Clubroot in Canola-
Research Updates of 2020

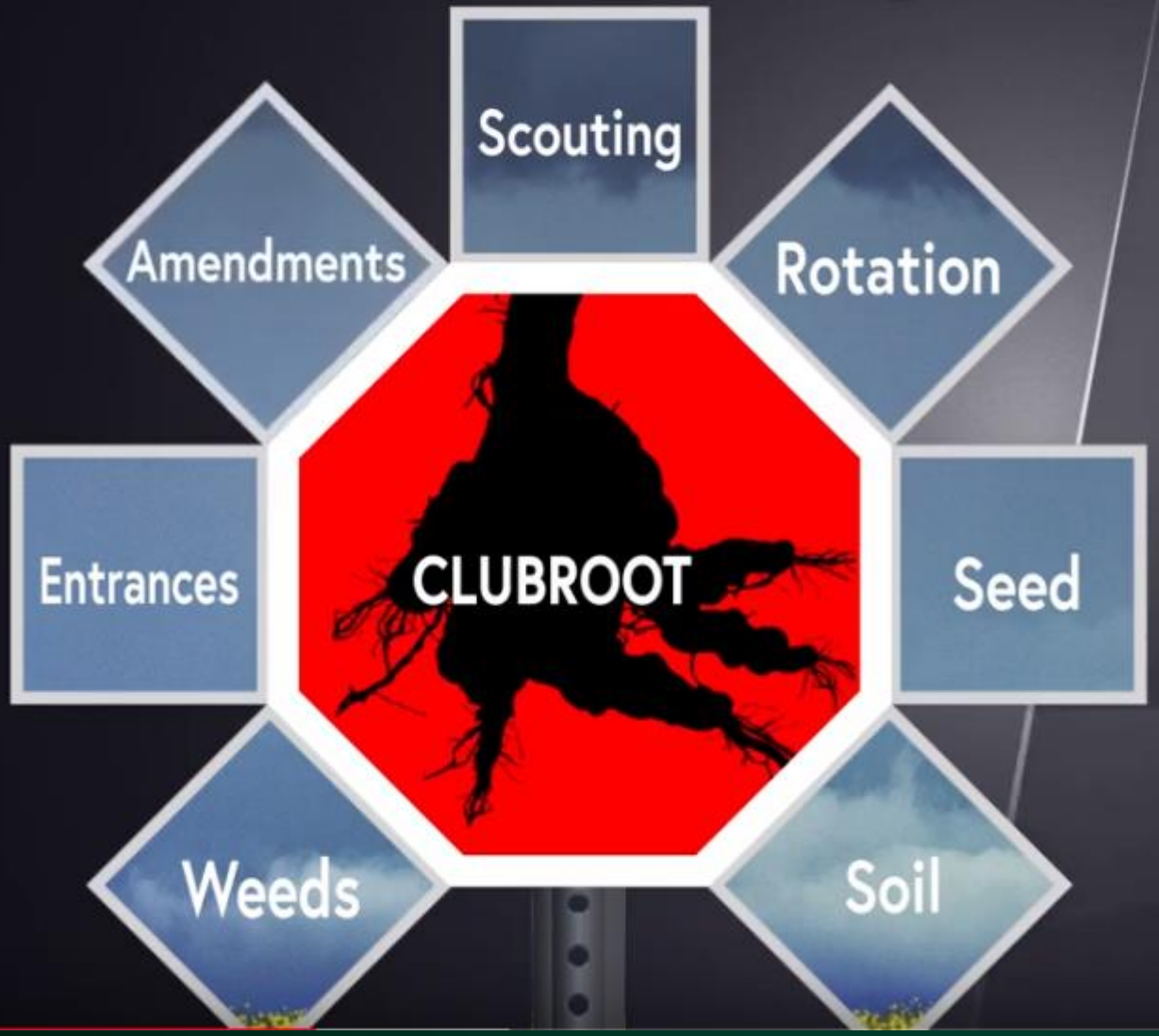
Venkat Chapara, PhD
Plant Pathologist,
Langdon REC

Canola Expo 2020
December 8th, 2020

Clubroot

- Causal agent *Plasmodiophora brassicae*
- Obligate biotrophic soil-borne plant pathogen
- Not a fungus/amoeba/slime mold but has some characters similar from each
- Infects hosts of brassica family
  - E.g. Canola, cauliflower, cabbage, rutabaga, radish, turnip, brussel sprouts, kale etc.
  - Susceptible brassica weeds: wild mustard, Shepard's purse, volunteer canola, stink weed
  - Model Organism: *Arabadopsis*
- Prefers acidic soils but found in the soils of pH up to 7.2
- Once in the soil can live as resting spores up to 20 years
- Pathogen infects roots; causes galls there by restricting the flow of water and nutrients to the plant
- If 100% of plants infected results in 50-80% reduction in yields (Europe and Sweden Research)
- Seen 25% of yield losses in Cavalier County, ND

Best Management Practices



To manage clubroot on canola in North Dakota
Current Research is focused on Best Management Practices

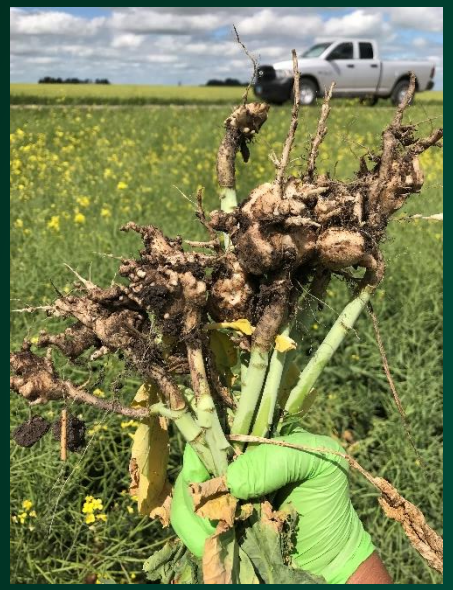
Source: Canola Council of Canada

Research Objectives studied in 2020

- **Statewide Clubroot Survey:**
  - Visual
  - Identification and Quantification of clubroot resting spores from soil
- **Clubroot management studies**
  - Seed treatments
  - Germplasm Evaluation
  - Canola Varietal Evaluation
  - Efficacy of Surfactants to manage clubroot
  - Efficacy of Surfactants with lime and without lime
  - Dose/rate determination of lime
- ***P. brassicae* Pathotypes of North Dakota**

Statewide Clubroot Survey

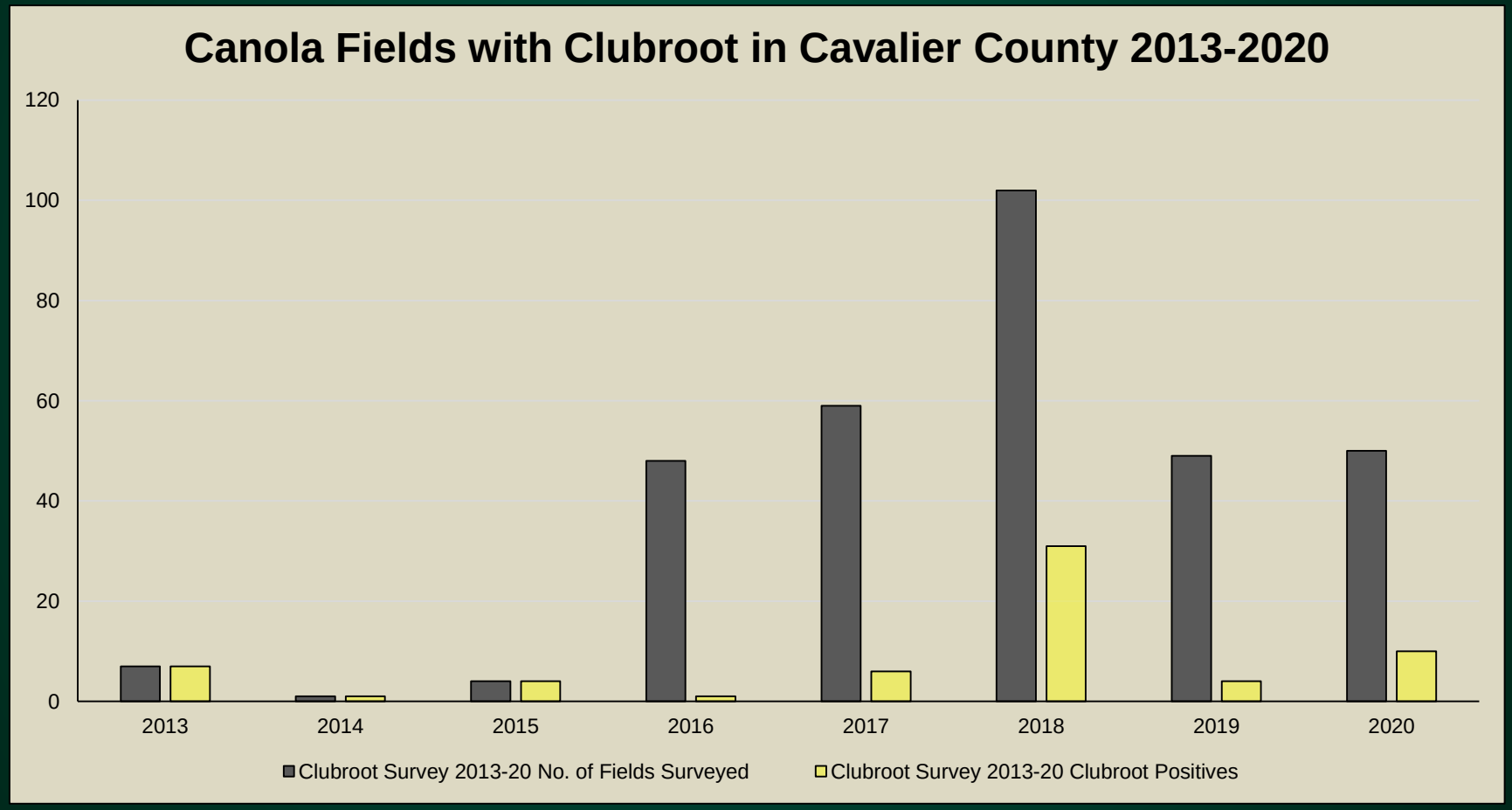
- **Visual**
  - Walking in a W pattern and uprooting the stubbles and look for presence of galls



- **Identification and Quantification of clubroot resting spores from soil**
  - Used Q-PCR the advanced Molecular technique to quantify the clubroot resting spores in soil
  - This enables us to identify fields infected with clubroot if we missed seeing symptoms during standing crop
  - Also determines the number of spores present per gram of soil

Clubroot on Canola in Cavalier County:2013-2020

- **20% of the fields found with clubroot (**Visual galls**)**



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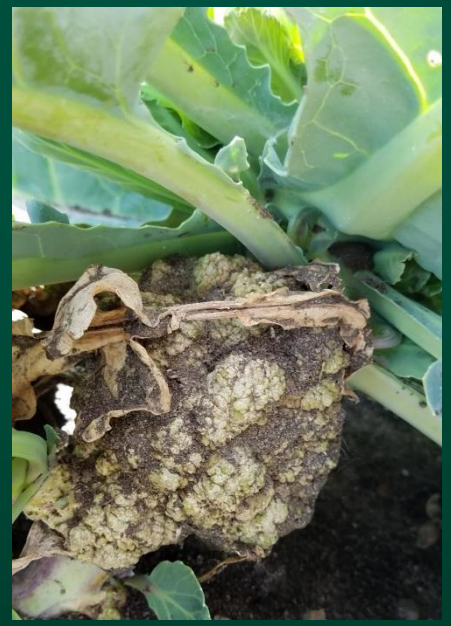
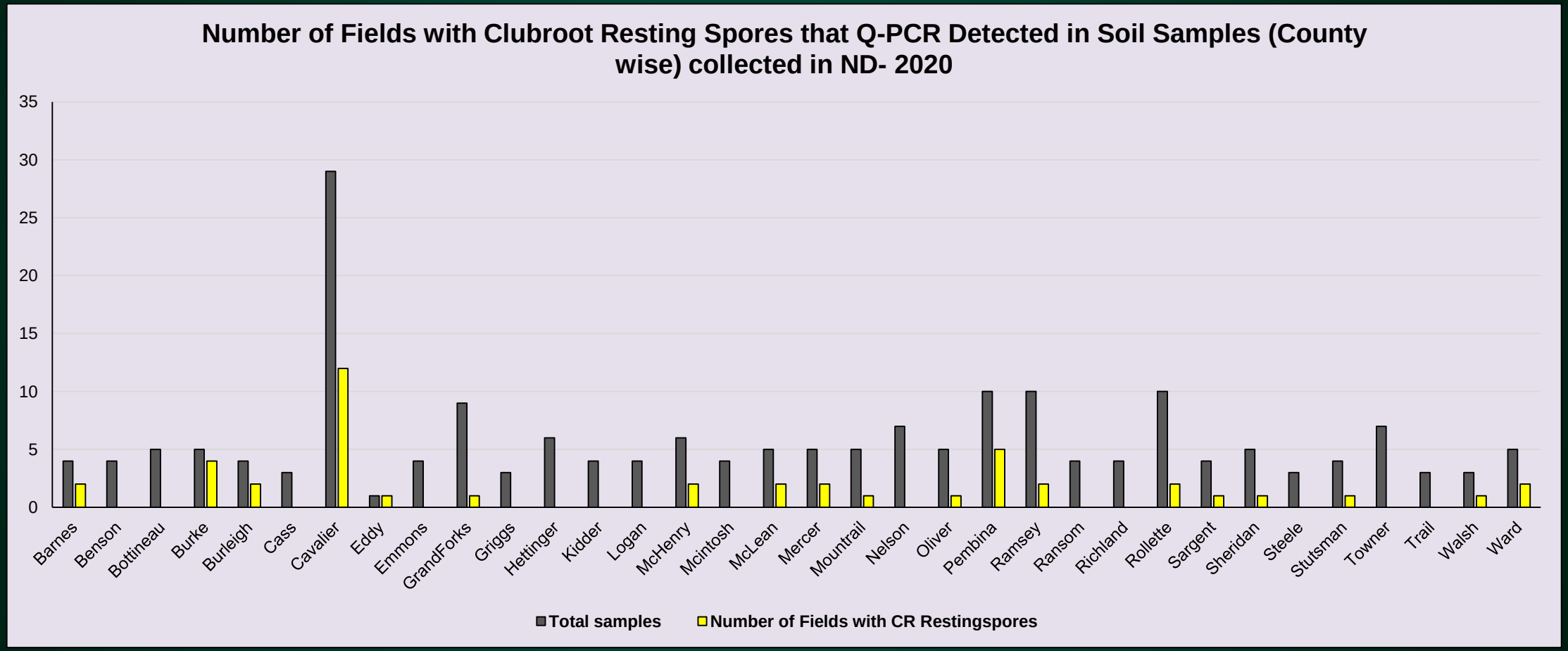
Clubroot Survey in Various Counties of North Dakota

- Visual galls found on brassica vegetables in McHenry County
- Resting spores found in soils-Confirmed with molecular tests using Q-PCR



Courtesy: Rachel Wald and Travis Prochaska

Clubroot Resting Spores found in soil samples from various Counties in ND



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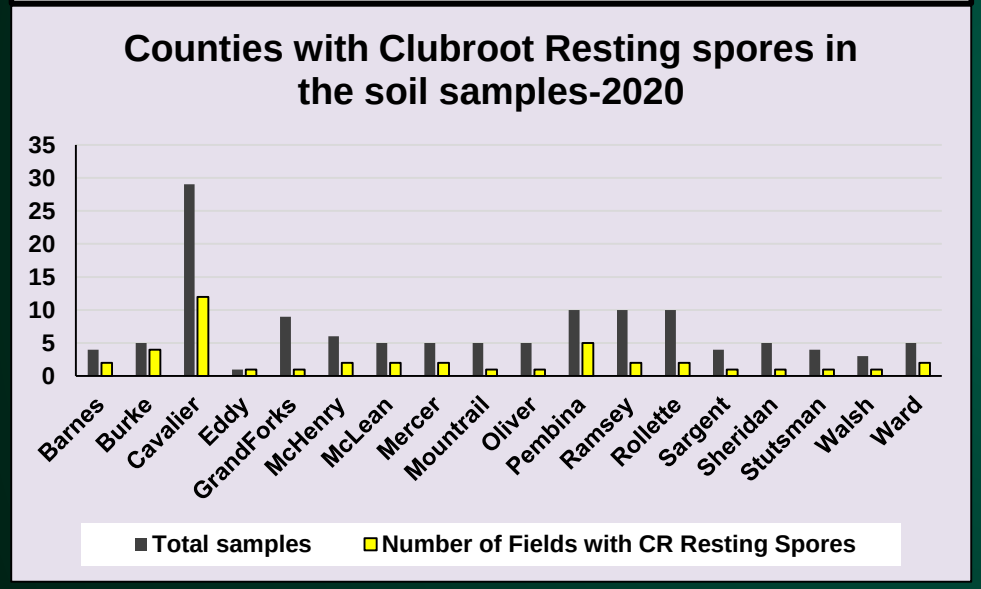
Collaborators: Travis Prochaska, Audrey Kalil, Zhaohui Liu, Jinwei G.
Soil Sampling in SE & SW Counties: Dante Marino and Del Rio

Fields with Clubroot Resting Spores found in Soil Samples from various Counties in ND-2020

Q-PCR Assays detected18 out of 34 Counties had fields with Clubroot Resting Spores



Quantified resting spores of P. brassicae from all those samples ranged from 500 to 40 million spores per gram of soil (minimum detection limit of the assay being 10 resting spores/gm of soil).

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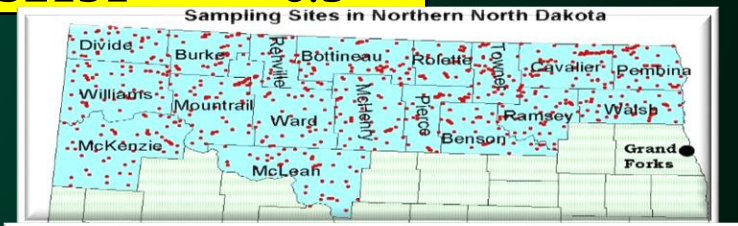
Number	County Name	Total samples	Number of Fields with CR Resting Spores
1	Barnes	4	2
2	Burke	5	4
3	Cavalier	29	12
4	Eddy	1	1
5	GrandForks	9	1
6	McHenry	6	2
7	McLean	5	2
8	Mercer	5	2
9	Mountrail	5	1
10	Oliver	5	1
11	Pembina	10	5
12	Ramsey	10	2
13	Rollette	10	2
14	Sargent	4	1
15	Sheridan	5	1
16	Stutsman	4	1
17	Walsh	3	1
18	Ward	5	2

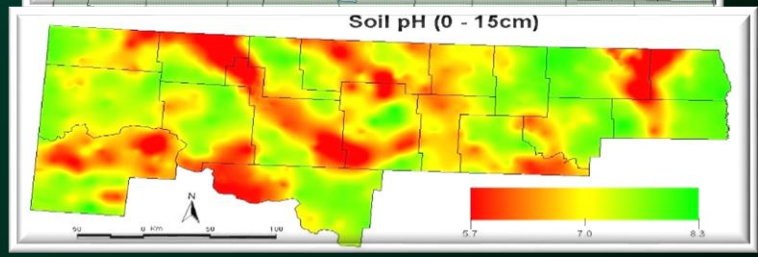
Interpretation of State wide Soil Sample Quantification Tests

County	Location	Spores/Gram	Crop	GPS Coordinates	pH
Barnes	Leal	500	Soybean	47.103884; -98.311069	**7**
Stutsman	Wadsworth (N.O.)	3 million	Pasture	47.229373; -99.332308	**8**
Barnes	Binghamptom	5 million	Canola	46.753053; -97.802422	**7.5**
Burleigh	Gibbs	90000	Pasture	46.852463; -100.66080	**6.6**
Burleigh	Driscoll	50000	Wheat	46.839536; -100.145555	**6.8**
Sargent		7000	Pasture	46.060146; -97.491226	**7.9**
Cavalier	Hay township	40 million	Canola	Anonymous	5.6
Eddy	EC20-1	1000000	Wheat	47.81445; -99.14765	7.5
Grand Forks	GFC20-7	500000	Cover Crop	47.80447; 97.55955	6.9
Rolette	RC20-8	700000	Canola	48.59576; -99.71068	5.8
Rolette	RC20-6	360000	Canola	48.67525; -99.52151	6.5

Samples form fields and counties represented with yellow background are to be monitored closely

Waiting for complete pH results





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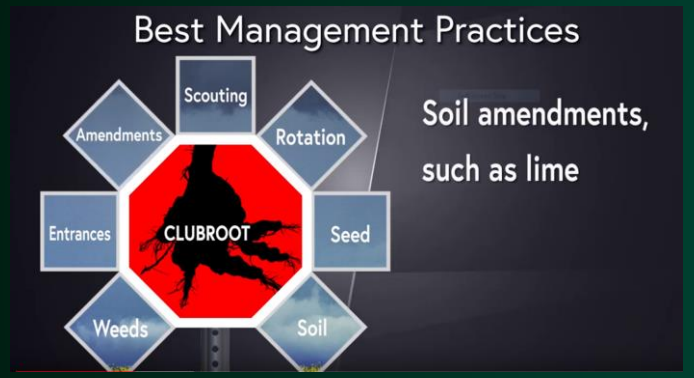
CLUBROOT MANAGEMENT STRATEGIES



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Objectives Tested

- **Clubroot management studies**
  - Germplasm Evaluation
  - Canola Varietal Evaluation
  - Seed treatments
  - Soil amendments with lime and without lime
  - Dosage/Rate determination of lime
  - Efficacy of Surfactants to manage clubroot
- **On going *P. brassicae* Pathotype Study with Canadian Plant Pathologists**

Land Preparation

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Objective 1: Canola Cultivar Evaluation along with other Brassica Hosts to Clubroot-2020

Aim: To evaluate performance and to monitor resistance breakdown

Cultivar	Description
6076CR	BrettYoung Seeds
4187RR	BrettYoung Seeds
INVIGOR L255PC	BASF
INVIGOR L234P	BASF
CP9919RR	Croplan Genetics
DKL30-42	Cargill
45CS40	Pioneer (Corteva)
45H33	Pioneer (Corteva)
CP955RR	Croplan Genetics
CP9978TF	Croplan Genetics
CP9982RR	Croplan Genetics
CS2600TFR	Canterra Seeds
Camelina	Winter Variety 'Joelle'
Rutabaga	Variety 'Laurentian'
Carinata	Unknown Variety
Turnip	Variety 'Purple Top White Globe'

16 treatments
4 replications
Randomized Complete Block Design

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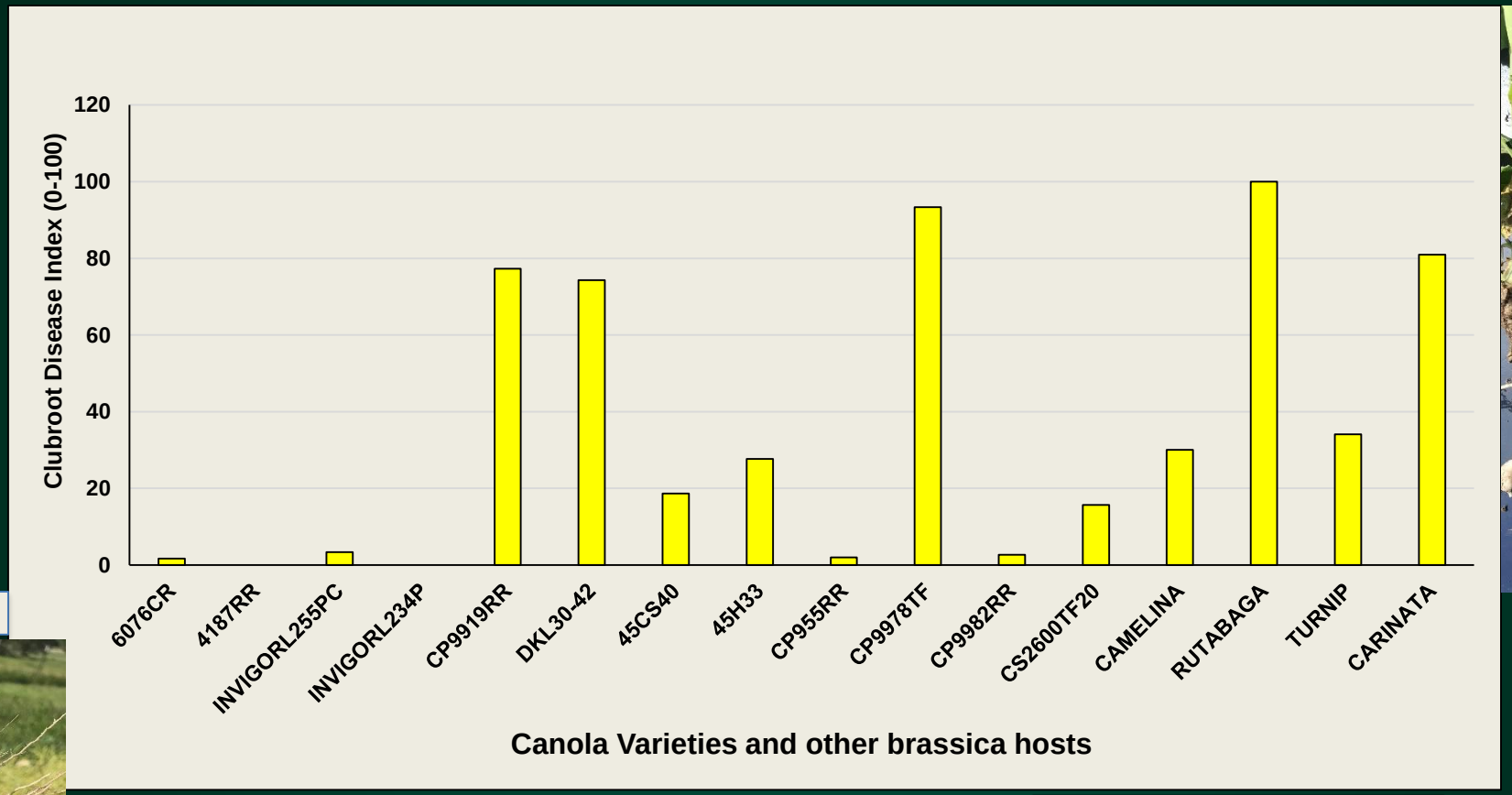
Canola Cultivar Evaluation along with other Brassica Hosts to Clubroot-2020



Clubroot galls on Carinata

Resistant Cultivar

LSD: 31.15
P-Value: 0.00001*

Scale:
DI <30% Resistant
DI 30-69% Intermediate
DI > 70 Susceptible
Validity of Trial >60% DI in susceptible check

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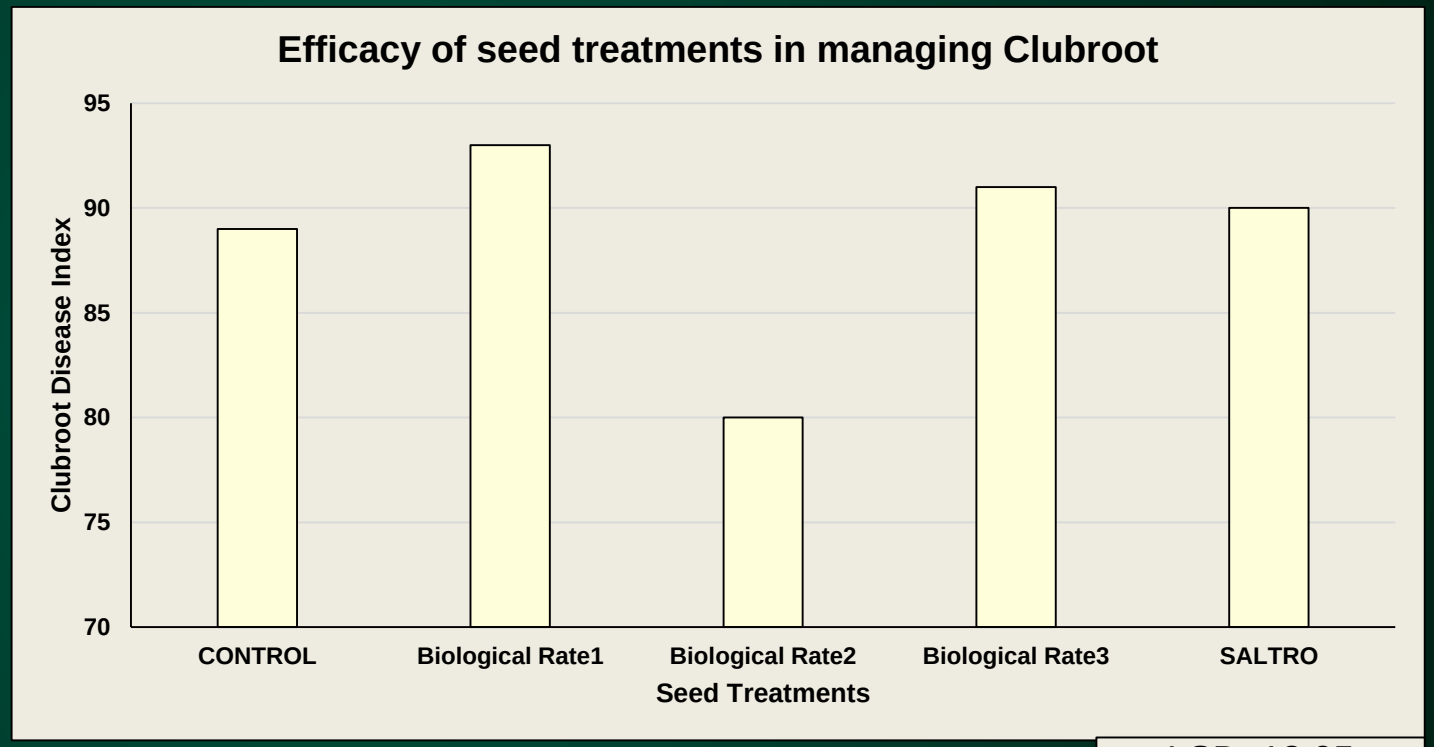
Objective 2: Evaluation of Seed treatments

Tested on: cv. Westar
5 treatments
4 replications
Arranged in
Randomized Complete
Block Design
Evaluated after 60days

*None of the seed treatments tested had effect on clubroot control



LSD: 13.95
P-Value: 0.35

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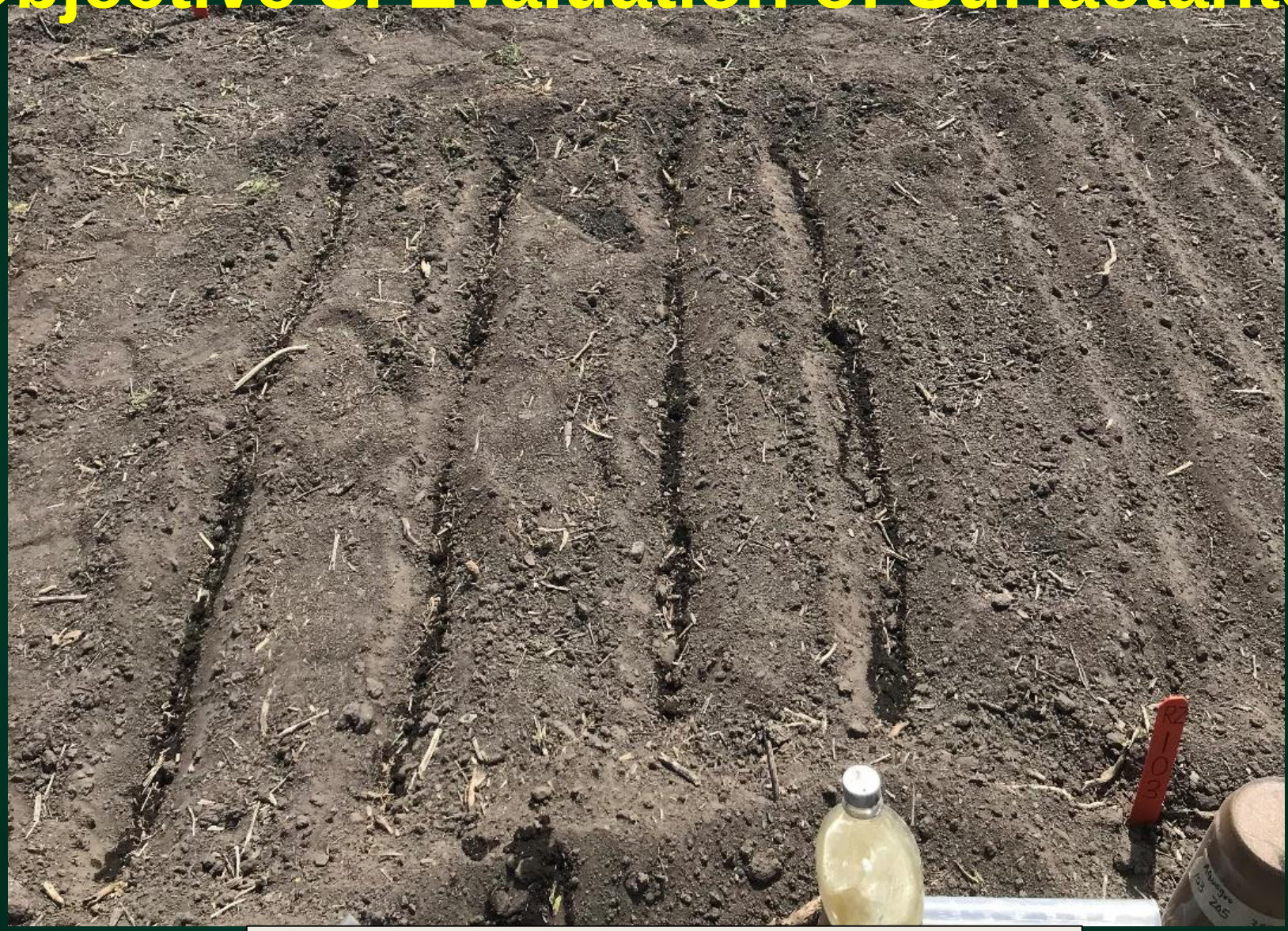
Objective 3: Evaluation of Surfactants



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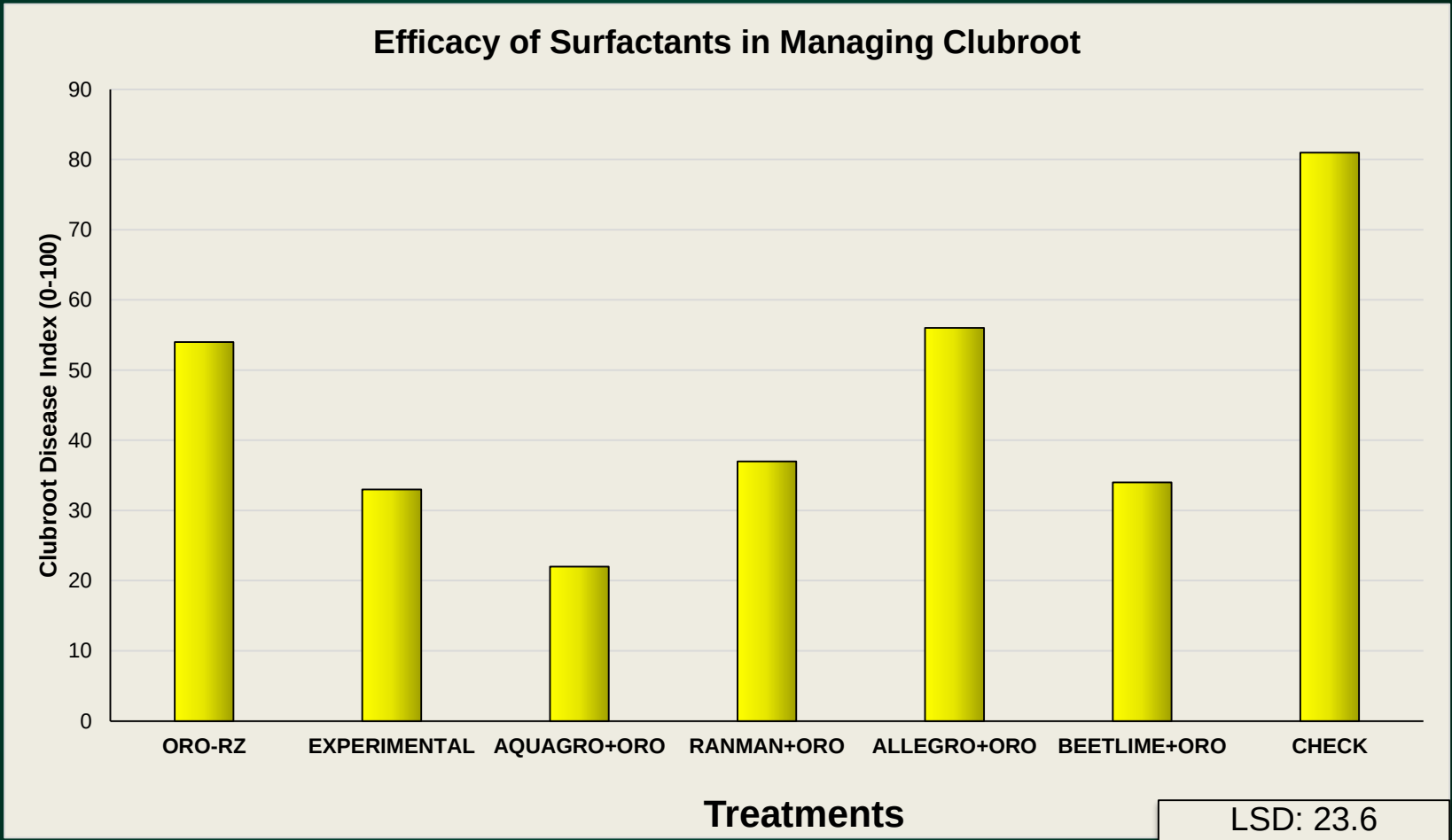
Soil Drenching of liquid formulations of Surfactants and Chemicals

Evaluation of Surfactants

Tested on: cv. L233P
7 treatments
4 replications
Arranged in Randomized Complete Block Design
Evaluated after 60days



LSD: 23.6
P-Value: 0.0012

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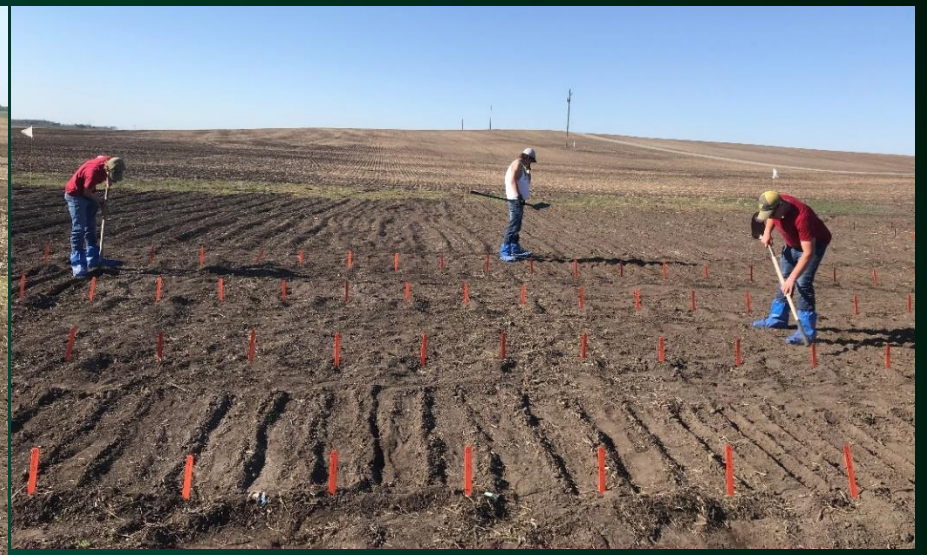
pH before and after application has no effect on clubroot control in case of surfactants

Objective 4: Evaluation of Surfactants with and without lime

Soil sample collection before application and after application of soil amendments



Soil Drenching of liquid Surfactants formulations and Chemicals

Evaluation of Surfactants with and without lime

cv. L233P

	Clubroot Disease Index P-Value
Bloc	0.479
Main Plot (Lime vs without Lime)	0.3275
Main Plot*Bloc	0.9504
Sub Plots	0.0001
Main Plot*Sub Plot	0.5752

Treatments	Rate	CR DI
Ranman+ORO	20 fl oz+2 pt/A	20
ORO Zero	CHK	84
ORO79 TWO	2 pt/A	33.5
ORO79 FOUR	4 pt/A	16
ORO79 EIGHT	6 pt/A	23
ORO09	4 pt/A	21.5
Mean		32.9
CV%		65
LSD(0.05)		22
p- Value (0.05)		0.00001

*The interaction results indicate that there were no differences among the treatments under the influence of lime applied and non-lime applied blocks

*There were differences in pH before and after application treatments in lime and surfactants applied blocks but not in surfactant alone applied blocks

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Objective 5: Evaluation of soil amendments at various Doses/rates to manage clubroot

Lime applied plots

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Three soil amendment products beet lime, pellet lime and wood ash were tested in different rates; arranged in a split plot design

Soil amendments Dose/rate Response in Managing Clubroot

cv. L233P

Source	P-value
Bloc	**0.7299**
Fac_A (Treatments)	**0.0469**
Fac_B (Rates)	**0.0006**
Fac_A*B	**0.293**

Fac_A	CR DI
Beet lime	31
Pellet lime	48
Wood Ash	57
Mean	**45**
CV (%)	**67**
LSD (0.05)	**22**
p-Value (0.05)	**0.0469**

Fac_B	CR DI
ZERO	81
5 t/ha	35
10 t/ha	37
15 t/ha	29
Mean	**45**
CV (%)	**67**
LSD (0.05)	**25**
p-Value (0.005)	**0.0006**

pH results: There were significant differences among the treatments tested in terms of increase in pH from before application to after application evaluation

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Pathotypes of *Plasmodiophora brassicae* present in North Dakota

Sample	North Dakota clubroot Pathotype Designation		
	Some et al. (1996)	Williams (1966)	Canadian Clubroot Differential Set
FFCR	P3	8	Novel
MMCR	P3	2	2C
PBCR-2	P2	8	8N
RBCR-4	P3	8	Novel
RBCR-5	P3	8	8D
YCR-16	P3	8	Novel

- The *P. brassicae* pathotype composition in North Dakota was quite distinct from that reported previously from Alberta, Canada, where the clubroot outbreak is most severe.
- None of the pathotypes identified could overcome first generation resistance, and
- In North Dakota, clubroot may still be managed by planting CR canola in a minimum 3-year rotation.

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Lime application on germplasm evaluation studies of Canola diseases blackleg and white mold

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GEHL
1410

Literature available on clubroot from NDSU

Chapara V, et al., J Agron Agri Sci 2019, 2: 008

HSOA Journal of Agronomy and Agricultural Science

Short Communication

Prevalence of Clubroot on Canola in North Dakota

Chapara V[1]*, Kalwar N[2], Lubenow L[2] and Chirumamilla A[2]

[1]*Langdon Research Extension Center, North Dakota State University, Langdon, USA*

[2]*NDSU Extension Service, Langdon, ND-58249, USA*

Abstract

Clubroot on canola was regular and more prevalent than expected in Cavalier County in the current survey. Prevalence of clubroot on canola has been increasing at rapid pace in North Dakota and has been confirmed in 33 fields in Cavalier County in 2016, which is five times more than it was in 2017. Contrastingly, no clubroot positive fields were found in any other canola growing counties of North Dakota that were surveyed. Continuous survey in coming years is required to prevent the spread and to design management plan of clubroot along with extensive outreach activities throughout North Dakota. Extensive education of growers in identifying clubroot disease, the biology of the pathogen, its prevalence and prevention is needed.

Keywords: Canola; Clubroot; *Plasmodiophora brassicae*

Clubroot of canola caused by Plasmodiophora brassicae (Woronin) is the new emerging disease in North Dakota since its identification on canola in 2013 (Chitteni et al. 2014). Clubroot is a soil borne disease that causes swellings, or galls on the plantroots of Brassicae family (Dixon 2009). These galls cause stefans premature ripening of canola plants and yield loss in the canola (Strelkov et al. 2005). Examination of roots for galls by digging up from the affected areas is the quick identification of clubroot incidence (Changara and Wright 2012). Clubroot disease incidence and development is favored by acidic soils (Tewari et al. 2005). However, later research proved that clubroot on canola is not only limited to acidic soils but can also occur in alkaline soils (Strelkov et al. 2007). The highest degree of clubroot disease infestation was observed at pH 6.6 (Palm 1963). P. brassicaeis soil-borne obligate parasite, thrives in the soil as resting spores that can remain viable in the soil up to 17.3 years indicating crop rotation of 3-4 years may not be a viable option and can spread from field to field on both agricultural and non-agricultural equipment (Wallenhammar 1996). Three-year survey was conducted by a survey group consisting one plant pathologist, two extension specialists of Langdon Research Experiment Station, Langdon, North Dakota and one NDSU Extension personnel of Cavalier County, North Dakota. Current objective of determination of clubroot spread and prevalence was done by visual inspection of canola plant roots for galls at two phases in the growing season, once at flowering (10 -100%) stage and at swathing of canola in seven northeastern counties (Pembina, Walsh, Nelson, Ramsey, Towner, Rolette and Cavalier) of North Dakota. The survey was done from the main entrance of the field, where the survey group walked along in a "W" pattern by stopping at 10 spots and uprooting 10 consecutive stems from the ground at each spot. Excess soil was shacked off. Roots then were visually examined for presence of galls. The three-year data prior to 2016 was obtained from North Dakota State University, industry and commodity group surveys done in Cavalier County North Dakota (Figure 2). Selection of counties to survey was donebased on canola acreage planted in that particular year and on assumptions of P. brassicae resting spore dissemianted in all directions through equipment, soil, and water to neighboring counties of Cavalier. In each county, one field in every 5,000 acres was scouted. Soil samples were collected from the clubroot positive and likely positive fields with an intent to know the pH of the infected soil at which clubroot infections were found. In all, a minimum of 5-10 fields per county were targeted for scouting. The survey results indicatedthat clubroot on canola was more prevalent in Cavalier Countythan expected in low pH soils that ranged from 4.5 to 6.4 (Data not shown).Likewise, the current survey results indicated that the prevalence of clubroot on canola has been increasing at rapid pacein North Dakota and has been confirmed in 33 fields in 2018, which is five times more than it was in 2017 (Figure 1), apart from Cavalier County there were no clubroot findings in any other counties surveyed (Figure 2). Disease surveys has been very crucial worldwide in managing a newly emerging disease like clubroot. Research reports of canola survey in central Sweden indicated that 78% of 190 fields surveyed were infested with clubroot (Wallenhammar 1996). Survey reports of clubroot in Alberta andManitoba provinces of Canada confirmed over 3000 and 600canola fields respectively were clubroot positives (Strelkov, 2018 Personnel communication at Clubroot International workshop). Spread of clubroot can be reducedby thorough sanitation and throughadopting integrated disease management consistingdisease resistant cultivars, longer crop rotations, and soil reclamation (Donald and Porter 2009). Extensive crop survey, determination of soil pH of canola fields with clubroot was foundto be an important arsenal in educating growers about the prevalence of clubroot in North Dakota on Canola. The prevalence data will be more fruitful when integrated with other available clubroot management practices. Survey and prevalence data can be used inoutreach activities to educate producers in identifying the disease, inform of potential risks and to encourage clubroot monitoring and adoption of sanitation practices. Removal of potentially contaminated soil from field equipment is an ideal one if practiced (Strelkov et al. 2011). Likewise, length of crop rotation with canola can be determined with the knowledge of detection of clubroot in a field.

***Corresponding author:** Venkataramana Chapara, Langdon Research Extension Center, North Dakota State University, ND-58249, Langdon, USA, Tel: +91 7012562580; Fax: +91 7012562580; E-mail: venkata.chapara@ndsu.edu

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NDSU North Dakota Agricultural Experiment Station

Soil Sampling to Quantify Clubroot Spores From Soil in North Dakota

Note: Please complete this form in its entirety to identify the soil sample location. The information will be used to compile a distribution map of clubroot infestations in North Dakota.

County: _____ Grower's name: _____ Phone: _____
(will remain confidential)

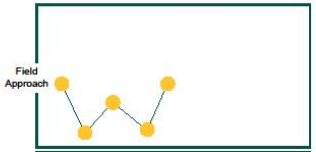
Field Identity							
Field ID	Latitude N	Longitude W (-)	OR	Township	Range	Section	¼

Latitude and longitude in decimal degrees is preferred.

Example: ***N: 48.659444 W: 98.24444 (GPS coordinates)*** - GPS coordinates can be obtained through "preferences" or other "setup" functions within the systems software.

Soil Sampling Survey Procedure

1. Walk in a "W" pattern in the field starting from the main entrance of the field (approach), low spots or flooded areas, low pH spots and areas of diseased patches as shown in the figure below.



Precautions: Do not drive into the field. Wear disposable boots and gloves, and disinfect your soil sampling equipment in the field.

2. At each sample point, clear away residue on the soil surface and collect soil core or scoop from the top 3 to 6 inches (a representative sample is five scoops or cores from each field). Be sure to maintain 300 feet from point to point of soil collection.
3. Air-dry the soil samples indoors in paper boxes and send or drop them off at one of the following address:

Zhaohui Liu
Department of Plant Pathology
NDSU Department 7660
P.O. Box 6050
Fargo, ND 58108-6050

UPS/FEDEX to
Zhaohui Liu
Department of Plant Pathology
Walster Hall 306
Fargo, ND 58102

Venkat Chapara
Langdon Research Extension Center
9280 107th Ave. N.E.
Langdon, ND 58249

NDSU NORTH DAKOTA AGRICULTURAL EXPERIMENT STATION
North Dakota State University, Fargo, North Dakota

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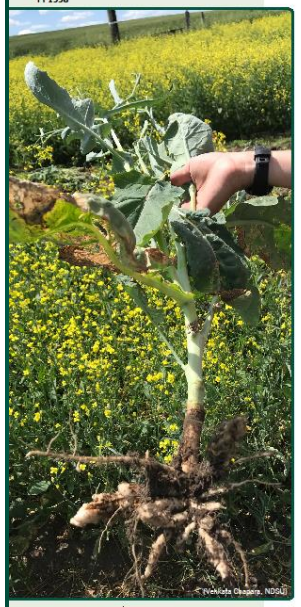

Canola Diseases: Clubroot

Madeleine Smith, NDSU Extension Agent, Pembina County
Anitha Chirumamilla, NDSU Extension Agent, Cavalier County
Lindy Berg, NDSU Extension Agent, Towner County
Venkata Chapara, Plant Pathologist, Langdon Research Extension Center
Fereshteh Shahoveisi, Canola Research Assistant, Department of Plant Pathology
Luis E. del Rio Mendoza, Canola Pathologist, Department of Plant Pathology
Sam Markell, Extension Plant Pathologist, Department of Plant Pathology

Clubroot is a serious disease threat to canola

NDSU EXTENSION
North Dakota State University, Fargo, North Dakota
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The host range of *Plasmodiophora brassicae* in North Dakota

Venkataramana Chapara[1], Prochaska T. J.[2], and Anitha Chirumamilla[3]

[1]North Dakota State University/Langdon Research Extension Center, Langdon, ND-58249
[2] North Dakota State University/North Central Research Extension Center, Minot, ND-58701
[3]NDSU Extension Service, Langdon, ND-58249
Corresponding author: Venkataramana Chapara
Fax number: 7012562580
e-mail address: venkata.chapara@ndsu.edu

Abstract

Plasmodiophora brassicae causes clubroot on brassica crops and is a new emerging disease on rapeseed in North Dakota. A two-year study was conducted to document the host range and symptomology on various brassica hosts to *P. brassicae* infections in field conditions. The results indicated that out of the 13 brassica hosts tested, 12 of them developed ellipsoidal galls on roots exhibiting the clubroot symptomology with a disease index (DI) ranging from 41 to 100%. False flax/ camelina (*Camelina sativa*) showed the least susceptibility among the brassica hosts tested. Symptomology of clubroot on various brassica hosts will serve as a pictorial guide in the future to educate growers and in choosing non-brassica cover crops in clubroot infected fields.

Prevalent Pathotypes of *Plasmodiophora brassicae* in North Dakota

Venkat Chapara[1], and Stephen E. Strelkov[2]

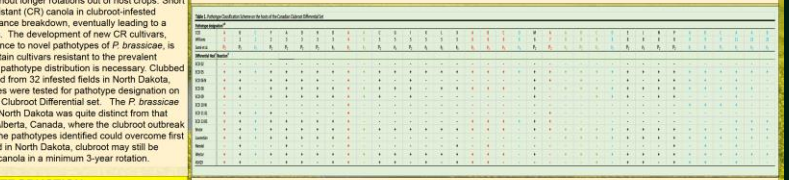
[1]Langdon Research Extension Center, North Dakota State University, Langdon, ND, 58249 U.S.A.,
[2]University of Alberta, Edmonton, AB, Alberta T6G 2P5, Canada.

ABSTRACT

Clubroot (*Plasmodiophora brassicae*) on canola (*Brassica napus*) is spreading faster than expected in North Dakota, causing significant economic losses. An integrated management approach, including longer crop rotations, sanitation and cultivar resistance, are recommended to minimize the impact of this disease. Currently, cultivar resistance is the main management tool sought by growers for clubroot management, without longer rotations out of host crops. Short rotations with clubroot resistant (CR) canola in clubroot-infested regions may lead to resistance breakdown, eventually leading to a decline in canola hectares. The development of new CR cultivars, preferably carrying resistance to novel pathotypes of *P. brassicae*, is therefore important. To obtain cultivars resistant to the prevalent pathotypes, knowledge of pathotype distribution is necessary. Clubbed canola roots were collected from 32 infested fields in North Dakota, and representative samples were tested for pathotype designation on the hosts of the Canadian Clubroot Differential set. The *P. brassicae* pathotype composition in North Dakota was quite distinct from that reported previously from Alberta, Canada, where the clubroot outbreak is most severe. None of the pathotypes identified could overcome first generation resistance, and in North Dakota, clubroot may still be managed by planting CR canola in a minimum 3-year rotation.

MATERIALS & METHODS

* Clubbed galls from 32 canola fields were collected in annual survey of clubroot in North Dakota, USA
* Pathotyping was done under greenhouse conditions
* Six representative samples were evaluated for pathotype designation on the Canadian Clubroot Differential (CCD) set
* Thirteen differentials were inoculated with resting spores of *P. brassicae* and the experiment was repeated
* Galls on the differentials were evaluated after 45 days with clubroot



* Pathotype designations on the CCD set include a number to indicate the classification according to the system of Williams (1966), followed by a letter denoting the CCD designation (e.g., pathotype 2A, 2B, 2C) (Strelkov et al. 2020; Askarian et al. 2020)
* Since the CCD set includes all of the differentials of Somé et al. (1996), designations according to that system can also be obtained

INTRODUCTION

- *Plasmodiophora brassicae* causes clubroot on canola and is an emerging disease in North Dakota
- Can cause significant yield losses under favorable conditions (low pH soils, susceptible cultivar)
- Cultivar resistance, crop rotation and equipment sanitation are some of the common recommended practices to manage clubroot
- Planting resistant cultivars at shorter intervals increases the chances of resistance breakdown and development of novel pathotypes of *P. brassicae*
- Knowledge on the prevalent pathotypes in an area helps breeders to develop resistant cultivars and to develop integrated disease management guidelines
- The objective of this research is to determine the prevalent pathotypes of *P. brassicae* in North Dakota

Figure 1: Galls on canola roots due to *P. brassicae* infections in field were collected for pathotyping study

RESULTS

Sample	North Dakota clubroot Pathotype Designation		
	Somé et al. (1996)	Williams (1966)	Canadian Clubroot Differential Set
FFCR	P3	8	Novel
MMCR	P3	2	2C
PBCR-2	P2	8	8N
RBCR-4	P3	8	Novel
RBCR-5	P3	8	8D
YCR-16	P3	8	Novel

DISCUSSION

* The *P. brassicae* pathotype composition in North Dakota was quite distinct from that reported previously from Alberta, Canada, where the clubroot outbreak is most severe.
* None of the pathotypes identified could overcome first generation resistance, and
* In North Dakota, clubroot may still be managed by planting CR canola in a minimum 3-year rotation.

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NDSU NORTH DAKOTA AGRICULTURAL EXPERIMENT STATION

Summary

- Visual surveys indicate 20% of fields surveyed has Clubroot on Canola in Cavalier County in 2020
- Molecular studies of soil samples indicate 53% of the fields surveyed has clubroot resting spores in ND
- Clubroot Resistant Varieties are still holding good against the pathotypes present in ND soils
- Tested germplasm results are not presented
- Tested seed treatments had no efficacy in clubroot control
- Surfactants had an effect on Clubroot, however more testing has to be done
- Beet lime showed efficacy in all the rates tested
- Pathotyping studies are still being continued with University of Alberta, Edmonton, Canada

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Thank You and Questions?