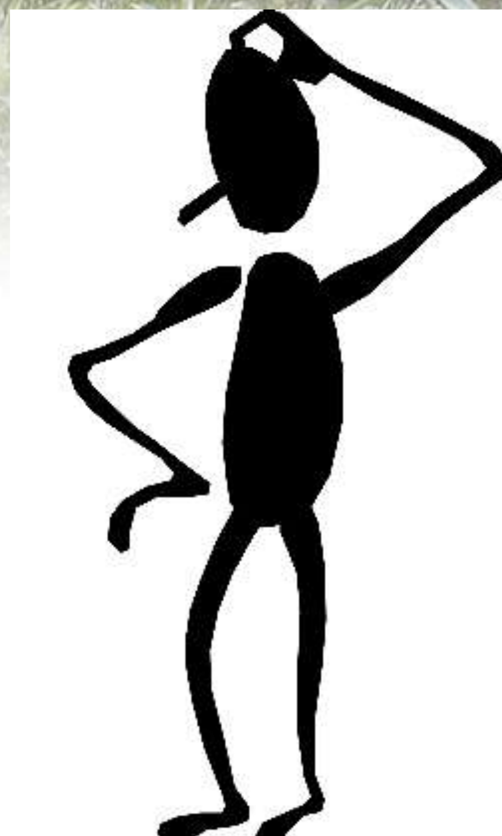
- The colleagues, post-docs, grad students and technicians who do the hands-on research!
- Dr. M.R. McDonald for many discussions of the future of disease management.

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.