Management of Clubroot of Canola in Alberta, Canada

S.F. Hwang[1, 2] and S.E. Strelkov[2]

[1]Alberta Agriculture and Forestry
[2]University of Alberta

2018 International CLUBROOT Workshop
Edmonton, AB Canada
Aug. 7 - 9, 2017

Acknowledgments

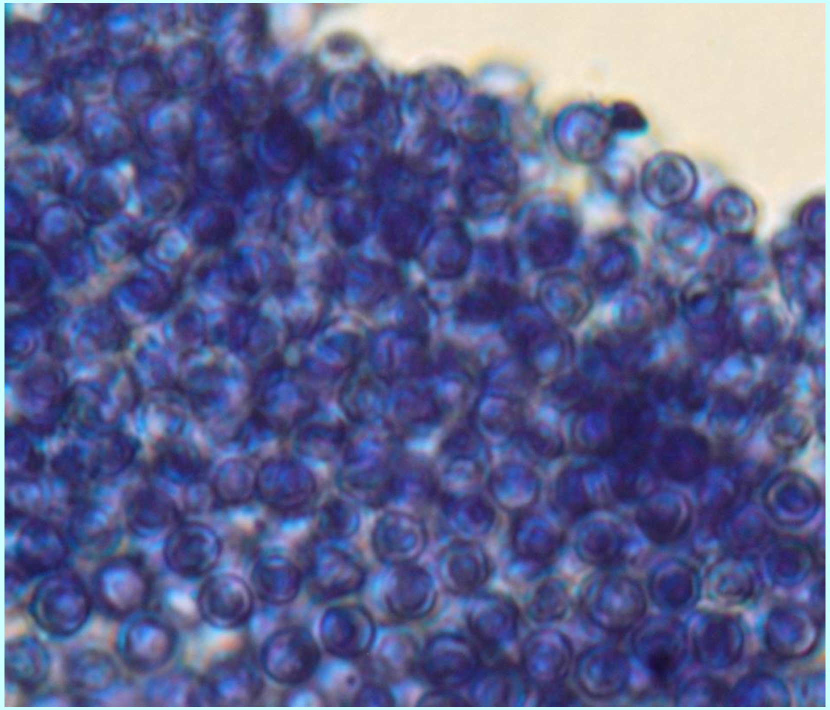
- **Graduate students, Research personnel and Collaborators**
- **CCC Agronomists, Agricultural Fieldmen**
- **Canola Council through AAFC GF2 Canola Science Cluster**
- **GF2 Pest Management and Surveillance Implementation (PMSI)**
- **Alberta Crop Industry Development Fund**
- **Western Grain Research Foundation**
- **ACPC, SaskCanola, MCGA and other industry partners**

Outline of Presentation

- Equipment sanitation
- Genetic resistance and resistance breakdown
- Fumigants – Vapam and Basamid
- Crop Rotation – interval between canola crops
- First report on clubroot in the Peace Region
- New molecular markers specific to P5x.
- Conclusions & Future Research

Clubroot of Canola

- Caused by *Plasmodiophora brassicae*
- Soilborne pathogen
- Spores persist > 15 years
- Very difficult to eradicate once established in a field
- First identified on Prairie canola in 2003 (12 fields)
- Spread rapidly, now in over 2700 fields
- Yield losses threaten canola production in western Canada

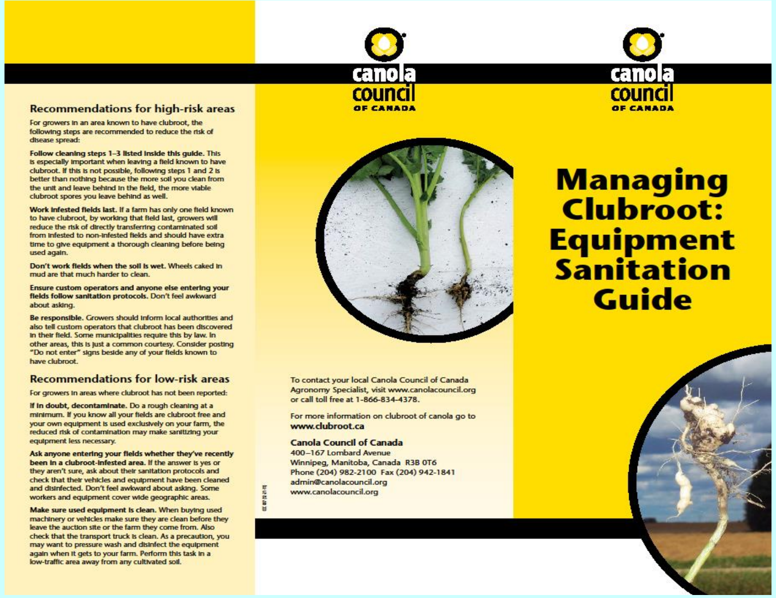


- As galls mature, begin to decay
- Decaying galls become soft/mushy, brownish in color

Root galls can release up to 800×10^6 spores/g gall x 20 g/gall in a mature plant (up to 16 billion spores per plant)

Clubroot management – Equipment sanitation

- Clubroot spread by infested soil on machinery
- Machinery sanitized by:
  - Removing excess soil
  - Power washing
  - Disinfection



Recommendations for high-risk areas

For growers in an area known to have clubroot, the following steps are recommended to reduce the risk of disease spread:

Follow cleaning steps 1–3 listed inside this guide. This is especially important when leaving a field known to have clubroot. If this is not possible, following steps 1 and 2 is better than nothing because the more soil you clean from the unit and leave behind in the field, the more viable clubroot spores you leave behind as well.

Work infested fields last. If a farm has only one field known to have clubroot, by working that field last, growers will reduce the risk of directly transferring contaminated soil from infested to non-infested fields and should have extra time to give equipment a thorough cleaning before being used again.

Don't work fields when the soil is wet. Wheels caked in mud are that much harder to clean.

Ensure custom operators and anyone else entering your fields follow sanitation protocols. Don't feel awkward about asking.

Be responsible. Growers should inform local authorities and also tell custom operators that clubroot has been discovered in their field. Some municipalities require this by law. In other areas, this is just a common courtesy. Consider posting "Do not enter" signs beside any of your fields known to have clubroot.

Recommendations for low-risk areas

For growers in areas where clubroot has not been reported:

If in doubt, decontaminate. Do a rough cleaning at a minimum. If you know all your fields are clubroot free and your own equipment is used exclusively on your farm, the reduced risk of contamination may make sanitizing your equipment less necessary.

Ask anyone entering your fields whether they've recently been in a clubroot-infested area. If the answer is yes or they aren't sure, ask about their sanitation protocols and check that their vehicles and equipment have been cleaned and disinfected. Don't feel awkward about asking. Some workers and equipment cover wide geographic areas.

Make sure used equipment is clean. When buying used machinery or vehicles make sure they are clean before they leave the auction site or the farm they come from. Also check that the transport truck is clean. As a precaution, you may want to pressure wash and disinfect the equipment again when it gets to your farm. Perform this task in a low-traffic area away from any cultivated soil.

canola council OF CANADA

To contact your local Canola Council of Canada Agronomy Specialist, visit www.canolacouncil.org or call toll free at 1-866-834-4378.

For more information on clubroot of canola go to **www.clubroot.ca**

Canola Council of Canada
400–167 Lombard Avenue
Winnipeg, Manitoba, Canada R3B 0T6
Phone (204) 982-2100 Fax (204) 942-1841
admin@canolacouncil.org
www.canolacouncil.org

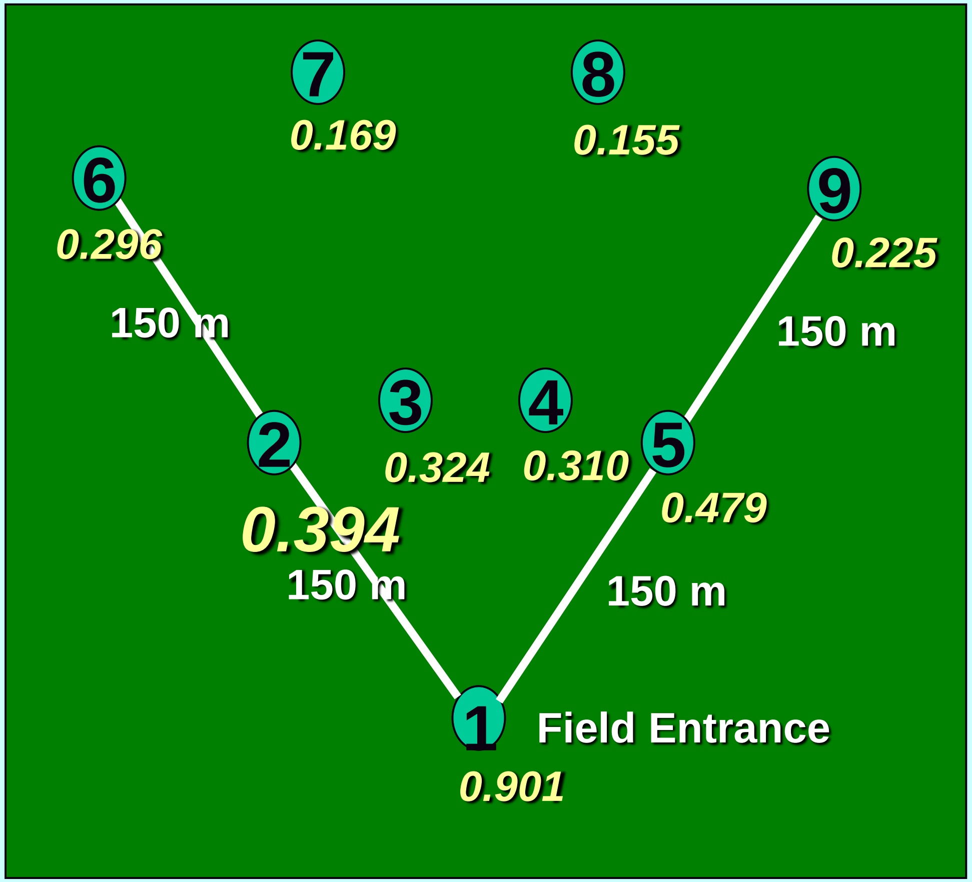
canola council OF CANADA

Managing Clubroot: Equipment Sanitation Guide

Clubroot management – Genetic Resistance

- **Companies released resistant lines against common pathotyes (2009-13) :**
  - **Pioneer**
  - **Monsanto**
  - **DL Seeds**
  - **Etc.**
  - **CPS**
  - **Bayer**
  - **Cargill**
- **Resistance soon became the most important clubroot management tool – often the only management tool.**

Clubroot management – Fumigation



Cao et al. (2009) Can. J. Plant Pathol.

- Maximum clubroot near field entrances
- Clubroot outbreaks may be contained by reducing populations near field entrances or new infection foci
- Soil fumigation with has been proposed to eradicate isolated infestations in canola fields

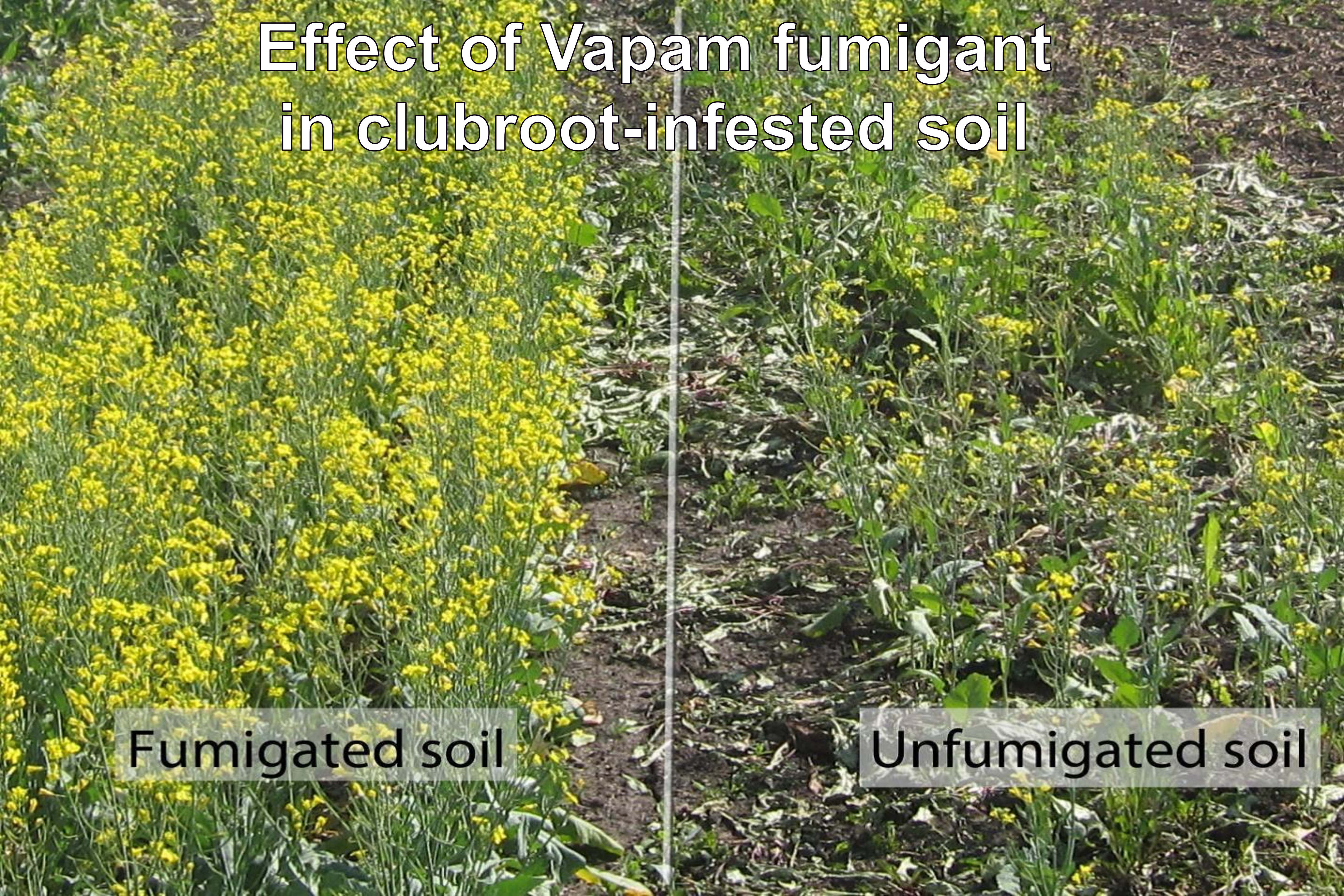
1. Efficacy of Vapam fumigant against clubroot (*Plasmodiophora brassicae*) of Canola

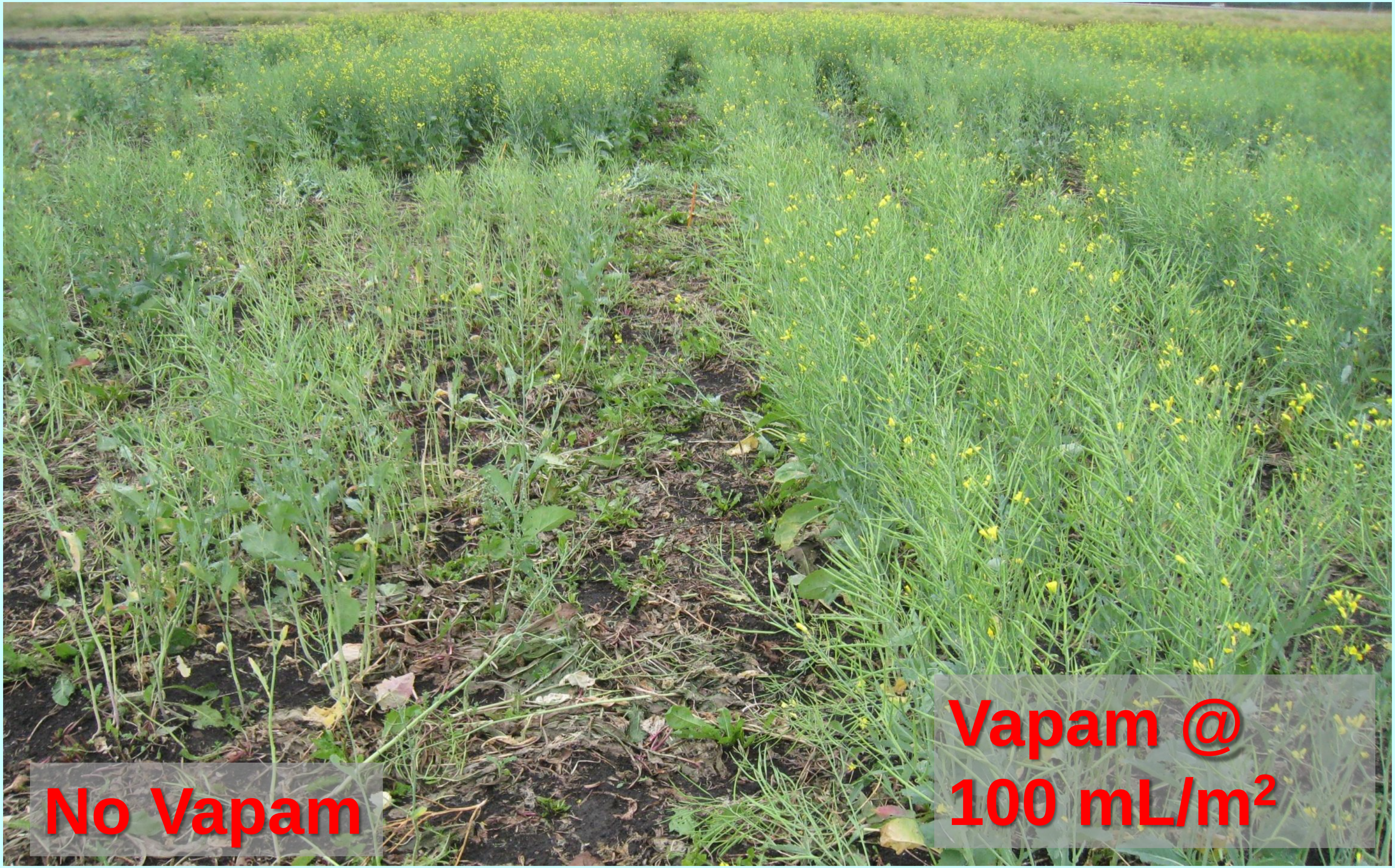
Vapam HL

- A broad-spectrum fumigant used in vegetable production
- suppresses nematodes, fungi and weed seeds
- 42% sodium methyldithiocarbamate
- releases methyl isocyanate

Hwang et al., Plant Pathology (2015) Doi: 10.111/ppa12207

Vapam concentration affects growth of canola and disease response in clubroot-infested soil


Effect of Vapam fumigant
in clubroot-infested soil
Fumigated soil
Unfumigated soil


No Vapam
Vapam @
100 mL/m2

Results – Post application of Vapam

- Vapam treatment improved emergence and yield and reduced disease severity
- A 12-day plastic covering after Vapam treatment improved emergence and yield and reduced disease severity
- Water volume did not affect Vapam efficacy
- Incorporation increased yield and biomass, reduced disease severity

Eur. J. Plant Pathology (2017)
DOI 10.1007/s10658-017-1281-y

Conclusions - Vapam

- **Vapam application is too expensive for large-scale application**
- **Requires specialized training to apply**
- **Effective for small-scale clubroot mitigation (<1000 m^2)**
- **No effect of water treatment – apply before rain.**
- **Incorporate Vapam into soil with tillage to improve Vapam efficacy**
- **Plastic covering for 12 days improves Vapam efficacy**

- **Vapam is an effective tool for containment of isolated clubroot infection foci.**

Suppression of clubroot using Basamid (dazomet)

Basamid

- A broad-spectrum fumigant used in vegetable production
- Granular formulation is more stable and user-friendly than Vapam

Hwang et al. 2018 Can. J. Plant Sci.
https://doi.org/101139/CJPS-2017-0099

Effect of inoculum concentration and Basamid application rate

Control 150 mg/L 200 mg/L

Control 150 mg/L 200 mg/L

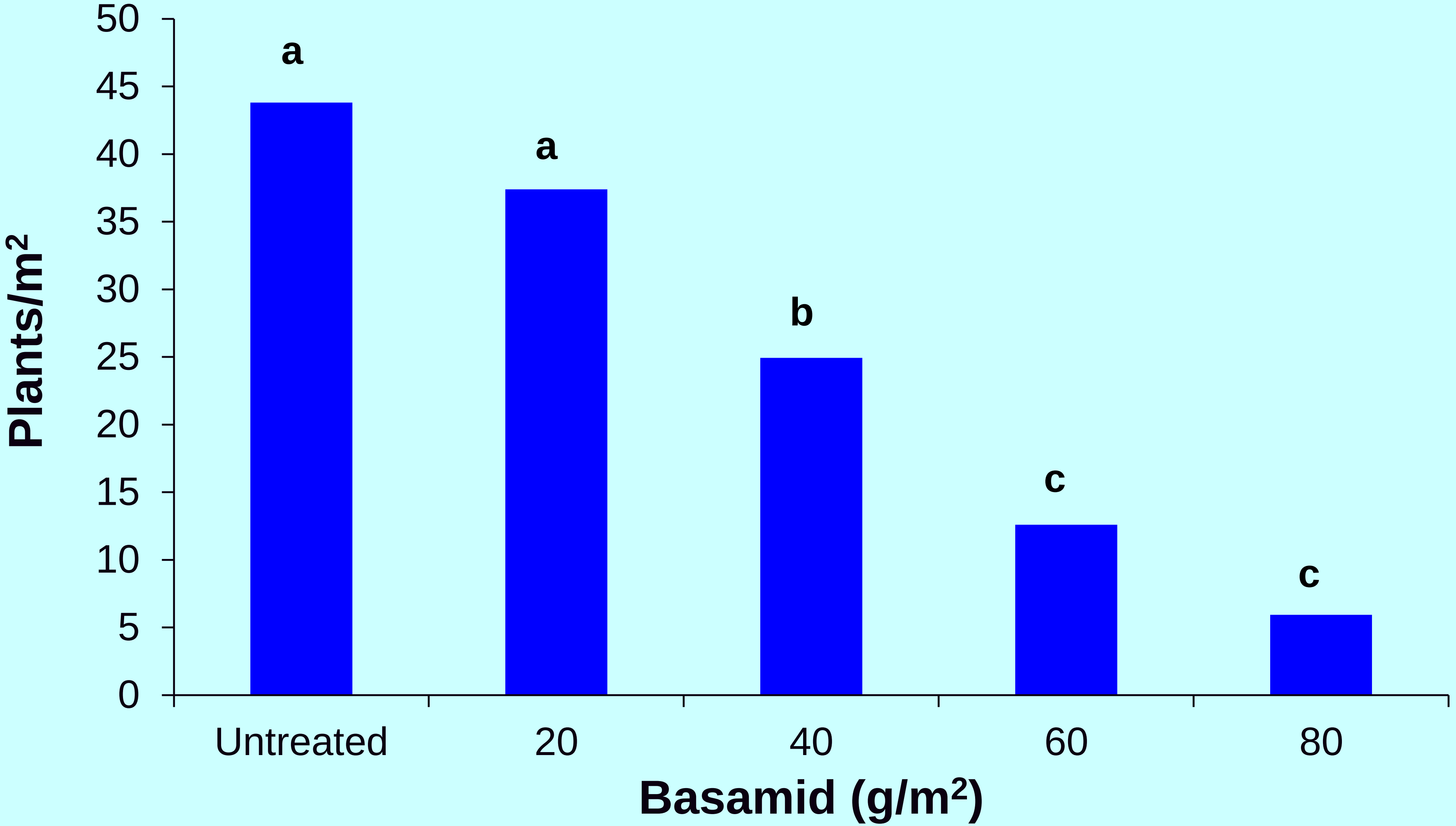
10^4 spores/mL

10^6 spores/mL

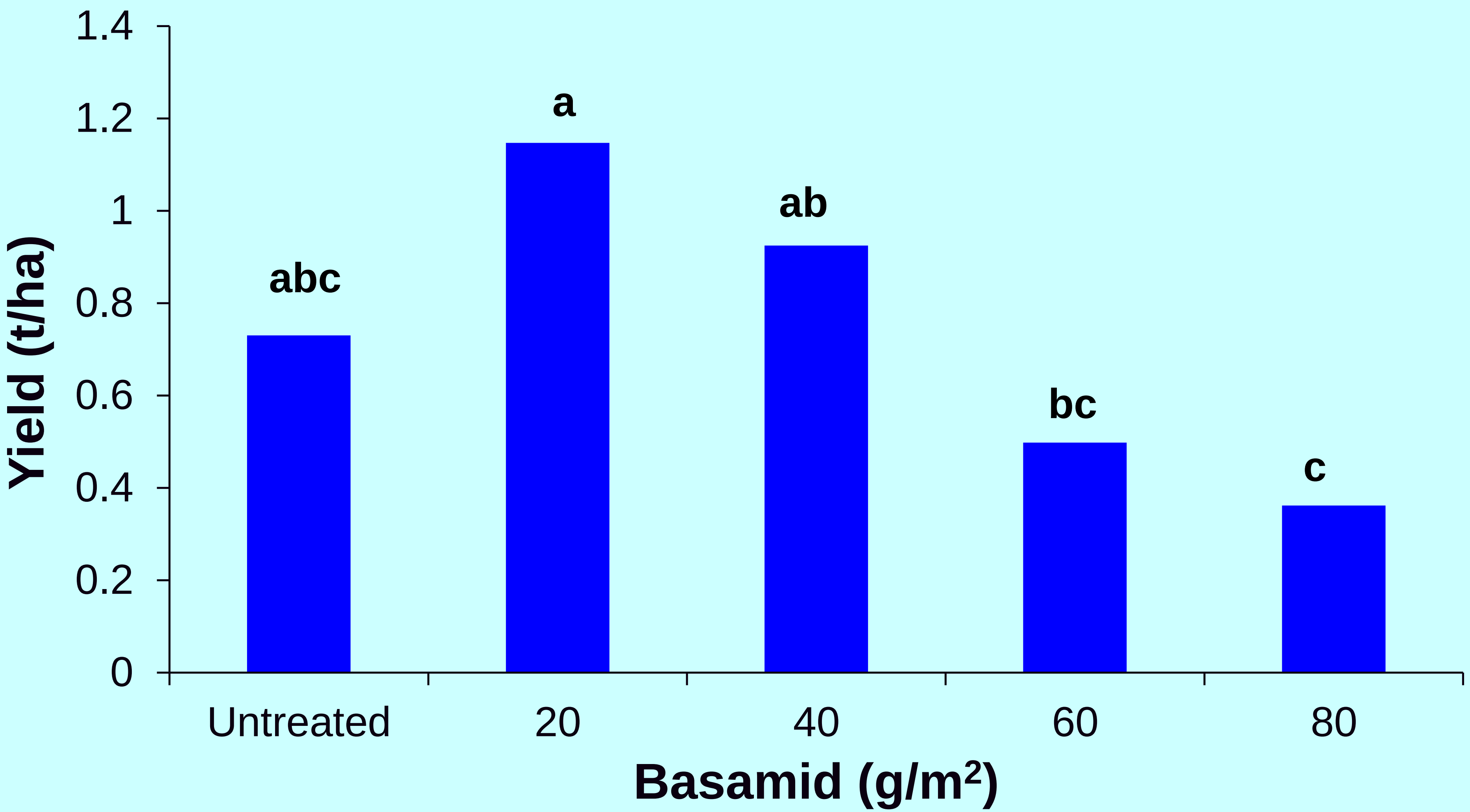
Field study – Basamid rate

- **Basamid was applied to 9 m^2 field plots at 0, 20, 40, 60 or 80 g/m^2 in 2014 and 2015**
- **Soil was tilled to incorporate the product, then covered with plastic for 1 wk.**
- **The plots were seeded with susceptible cv. 45H31.**
- **Data: Plant counts, plant height, disease severity, gall mass, yield**

Results - Plant populations declined with increasing Basamid application rate.



Results - Yield was greater where Basamid was applied at 20 g/m^2 compared to 80 g/m^2.

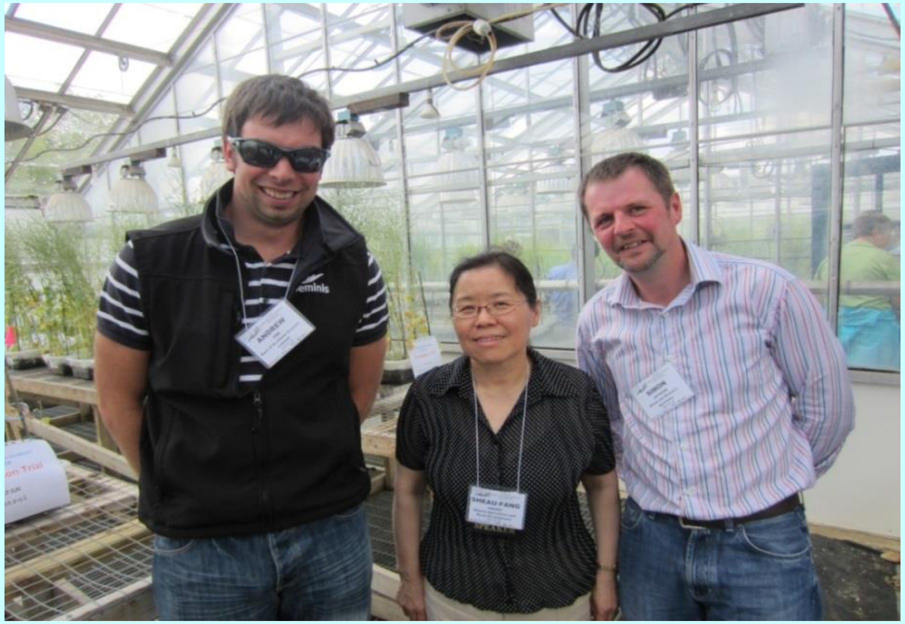


Conclusions - Basamid

- Basamid promoted seedling establishment and growth in clubroot-infested soils.
- Reduction in emergence and growth under field conditions may have resulted from an inadequate venting period before seeding.

- Basamid reduced disease expression in all clubroot-infested soils.
- Basamid promoted higher yield in clubroot-infested soils.

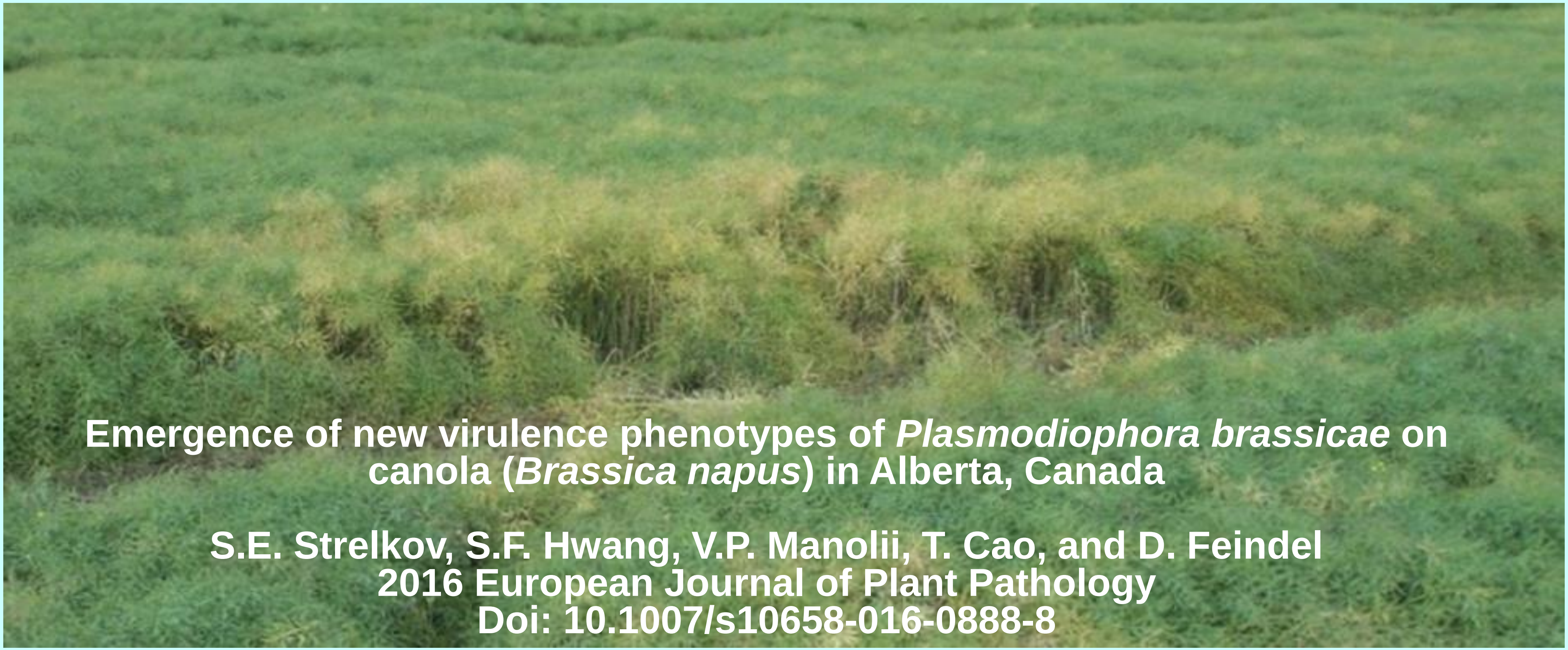
2013 International Clubroot Workshop



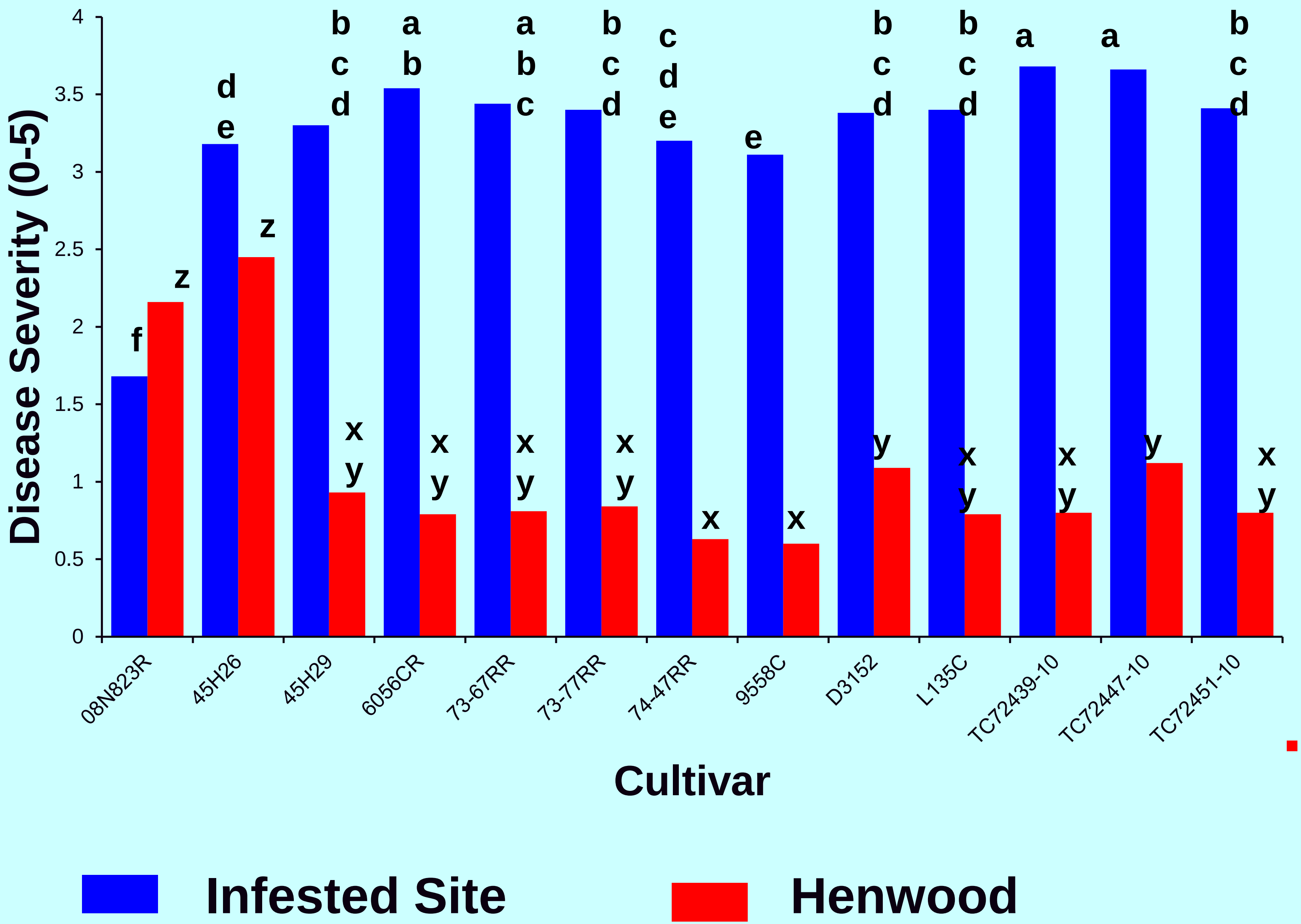
2013 International Clubroot Workshop

First Signs of Trouble - 2013

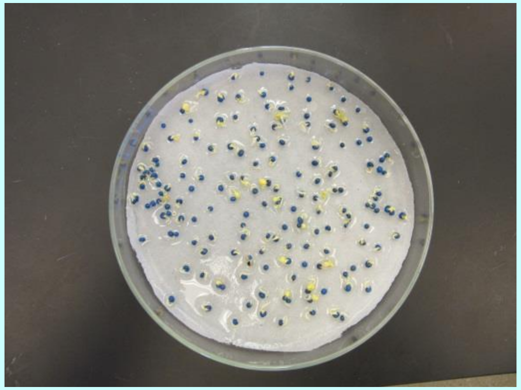
- **In 2013, six canola fields growing a CR cultivar were found to have patches with high clubroot severity**



New Strains Virulent on All Available 'Resistant' Cultivars



Pathotype analysis – Phase 2 and Phase 3



Pathotype Classification

- **New strain was referred to as ‘pathotype 5x’**
- **New strain of *P. brassicae* behaves like pathotype 5 based on classification system of Williams (1966)**
  - **But this does not reflect its increased virulence on CR canola**

Highlights limitations of this pathotype designation system for identifying strains from Canadian canola

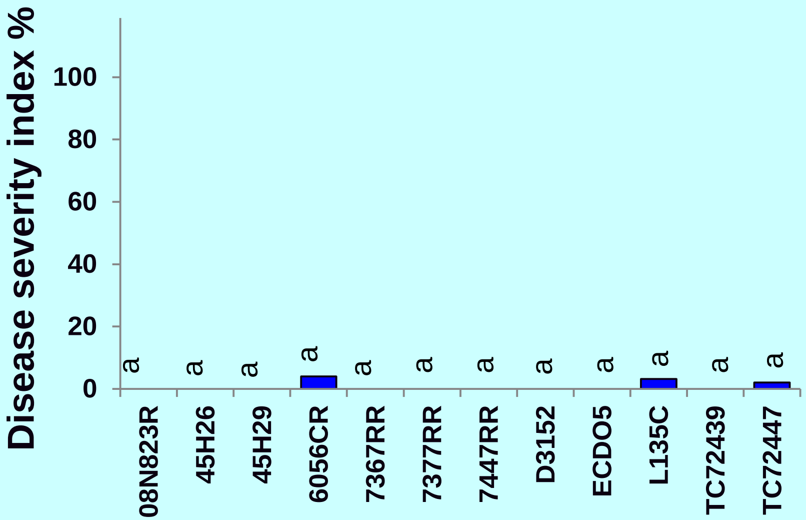
Effects of inoculum density of pathotype 5X on clubroot-resistant canola

- Pathotype 5x was inoculated into soils at 10^3 to $2x10^6$ spores/g
- 8 CR resistant canola cultivars (P3) were planted
- Susceptible checks were 45H26 and ECD 05
- After 6 wk growth in Greenhouse, plants were uprooted, and gall weight and disease severity were assessed

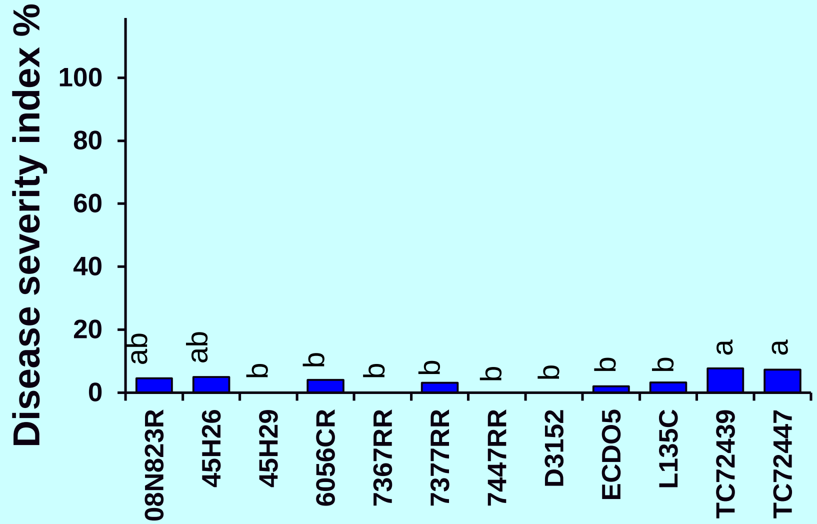
Hwang et al., 2017 Plant Pathology 66: 1318-1328.
Doi: 10.1111/ppa.12688.

Effect of CR5 on CR-resistant cultivars

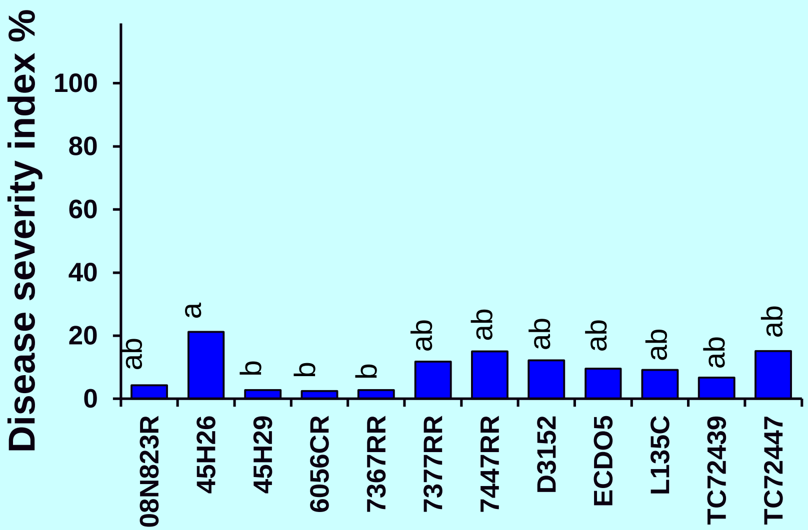
Inoculum concentration ($1x10^3$)



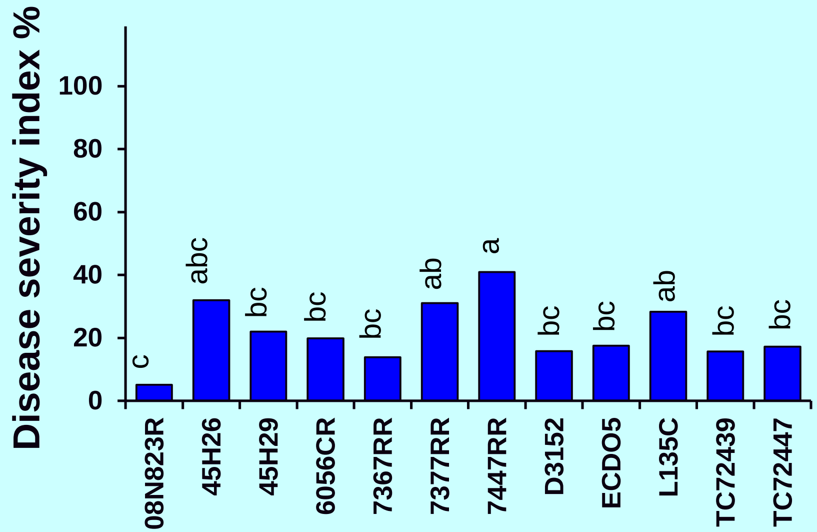
Inoculum concentration ($5x10^3$)



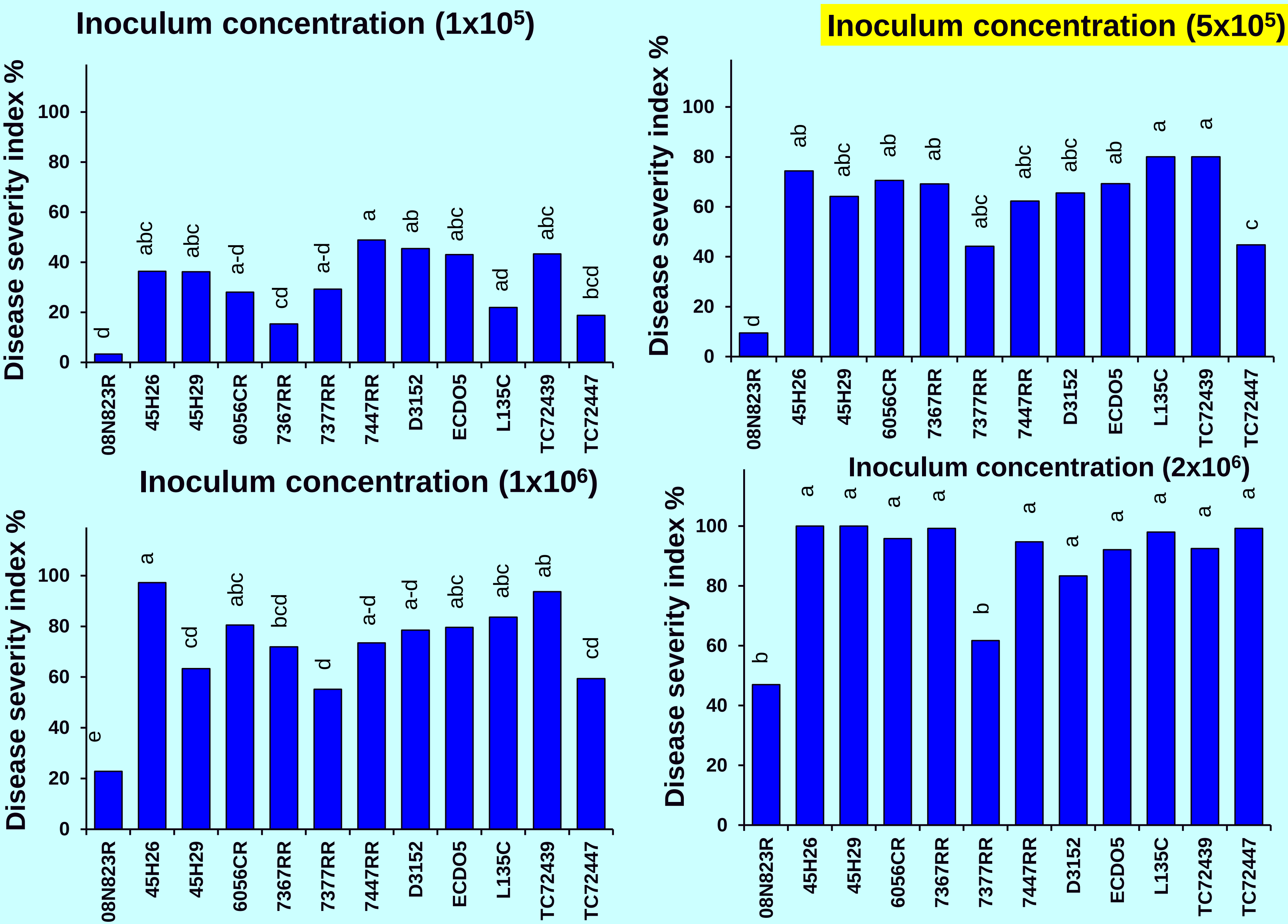
Inoculum concentration ($1x10^4$)



Inoculum concentration ($5x10^4$)



Effect of CR5 on CR-resistant cultivars



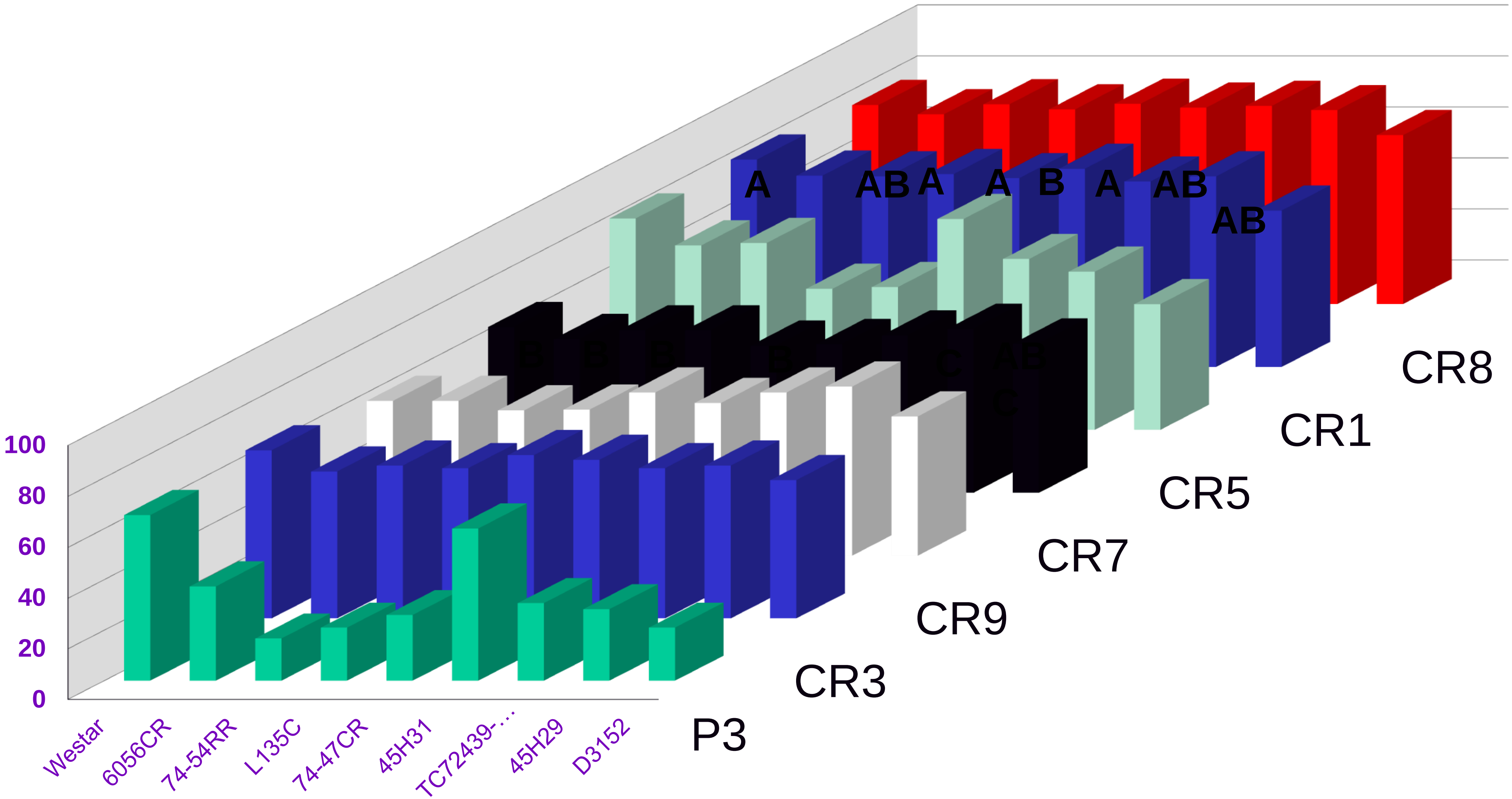
Results & Discussion

- **All cultivars showed low disease reaction at inoculum concentrations of 5×10^3 spores/g of soil and below.**
- **All cultivars tested showed a high disease reaction to 5x at inoculum concentrations above 5×10^5 spores/g of soil.**
- **High spore populations are important for clubroot development, regardless of pathotype.**
- **Spore populations need to be suppressed or prevented from multiplying.**

Comparison of pathotype virulence

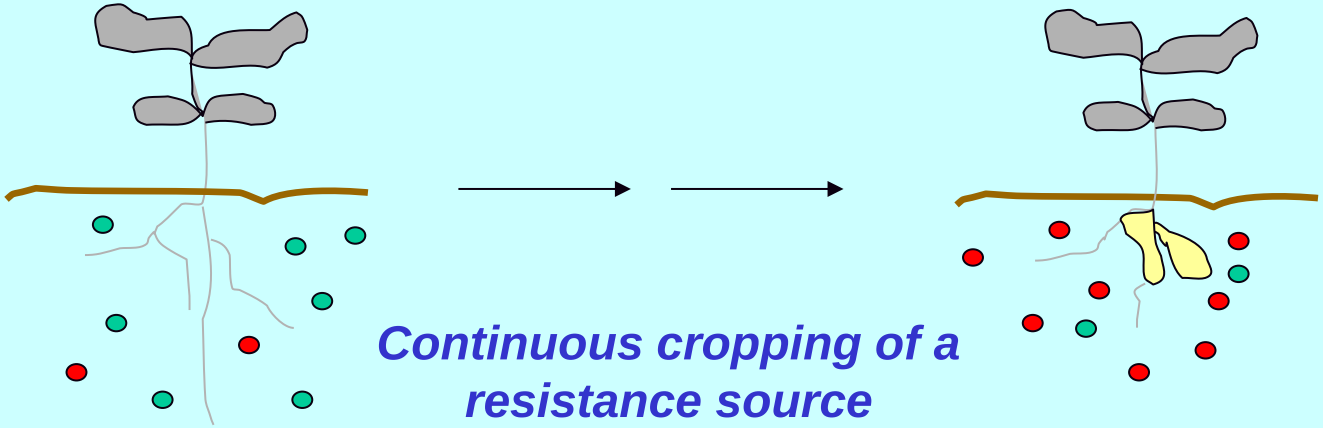
- Six resistance-defeating strains of clubroot were inoculated into soil at 2 x 10^6 spores/mL
- 8 CR resistant canola cultivars were planted into each pathotype, along with susceptible check 45H31 and susceptible cultivar Westar
- The pots were grown in a greenhouse for 6 weeks
- Plants were uprooted and disease severity was assessed.

Effects of resistance-defeating clubroot strains on disease severity in CR canola



Clubroot management – Rotation

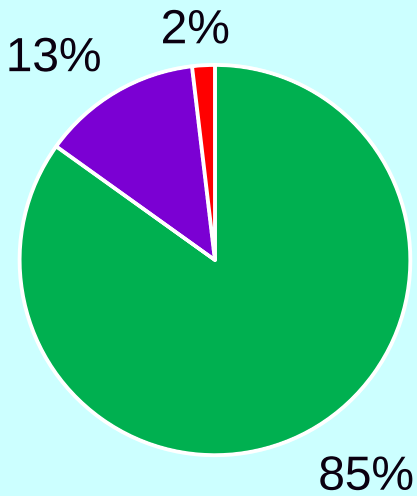
- Short rotations may be risky
  - *P. brassicae* can adapt to the selection pressure imposed by resistant hosts
    - Increased diversity in pathogen strains
    - Loss of effectiveness of resistance
  - If rotation not followed, how long does resistance last?



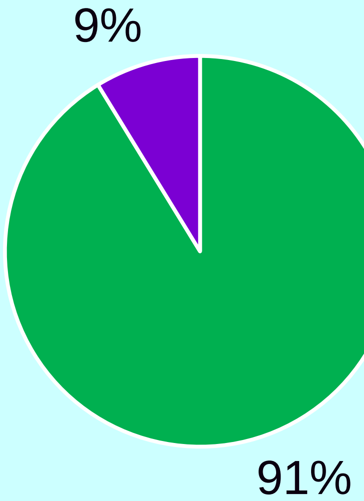
Continuous cropping of a resistance source

2015 Canola rotation frequency – 5598 fields

Athabasca (1278 fields)



Thorhild (947 fields)

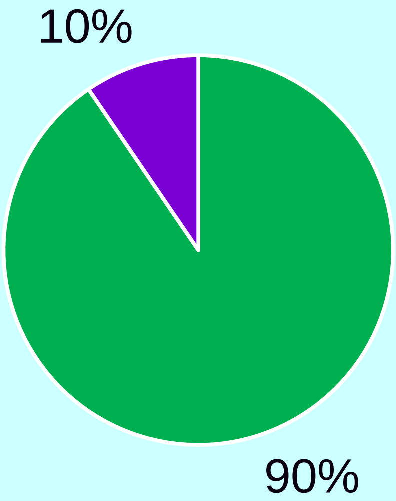


Canola 2/5 years
(2-3 year break)

Canola 3/5 years
(1 year break)

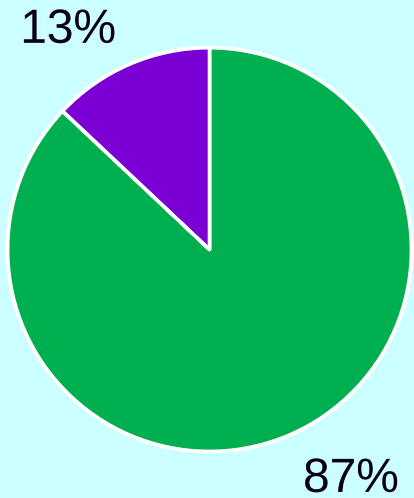
Canola 5/5 years

Sturgeon (1238 fields)

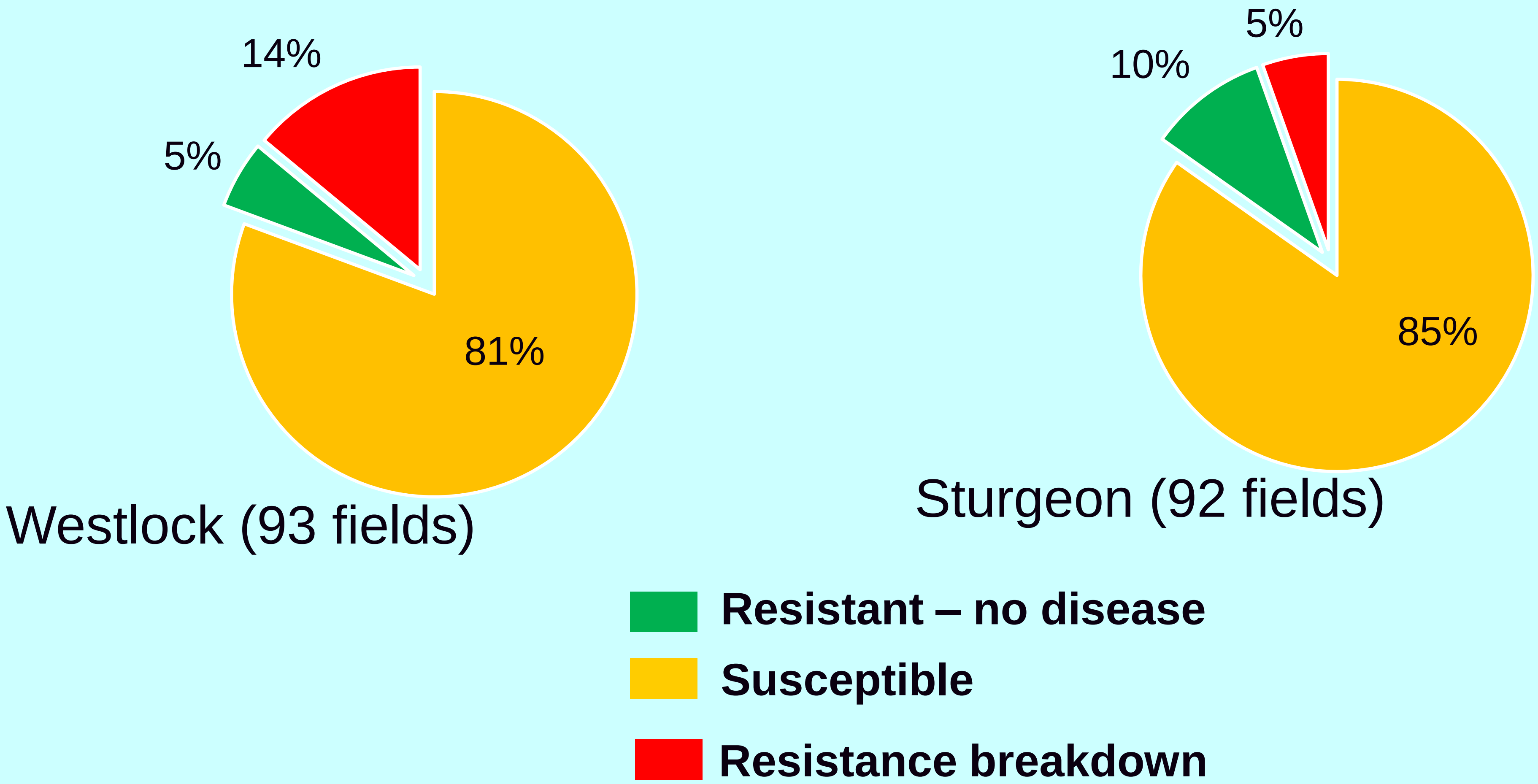


Most growers follow a healthy rotation; 10-15% do not!

Westlock (2135 fields)



Clubroot resistance frequency in 2 counties - 2015



Influence of resistant cultivars & intervals between canola crops

Objective:
To examine the effect of interval between canola crops on *P. brassicae* resting spore populations and clubroot severity.

2015 Plant Pathology *http://Doi:10.1111/ppa.12347*

Effect of canola-free interval on clubroot severity, spore numbers and growth of canola

		2013	2014	2015	2016	2017
0	Continuous canola	C	C	C	C	C
1	One-year break	C	B	C	B	C
2	Two-year break	C	C	B	B	C
3	Three year break	C	B	P	B	C

Canola
Barley
Pea

Field study

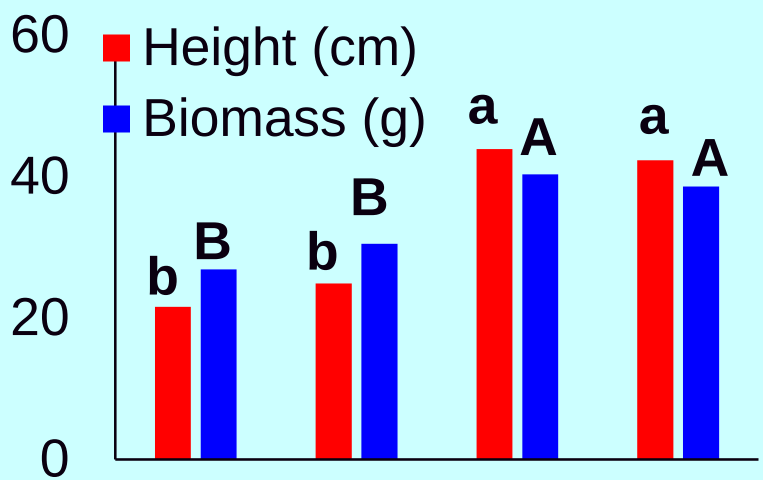
Effects of canola-free intervals

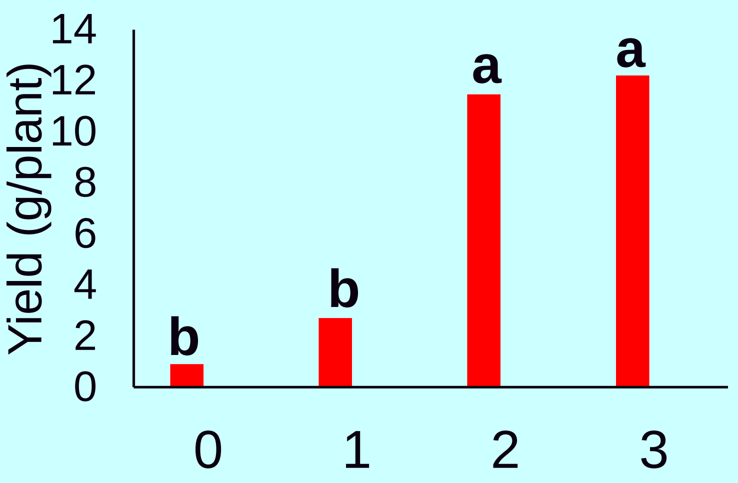
- **2013: Susceptible canola was grown in containers using soils infested with 0.5 x 10^8 spores/mL or in field plots (soils infested with 10^8 spores/mL)**

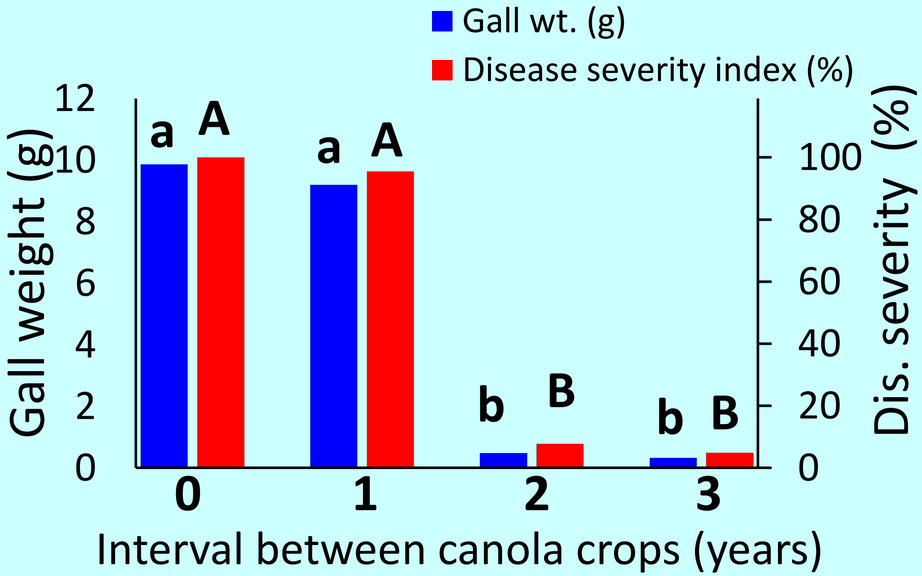
- **2014-17: the crop was rotated as follows:**
  - ❑ **Continuous canola**
  - ❑ **BCBC – Alternating barley and canola**
  - ❑ **CBBC – Two year interval without canola**
  - ❑ **BPBC – Three-year interval without canola**

- **In the final year (2017), data on crop emergence, disease severity, gall weight and yield were collected.**

Effects of interval between canola crops – Container-grown



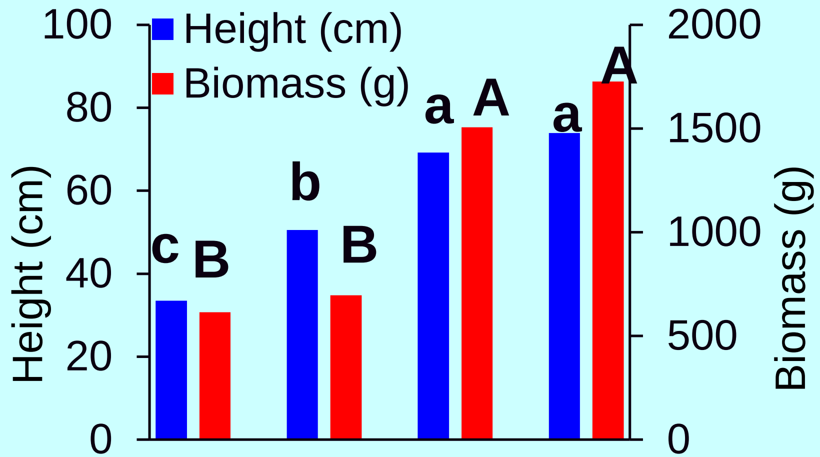


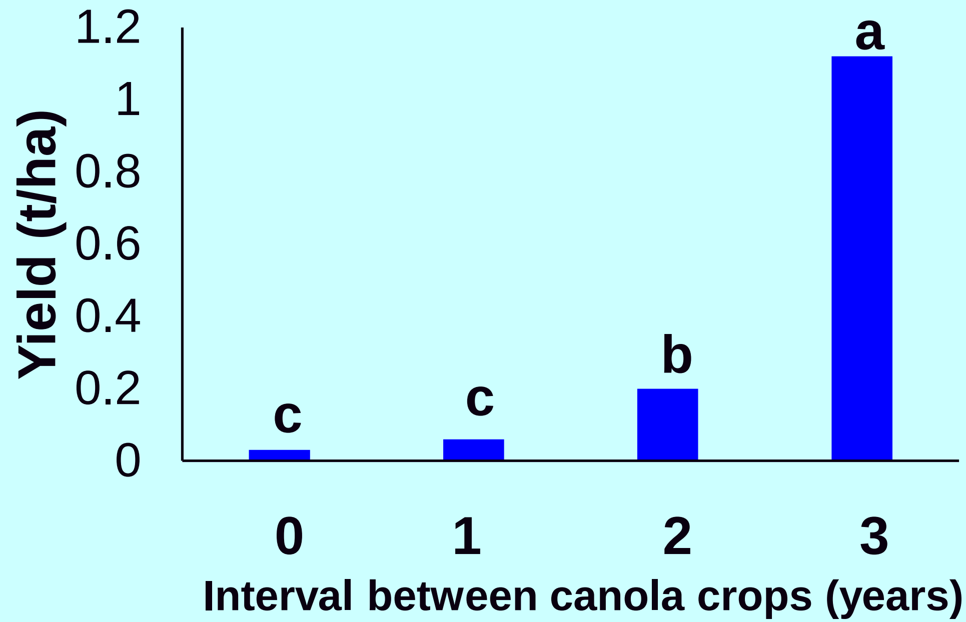


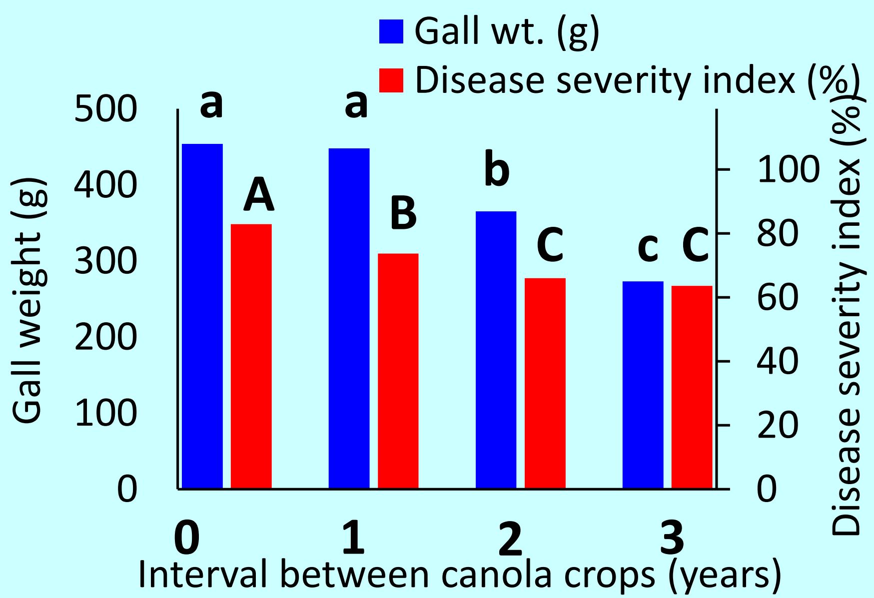
- Gall mass and disease severity were lower with a 2- or 3-year interval between canola crops
- Plant height, biomass and yield were greater for 2- and 3 year intervals between canola crops

Effects of interval between canola crops on growth of canola grown in containers

Effects of interval between canola crops – Field 2017







Yield was greater for a 3-year interval between canola crops compared with a 2-year interval.

Effects of interval between canola crops on growth of canola field conditions 2017

Continous Canola

1-year interval

2-year interval

3-year interval

First report of clubroot on canola in the Peace Region of Alberta - 2017

S.F. Hwang[1], H.U. Ahmed[1], Q.X. Zhou[1], V.P. Manolii[2], G.D. Turnbull[1], R. Fredua-Agyeman[1], S. Kaus[3] and S.E. Strelkov[2]*

[1]Alberta Agriculture and Forestry
[2]University of Alberta
[3]Big Lakes County, High Prairie, AB

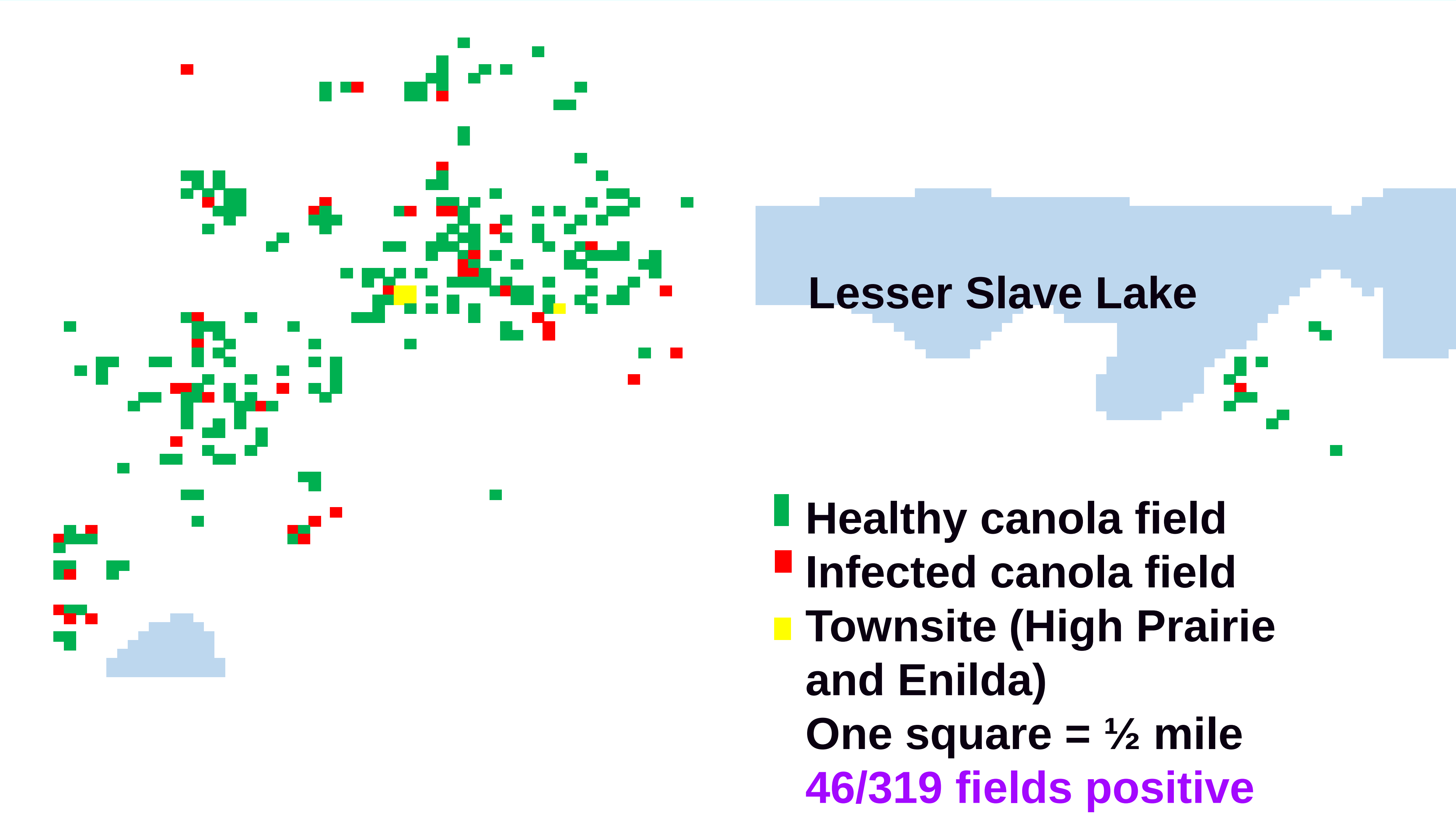
Survey of Big Lakes District

- **The Municipal District of Big Lakes connects West-Central Alberta with the Peace River region.**
- **Every canola field in the Municipal District of Big Lakes (319 fields) was surveyed in 2017.**

Objectives

- **Determine the occurrence and distribution of clubroot in the Municipal District of Big Lakes**
- **Identify and characterize the variation in virulence of *P. brassicae* isolates recovered from this area.**

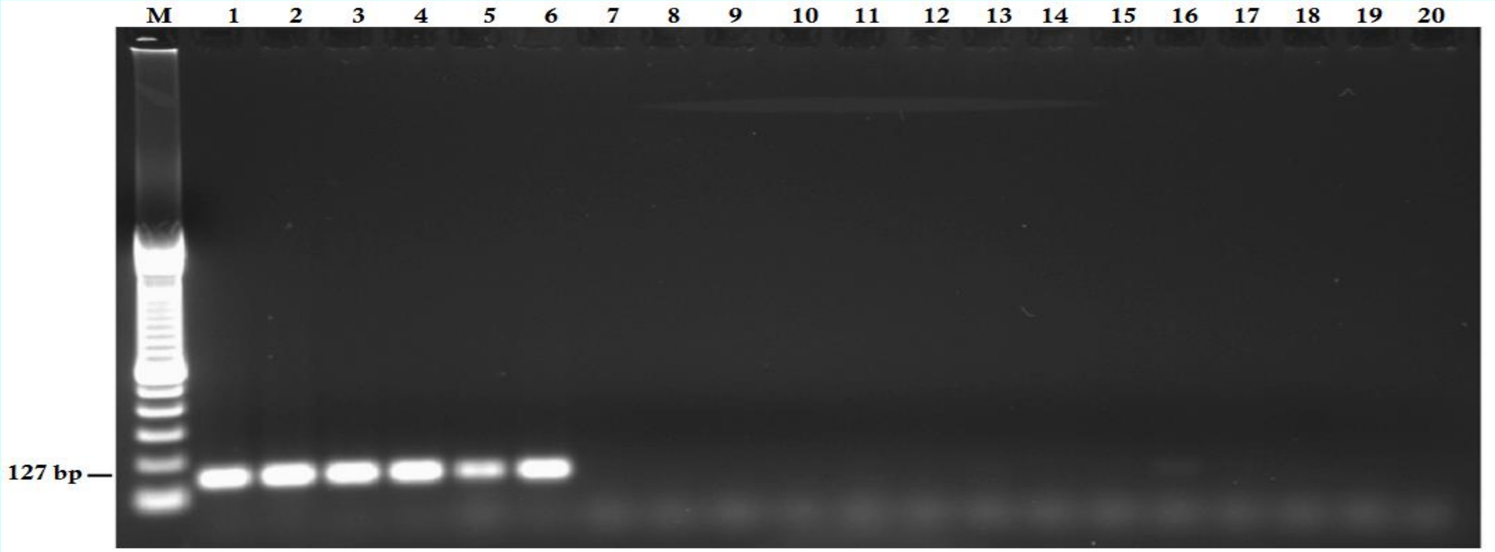
Canola fields – Big Lakes County 2017



Materials and Methods: Virulence

- **Canola roots from 46 fields were tested for clubroot symptoms**
- **Spores were extracted from one affected root from each of 20 positive fields.**
- **The spores were inoculated onto 12 seedlings of 13 pathotype differentials**
- **DNA was extracted, and amplified using a P5x – specific primer and a non-specific *P. brassicae* primer.**

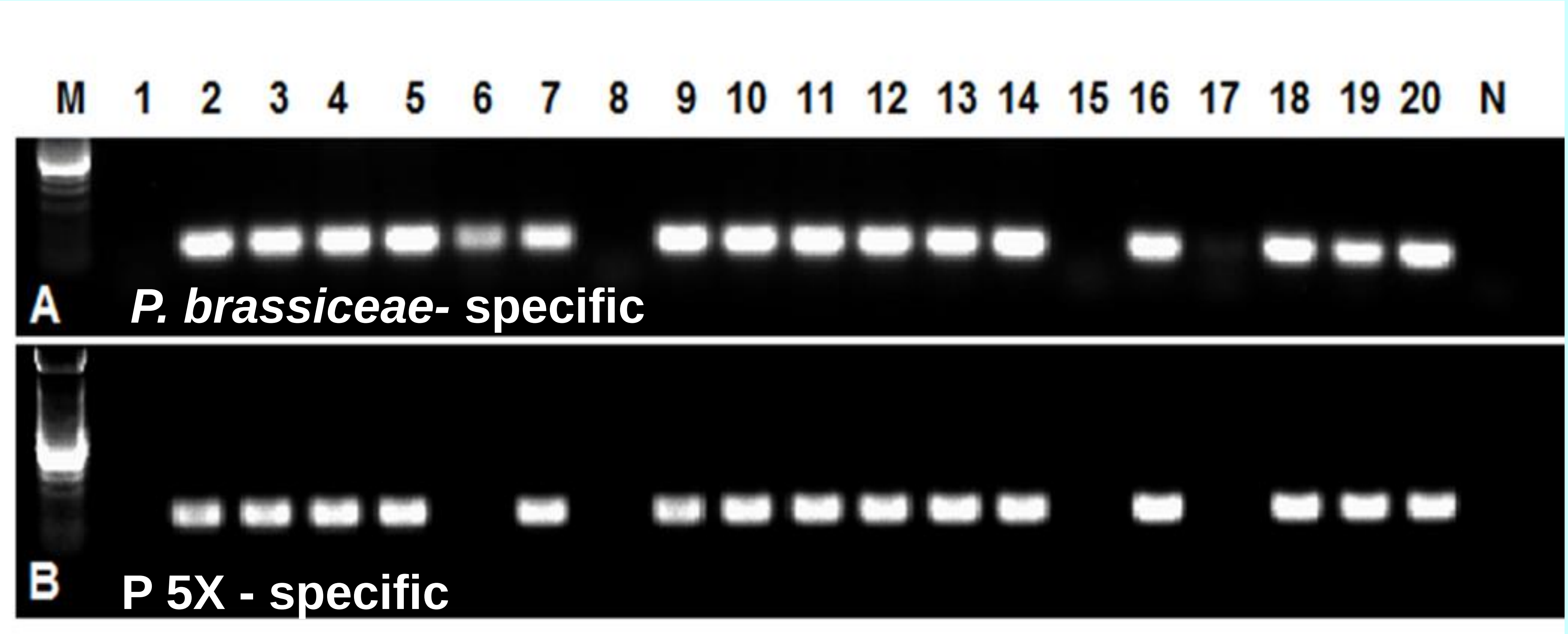
A molecular marker to detect P5-like pathotypes of *Plasmodiophora brassicae* in canola



- **Primers P5xF3 and P5xR3 amplified a 127 bp product from all new pathotype 5-like strains.**
- **As little as 0.5 pg of *P. brassicae* DNA detected**

Zhou, Q., S.F. Hwang, S.E. Strelkov, R. Freuda-Agyeman and V.P. Manolii. 2018. Plant Pathology 67: 1582-1588.

Results

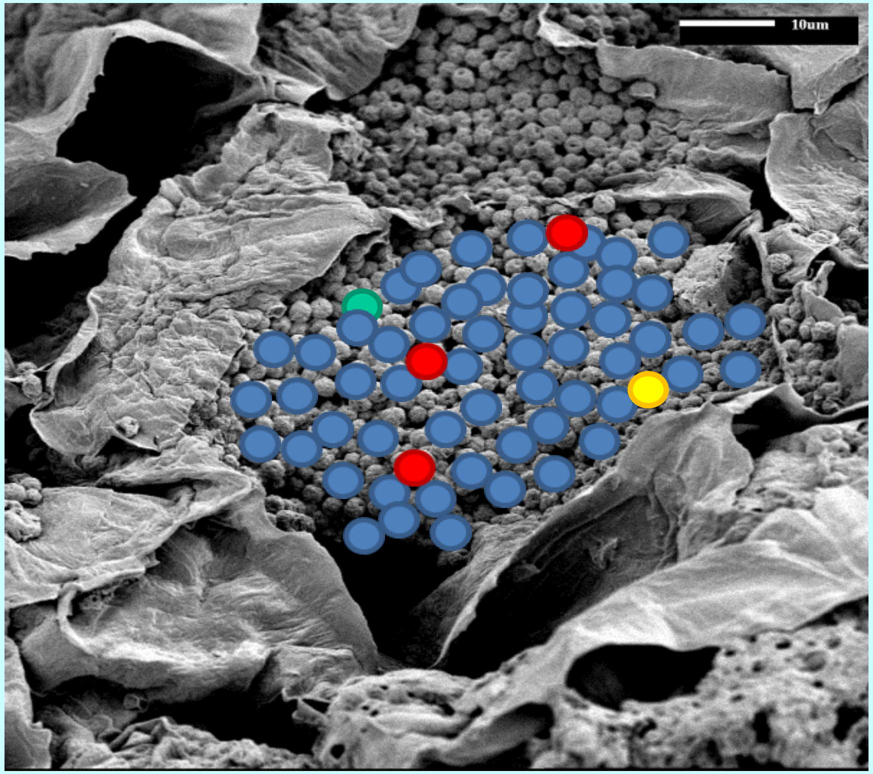

M 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 N
A
P. brassiceae- specific
B
P 5X - specific

Results

- **Clubroot was found in 20 of 319 fields, scattered throughout the area.**
- **Disease incidence ranged from 0.5 - 36%.**
- **10 fields showed high disease severity (2 – 3).**
- **15 fields showed a positive result in response to the P5X primer.**

Novel strains are present at low concentrations

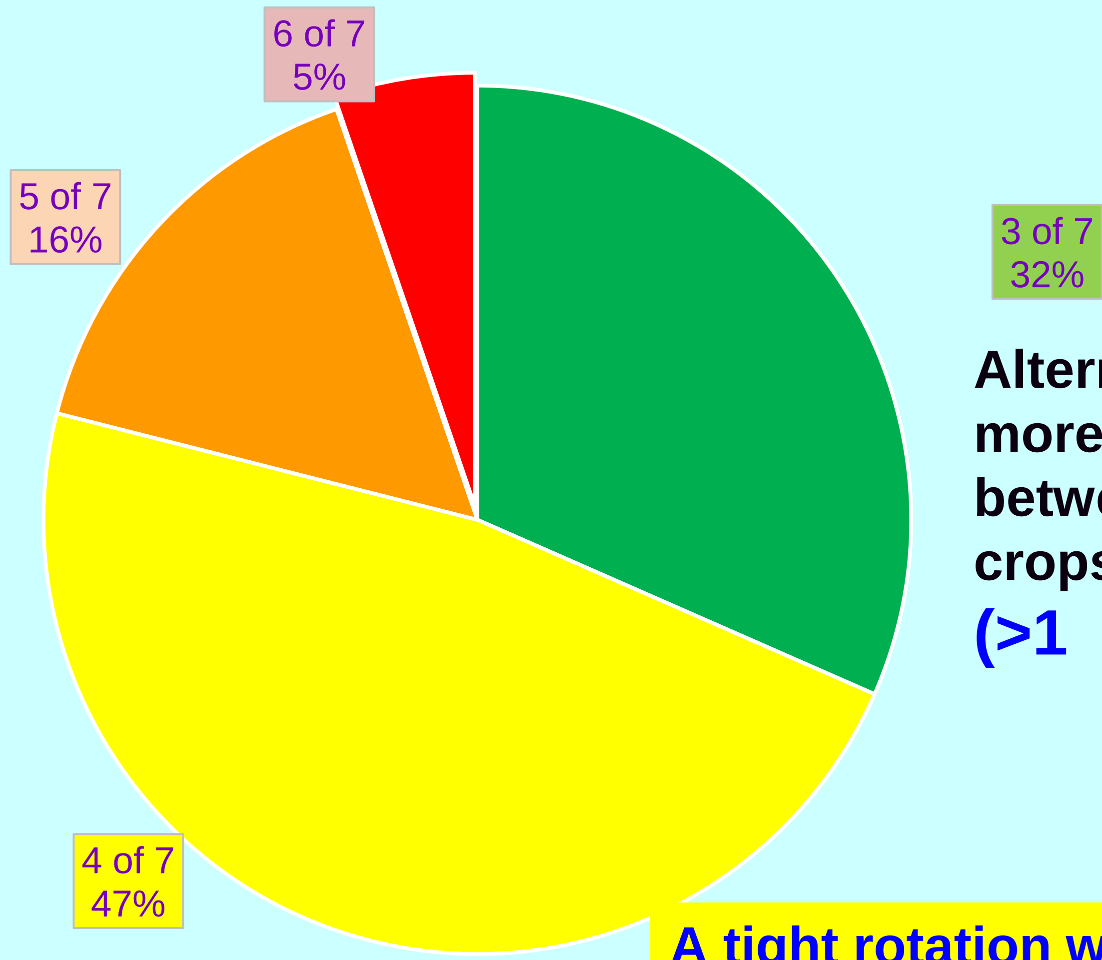
- **New pathotypes (eg. P5x) found in 0.005% of spores (5/100,000 spores)**
- **If 1 plant has 16 billion spores, over 850,000 could be a novel pathotype**
- **The 'old' pathotype 3 is still predominant in most clubroot-infested fields**
  - **Resistance is still effective in those fields**



Frequency of canola cultivation (yr/7) in 20 clubroot-infested fields in Big Lakes County

At least two years back-to-back canola

(0 to 1-year break)



Alternating or more than one year between canola crops

(>1 year break)

Alternating canola and another crop

(1-year break)

A tight rotation was followed in most of these infected fields!

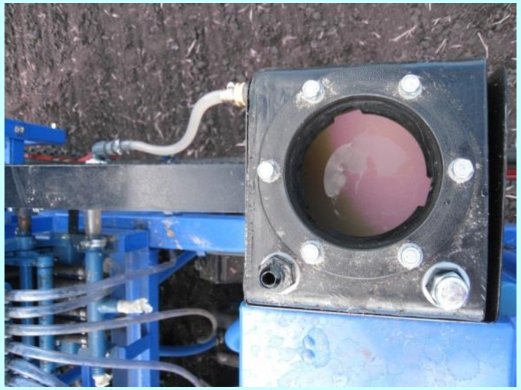
Conclusions - Clubroot Management

- **Reduce soil movement**: Clean machinery moving from field to field.
- Genetic resistance is likely to be overcome if short rotations are used – A 2-year or greater break from canola has been shown to reduce spore viability.
- **Fumigation** is useful for treating clubroot hotspots; too expensive for whole fields.
- Clubroot is spreading into the Peace Region – short rotation may be the cause
- A primer has been developed to distinguish P5X – type of spores from others.
- Spores from each infected plant represent a wide variety of virulence types.

- Breeding efforts should focus on multiple resistance genes, and tested against multiple virulence types.
- Integrated management techniques should be combined with cultivar resistance

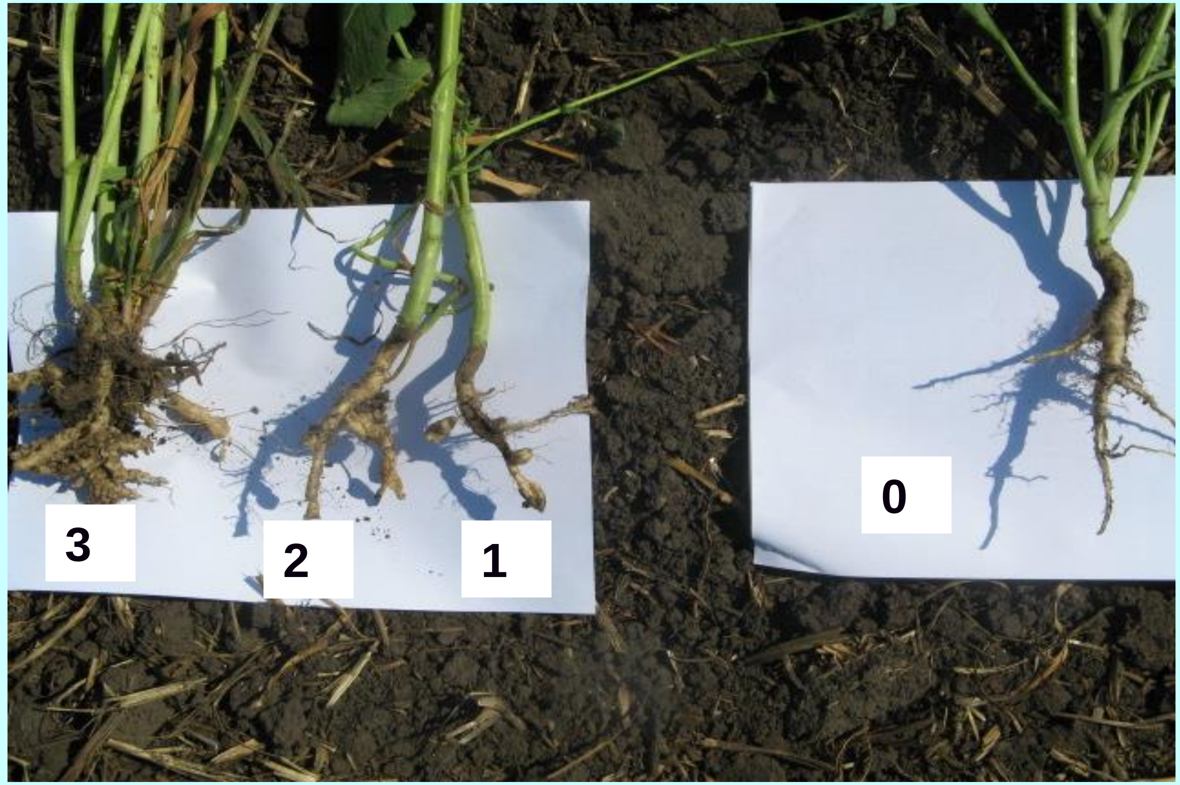
Consortium field nursery- Henwood

- A field site was set up near Edmonton in 2011
  - Infected field soil was supplemented with pathotype 3 and sulfur to reduce pH.



Field testing (P3) – Edmonton, 2008-18

Rating scales – Disease index



Incidence*severity/highest severity(3)

100*3/3=100   examples   100*1/3=33

2018 - Clubroot Nursery in Henwood

Many thanks to Alberta Agriculture for supporting infrastructure!

Alberta Agriculture and Forestry

Search for new CR sources in 2018

Multiplication of new clubroot strains in greenhouse (2015-17)

> 90% infection rate in 2017

Field nursery for new clubroot strains

Evaluation of Lime Products as a Clubroot Management Tool (Nicole Fox)

Evaluation of effects of lime residues (Keisha Hollman)

Evaluation of effects of weeds on clubroot populations (Brittany Hennig)

Effect of inoculum density of *Plasmodiophora brassicae* on yield of canola (Andrea Botero Ramírez)

2018 - Clubroot Nursery at CDC North, Edmonton, Alberta

Welcome Clubrooters to CDC North!

Alberta Agriculture and Forestry

Agriculture and Agri-Food Canada / Agriculture et Agroalimentaire Canada

canola council of Canada

University of Alberta
Edmonton · Alberta · Canada