Highlights of 10 Years of Clubroot Research in Western Canada

Synergy Alberta Conference 2013

Sheraton Red Deer
Red Deer, AB
October 30, 2013

Ron Howard, Plant Pathologist
Alberta Agriculture and Rural Development
Crop Diversification Centre South, Brooks, AB
Outline

- Introduction
- An Overview of the Canadian Canola Industry
- A Clubroot Backgrounder
- Clubroot Research Highlights 2003-13
- Future Actions against Clubroot
- Acknowledgements
Overview of the Canola Industry

- A synthetic crop developed at the University of Manitoba in the 1970s
  - Traditional crossing of winter rapeseed with a type of cabbage
- Canola oil is low in saturated fat
- Worth $19.9 B annually to the Canadian economy
- 10 industry sectors
- 85% of production is exported
- 249,000 Canadian jobs
- Economic impact (western Canada)
  - BC - $432 M
  - AB – $6.1 B
  - SK – $8.2 B
  - MB - $3.4 B
Clubroot Backgrounder

- Diseases are an important issue for crop producers
- They can negatively affect yield, quality, value and saleability of raw and processed commodities into domestic and international markets
- Diseases can spread quickly within and between fields by natural and man-made means
  - Natural – Wind, rain, water & soil erosion, insects, etc.
  - Man-made – Transport of infested seed, soil & crop residues
- Farm-level biosecurity practices are now being adopted by crop producers
What is Clubroot?

- Clubroot is an infectious plant disease that affects members of the cabbage family, e.g. cole crop vegetables, canola, mustard and cruciferous weeds.
- The pathogen that causes clubroot is *Plasmodiophora brassicae*.
- The name “Clubroot” comes from the characteristic galls produced on the roots of infected plants.
- Clubroot can be spread from field to field by infected plant parts and infested soil.
Disease Development

- Clubroot is generally favored by acidic soils
- Abundant soil moisture is required for infection, especially early in season
- It takes about six weeks from the time of infection to full-blown symptom development
- Characteristic symptoms are wilted or stunted plants and multi-lobed root galls containing large quantities of resting spores
- Resting spores may survive in soil for up to 20 years; however, their half-life is about 4 years
Life Cycle

- Zoospore
- Zoospores infect root hairs
- Plasmodium in cell
- Resting Spore Germinates
- Root cells breakdown Releasing Resting Spores
- Club Roots Disintegrate
- “Clubbed” Roots of Infected Brassica
Need 1000 to 100,000 resting spores per gram of soil to initiate root infections in host plants
Symptoms on Canola – Delayed Flowering
Wilting and Leaf Yellowing
Severe Root Galling
Premature Ripening
Decaying Galls
Symptoms on Chinese Cabbage
Disease Spread

- *Plasmodiophora brassicae* is primarily a soil-borne plant pathogen.
- It can spread via movement of infested soil:
  - Farm machinery, vehicles, tools and footwear
  - Soil erosion and water run-off
  - Construction equipment
- Infected vegetable transplants and fodder crops can also spread the clubroot pathogen.
- Soil tag/external contamination of seed and crop residues may also be important.
Mechanisms of Clubroot Spread

- Main means of spread between fields is infested soil carried on farm machinery

- Other dispersal mechanisms have been implicated:
  - Vehicles
  - Construction & oilfield equipment
  - Wind
  - Water
  - Seed & plant material
  - Animals

Cao et al. 2009
Occurrence of Clubroot in Alberta

- Clubroot was seen on cole crop vegetables in some home gardens in Alberta in the late 70’s.
- A heavy infestation was observed in cabbage in a market garden in the Leduc area in 2001.
- First found in canola in 2003 northwest of Edmonton (Sturgeon County) – 12 fields.
- No clubroot was detected in surveys conducted in 2004 (dry growing season).
- Annual surveys have been conducted since 2005.
Economic Impact of Clubroot

- For oilseeds:
  50% yield reduction at 90% infestation to 10% yield reduction at 20% infestation in Sweden (A-C. Wallenhammar et al., 1999)

- For vegetables:
  $13 million in losses to Australian vegetable industry (Donald et al., 2001).
Where did Clubroot come from?

- Clubroot was likely introduced by early settlers on infected vegetable transplants (e.g. cabbage) or on fodder crops (e.g. turnips) grown in infested soil.
- The clubroot pathogen could have built up in the soil in infested yards and gardens over time.
- Manure from animals fed with infected crops and applied onto fields might have spread the disease.
- As farmsteads were abandoned and merged into fields, clubroot could have spread within and between farms via infested soil carried on machinery and equipment, and perhaps with spore-contaminated common seed.
Why is Clubroot Important?

- Clubroot represents a significant threat to Alberta’s canola industry, which is valued at over $6.1 billion.
- Clubroot also poses a risk to mustard and cole crop vegetable production.
- Soil and environmental conditions that are favorable for clubroot development occur in areas from the Peace Region to southern Alberta.
- Clubroot is a very difficult disease to manage once it becomes established, so trying to prevent the disease from coming onto farms is very important.
What’s being done to Control Clubroot?

- Clubroot was added as a declared pest to the Agricultural Pests Act (APA) in April 2007
  - This move was supported by Agriculture Service Boards and the Alberta Canola Producers Commission
- The APA is the foundation legislation that allows Ag Service Boards to develop control and enforcement measures for designated pests
- The APA has facilitated implementation of the province’s Clubroot Management Plan and the creation of the Clubroot Management Committee which consists of government and industry representatives
  - The aim of the plan is to minimize the spread and build-up of clubroot in canola, mustard and market garden/vegetable fields
1. Remove soil from equipment and machinery prior to moving it out of infested fields
2. Use long rotations between successive crops of canola, mustard and cruciferous vegetables
3. Use direct seeding or minimum tillage where possible
4. Avoid spreading straw, hay, green feed, silage and manure harvested from clubroot-infested fields onto clean fields
5. Avoid planting common, untreated seed harvested from clubroot-infested fields
6. Plant clubroot-resistant canola and vegetable varieties
Clubroot Research – Key Areas

- **Surveillance** – Survey canola and vegetable fields to determine the geographical distribution, incidence, severity and economic impact of clubroot.

- **Pathogen Biology** – Study pathogen behavior; develop detection and diagnostic tools; monitor pathotypes.

- **Breeding for Disease Resistance** – Screen germplasm of *Brassica* spp. for resistance; develop standard bioassays and biotech tools; undertake resistance breeding.

- **Disease Management** – Develop/improve clubroot control practices (cultural, chemical and biological methods); validate forecasting models.
Clubroot Risk Mitigation Initiative

- Inaugurated in 2009 by Agriculture and Agri-Food Canada
- CRMI aimed to promote a collaborative research approach to develop integrated and sustainable strategies for managing clubroot
- Better coordination between industry and government stakeholders
- Built on current research projects
- Funding from the ‘Growing Forward’ Program
- Research pillars: Pathology, Breeding and Disease Management
- About $4 million was allocated for 4 years (2009-13)
1. Disease Surveillance

- Clubroot was first seen on canola in 2003 northwest of Edmonton (Sturgeon County)
  - A grower observed wilted, yellow plants in his field
  - An agronomist with Sturgeon Valley fertilizers suspected clubroot and brought some infected plants to Dr. J.P. Tewari at the University of Alberta who confirmed the disease
  - A survey of 70 fields in the area revealed 12 infected crops
- Annual surveys have been carried out since 2004
- >5000 canola & vegetable fields have been surveyed
- Clubroot has been confirmed in 4 vegetable fields and over 1000 canola fields in Alberta since 2003
2003 infestation
Field Survey Protocol

1. Survey fields from flowering onwards
   • Post-harvest (stubble surveys) - Little physical effort is needed to walk through the crop

2. Survey the field in a “W” pattern with 10 stops

3. Also look at “problem areas” such as field entrances, low areas, near pivot points, etc.

4. Dig up roots at each sampling site, visually examine them for clubroot, and record the number of symptomatic plants

5. Retain suspect samples for confirmatory lab testing

6. Follow biosecurity protocols, e.g. protective footwear, sanitization of tools and vehicle tires, etc.
Field Survey Protocol

- Access
  - 10 m
  - 30 m
  - 1st sample site
  - 100 m

Continue to 10 sites
Alberta Clubroot Map (2003-2012)

Cumulative clubroot infestations as of November 2012 from Univ. Alberta, Alberta Agriculture and county surveys

As of 2012, Alberta had 1064 confirmed clubroot-infected canola fields in 24 counties
Characteristics of Infested Fields

- Level of infestation are often highest at the field entrance where equipment starts working.
- Clubroot is not restricted to fields with acidic soils:
  - pH of clubroot-positive fields in Alberta has ranged from 4.8 to 7.6 with a 6.2 average.
- There is a significant negative correlation between disease incidence and severity and soil pH:
  - Less disease as the pH goes up.
  - Acidic soils are the most at risk.
- Most heavily infested fields in Alberta have occurred where canola-canola and canola-cereal-canola-cereal crop rotations have been followed.
2. Pathogen Biology - Pathotypes

- Many pathotypes (‘races’) of *P. brassicae* have been reported around the world
  - Differ in ability to infect different species of crucifers and different varieties and cultivars within a species
- It is important to know which pathotypes are prevalent in canola and vegetables in Alberta
- Breeders need this information so they can incorporate appropriate resistance genes
- University of Alberta scientists have analyzed pathogen populations from throughout the clubroot-affected areas
Host Differential Sets

- Pathotypes are identified based on the reaction of a series of host varieties known as a “differential set”

Isolates and populations were tested on three sets of differential hosts:
- European Clubroot Differential series (15 hosts)
- Williams’ series (4 hosts)
- Somé et al. series (3 hosts)
Pathotype Testing

- Both “field populations” and “single-spore” isolates are being tested.
- Testing with single-spore isolates is more difficult than field populations, but may better reflect natural diversity.
  - Host reactions to rare pathotypes may be masked by the reactions to the predominant pathotypes.
Pathotype Composition in Alberta

"Field Populations"

Pathotype 3 (Williams) ≈ P₂ (Somé et al.)
Pathogen Biology – Spore Dispersal

- *Plasmodiophora brassicae* is a soil-borne plant pathogen.
- Spread through infected soil and crop residues has been well documented.
- Dispersal of spores by soil and water erosion and as dust on the surface of seeds harvested from infested fields is also possible, but has not been well studied.
- University of Alberta scientists have investigated these possibilities in clubroot-infested fields in central and southern Alberta.
BSNE (Dust) Samplers

<table>
<thead>
<tr>
<th>Height (cm)</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>105</td>
<td>5</td>
</tr>
<tr>
<td>80</td>
<td>4</td>
</tr>
<tr>
<td>60</td>
<td>3</td>
</tr>
<tr>
<td>35</td>
<td>2</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
</tr>
</tbody>
</table>
Highest concentration of spores found in any one sampler: \(2.2 \times 10^5\) resting spores per gram of soil

... but in most samplers, spore concentration ranged from: \(5.0 \times 10^2\) to \(1.6 \times 10^4\) resting spores/g soil
Evidence of Natural Seed Infestation

- Tested farm-harvested seeds of various crops for the presence of *Plasmodiophora brassicae* inoculum.
- Found resting spores on seed of field pea, canola, wheat, rye & barley and potato tubers using standard PCR testing methods.
Estimating Clubroot Resting Spore Loads on Naturally Infested Seed

<table>
<thead>
<tr>
<th>Crop</th>
<th>Spore Load (quantitative PCR)</th>
<th>Conventional PCR Result</th>
<th>Commercially Cleaned?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control (&quot;clean&quot; canola)</td>
<td>0</td>
<td>Negative</td>
<td>N/A</td>
</tr>
<tr>
<td>Pea</td>
<td>577</td>
<td>Positive</td>
<td>Yes</td>
</tr>
<tr>
<td>Canola</td>
<td>4,380</td>
<td>Positive</td>
<td>No</td>
</tr>
<tr>
<td>Wheat</td>
<td>34,273</td>
<td>Positive</td>
<td>No</td>
</tr>
</tbody>
</table>

Spore loads as determined by qPCR on samples testing positive by conventional PCR.
Disease Spread: Relative ‘Risk Matrix’

**Equipment**
Large amounts of soil moved, can quickly establish new infections
**MITIGATION:** equipment cleaning & sanitation

**Dust & Water Erosion**
Risk not fully assessed, may contribute to short distance dispersal; risk is function of amount of soil & distance travelled
**MITIGATION:** minimize erosion processes

**Seeds & Tubers**
Limited amounts of inoculum, potential for long distance dispersal
**MITIGATION:** seed cleaning & seed treatments

S.E. Strelkov
3. Clubroot Resistance Breeding

- Introgression of resistance into Canadian spring canola germplasm
  - Crossing of resistant winter canola and/or rutabaga with spring canola
  - Re-synthesis of *B. napus* from its resistant parental species *Brassica oleracea* and *Brassica rapa*

- Breeding programs are underway at western Canadian Universities and at research facilities operated by a number of multi-national companies
Clubroot Resistant Varieties/Lines

- **Pioneer Hi-Breed**
  - 45H29
  - D 3152: (Dupont)
  - VR 9558 GC (Viterra)

- **Monsanto** 73-67 RR: Yields about 112% of checks
  - 73-77 RR
  - 1960 (Canterra)
  - 74-47 CR (G08039)

- **Bayer**
  - L 135 C

- **DL Seeds**
  - TC 72451-10
  - TC 72447-10
  - 6056 CR
4. Clubroot Disease Management

- When clubroot was first discovered in 2003, limited information was available on how to manage it in the canola production systems used in western Canada, so applied research projects were undertaken in a number of areas.

- Cole crop vegetable producers have more clubroot control options than canola and mustard producers do and some of the vegetable disease management strategies were adapted to suit canola and mustard.

- Potential biological, chemical and cultural control methods have been investigated.
Chemical Soil Treatments
Effects of Soil-Applied Fungicides on Canola in Clubroot-infested Soil – Leduc, 2007
Soil Amendments

- Wood ash @ 2.5, 5 and 7.5 t/ha
- CaCN$_2$ @ 0.5 and 1.0 t/ha
- CaCO$_3$ @ 2.5, 5 and 7.5 t/ha
- Unamended control
Effects of Soil Amendments on Canola in Clubroot-infested soil – Leduc, 2008

Wood ash
7.5 t/ha

Control
Summary of Results

- Soil amendments such as calcium carbonate and wood ash, applied at 7.5 t/ha or more reduce the severity of clubroot and improve yield.
- As a chemical soil treatment, Terraclor applied at 90 kg/ha reduced the severity of clubroot, promoted growth, and improved yield; however, at 90 kg/ha it costs $1100/ac.
- Ranman (7.5 L/ha) improved plant height, plant cover and yield.
Prevention of Clubroot Spread

- *Plasmodiophora brassicae* is a soil-borne pathogen
- Soil movement has been implicated in spreading clubroot
- Infested soil can be moved by various means:
  - Agricultural machinery, equipment and farm vehicles
  - Agricultural products (dust and soil tag on seed, tubers, forages)
  - Custom operators (soil testing, fertilizing, seeding, harvesting)
  - Oil and gas companies (seismic, drilling, pipelining, servicing)
  - Contractors (road building, excavating, trenching, hauling soil)
  - Transportation industry (long-distance equipment hauling)
  - Recreational users (quadding, bogging, hunting)
  - Wind and water erosion, domestic livestock and wildlife movement
- Both local and long-distance spread of infested soil is possible, especially when fields are accessed by multiple users throughout the year
Sanitization of Machinery/Equipment

- Sanitization (cleaning and disinfection) of machinery, vehicles, tools and equipment has been used by vegetable growers to help control clubroot.
- The Alberta Clubroot Management Plan recommends:
  - Removing soil and plant debris from equipment (rough cleaning)
  - Cleaning contaminated surfaces by pressure washing
  - Applying a disinfectant (1-2% bleach) to cleaned surfaces
- Oil and gas companies have adopted similar practices ([http://www.capp.ca](http://www.capp.ca))
- Questions have been asked about the practicality and cost of sanitization measures, potential adverse environmental impacts, corrosion risks, hazards to applicators, and the relative effectiveness of current protocols, especially disinfectants.
Sanitization of Machinery and Equipment

- Compare physical and chemical treatments for removing soil and crop residues and for killing clubroot spores
  - Physical – dry heat, hot water, steam, freezing, scraping/brushing, compressed air
  - Chemical – bleach peroxide, quaternary ammonia, electrolyzed water, ozone, acetic acid, detergents
- Evaluate products for agricultural, oil and gas and construction applications
Pressure Washing and Steaming
Disinfectant Evaluation Results

- Efficacy of most products improved in response to increasing concentrations, e.g. $\frac{1}{2}x < 1x < 2x < 5x$ label rates
- Products evaluated at 20- and 30- minute exposure times were more effective than at 10-minute exposures
- At the various rates and timings evaluated, the relative performance of the products was:
  - Highly effective – Industrial Bleach, HyperOx, EcoClear
  - Moderately effective – Virkon, SaniDate
  - Marginally effective – KleenGrow, General Storage Disinfectant, Dutrion, BioStel EO Water, Thymox
Heat Treatment Results

- Warm water, even for extended periods of time, had little detrimental effect on resting spore viability.
- Spore viability declined as temperatures and the duration of exposure increased.
- Hot water (100°C) was the most effective treatment, but the duration of exposure needs to be several minutes.
- Metal objects tend to conduct heat away from the surface resulting in sub-lethal temperatures.
- Wet steam may be an option, but it requires special equipment.
Farm Equipment Sanitation Guide

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:

1. Follow cleaning steps 1-3 listed in this guide. This is especially important when harvesting a field known to have clubroot. If it is not possible, following steps 1 and 2 is better than nothing because the more time you spend uprooting the crop before the harvest, the more visible plant pathogen you avoid spreading the spread.

2. Work-infected fields last. An infected farm only has one field known to have clubroot. If working that field first, growers may reduce the risk of spreading clubroot from infected to non-infected fields and should not leave time to give equipment a thorough cleaning before being used again.

3. Don't work fields where the soil is wet. Wet soils can make it 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 report 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 around any of your fields known to have clubroot.

Recommendations for low-risk areas
For growers in areas where clubroot has not been reported.

1. Decontaminate. Do not clean at a minimum. If all your field's equipment is cleaned early in your cleaning sequence, the risk of contamination may make sanitizing your equipment unnecessary.

2. Ask anyone entering your fields whether they recently worked in a clubroot-infected area. If the answer is no, ask about their sanitation practices and check that their vehicles and equipment have been cleaned and disinfected. Don't feel embarrassed about asking. Some farmers and equipment owners have geographic areas.

3. Make sure equipment is cleaned. When using used machinery or vehicles make sure they are clean before and after they leave the infected site of the farm the crop. Also, check the transport track is clean. As a precaution, you may need to pressure wash and decontaminate the equipment again when it is cleaned in a non-infected area away from any clubroot.
Setting up to wash a drilling rig. >>

Swift Environmental Ltd.
#2, 51331 Range Road 224, Sherwood Park, Alberta, Canada T8C 1H3
Tel: 780.686.4301  Fax: 780.922.7610  Email: swiftenv@telus.net
Please visit our website: www.swiftenvironmental.com

The Ride-Side™ Berm is available exclusively through Swift Environmental Ltd.
The Ride-Side™ Berm is designed and manufactured by SEI Industries Ltd.
The Ride-Side™ Berm is a registered trade name of SEI Industries Ltd.
Future Action Against Clubroot

The following key activities are planned:

1) Enhance industry education and awareness to promote the adoption of best management practices within the agricultural, petroleum and construction industries

2) Continue research on the biology and control of clubroot

3) Continue annual disease surveys to determine the extent of spread within and outside of known infested areas

4) Support initiatives of the Canola Council of Canada (www.clubroot.ca)
Acknowledgements

- Alberta Crop Industry Development Fund
- Canola Council of Canada
- Alberta Agriculture and Rural Development
- Agriculture and Agri-Food Canada
- University of Alberta
- EnCana Corporation
- Harvest Energy Trust
- Enerplus Resources
- Alberta Canola Producers Commission
- Agriculture and Food Council of Alberta
- Canadian Seed growers Association
- SaskCanola
- Manitoba Canola Producers Association
- Disinfectant and Crop Protection Product Companies
- Alberta Counties and Municipalities
Ron Howard, Ph.D., P.Ag.
Research Scientist, Plant Pathology
Alberta Agriculture and Rural Development
Crop Diversification Centre South
301 Horticultural Station Road East
Brooks, AB T1R 1E6
Phone: 403-362-1328; Fax: 403-362-1326
Email: ron.howard@gov.ab.ca