Keeping a finger on the pulse of pulse crop pathology

Sabine Banniza

Advancements in Agricultural Research Seminar Series, presented by the College of Agriculture and Bioresources

March 21, 2023

CROP DEVELOPMENT CENTRE USASK

UNIVERSITY OF SASKATCHEWAN
College of Agriculture and Bioresources
AGBIO.USASK.CA

Government of Saskatchewan
Ministry of Agriculture

[Prof. W.P.] “Fraser, when he became full professor in 1925, began a study on the host relationship of *Puccinia coronate*, which culminated in the publication of two research papers with …….”

(Source: Plant Pathology in Canada, edited by I.L. Conners)


Chocolate spot of faba bean


Ascochyta pisi on pea

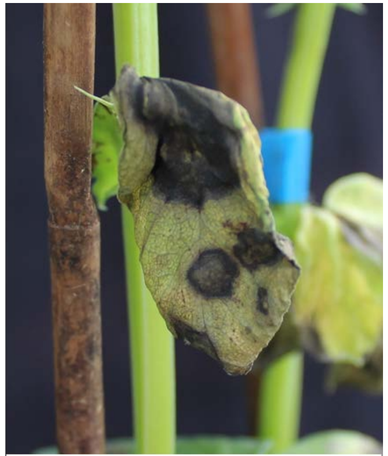

Ascochyta blight of chickpea


Sclerotinia white mould (l) and botrytis grey mould (r) on lentil


Stemphylium blight on lentil

Root rots


Mycosphaerella blight of pea


Stemphylium blight on faba


Ascochyta blight of lentil


Alternaria leaf spot on faba

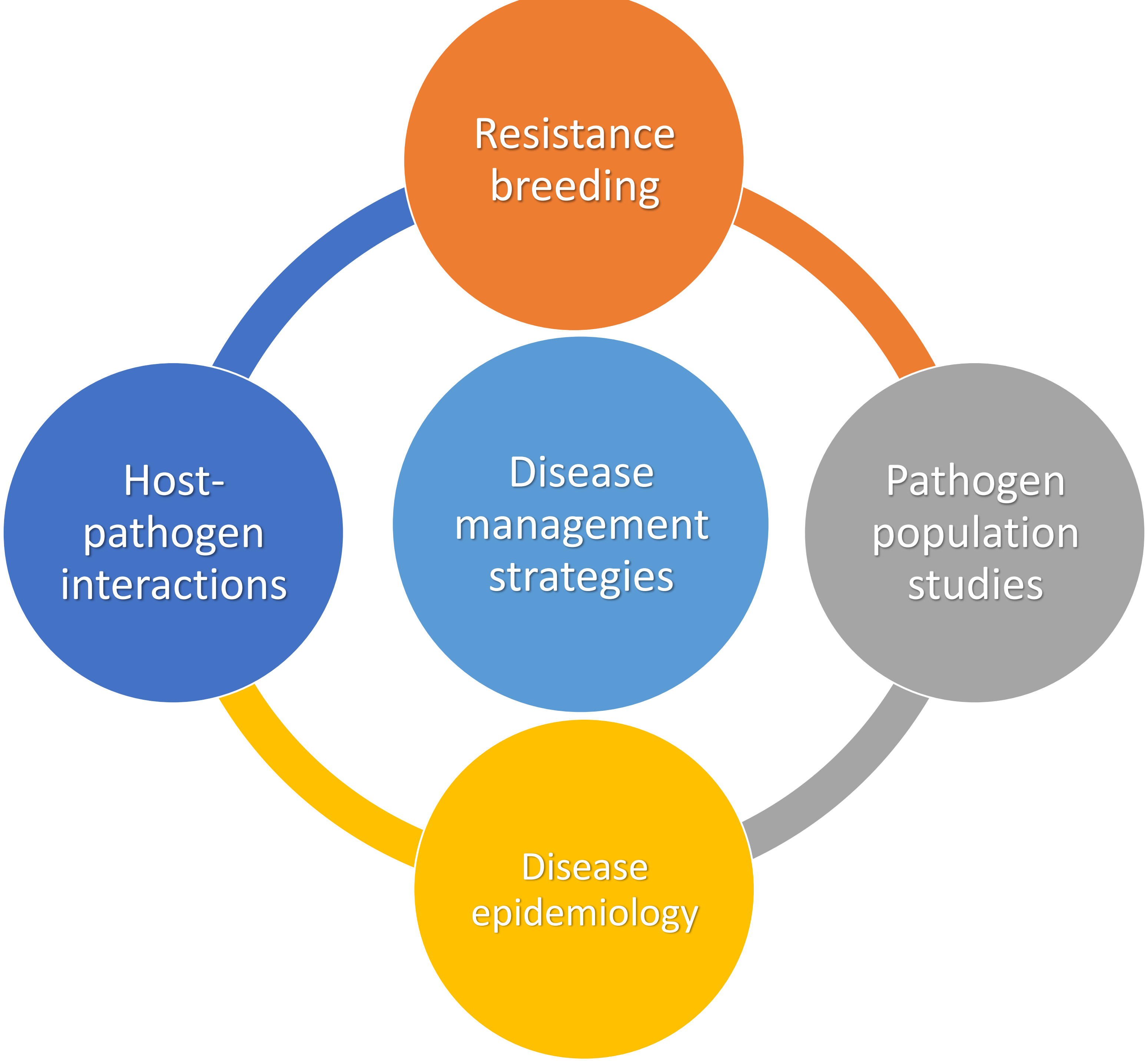

Anthracnose of bean


Halo blight of bean


Anthracnose of lentil


Common bacterial blight of bean


Blossom blight



Resistance breeding
Host-pathogen interactions
Disease management strategies
Pathogen population studies
Disease epidemiology

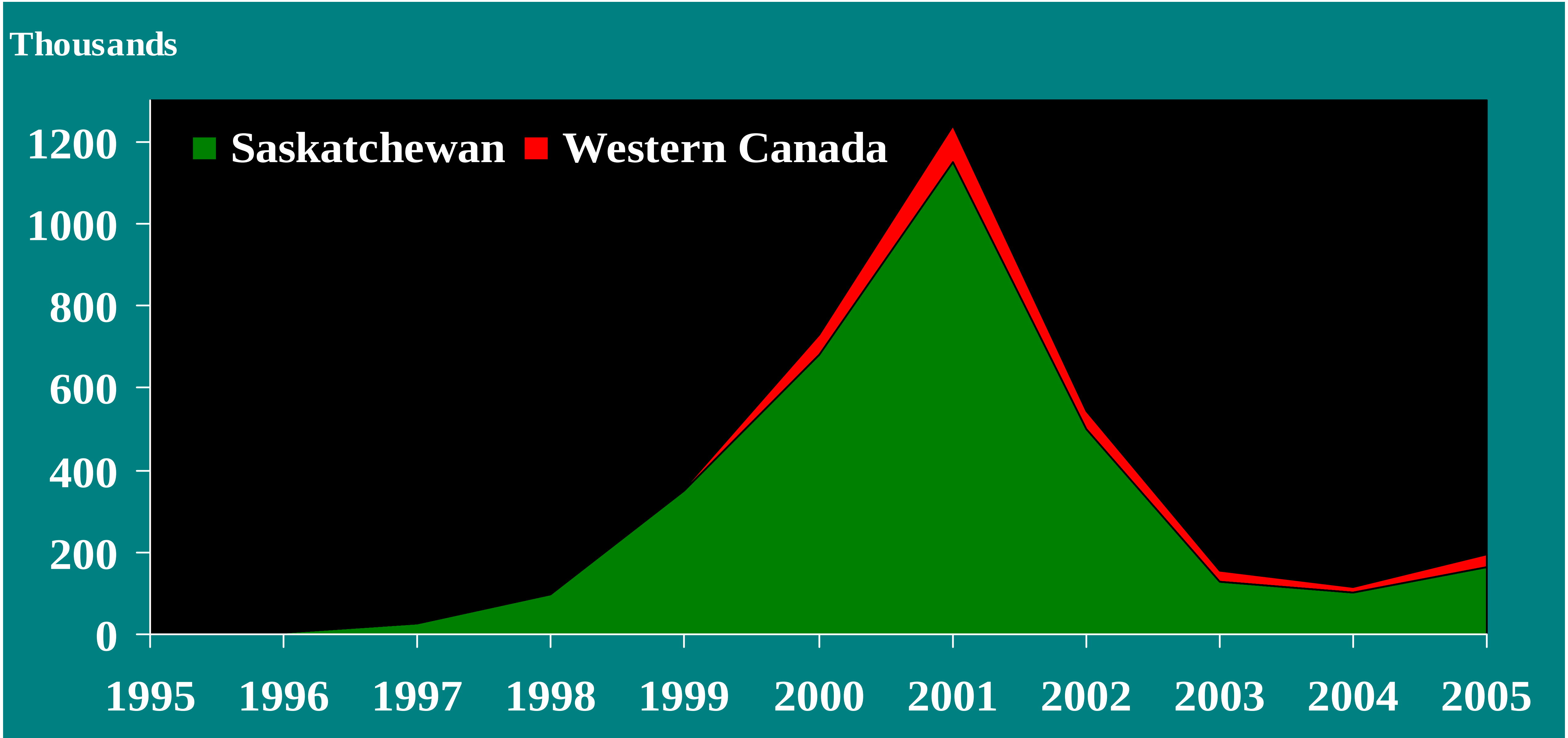


Management of ascochyta blight in chickpea in Canada

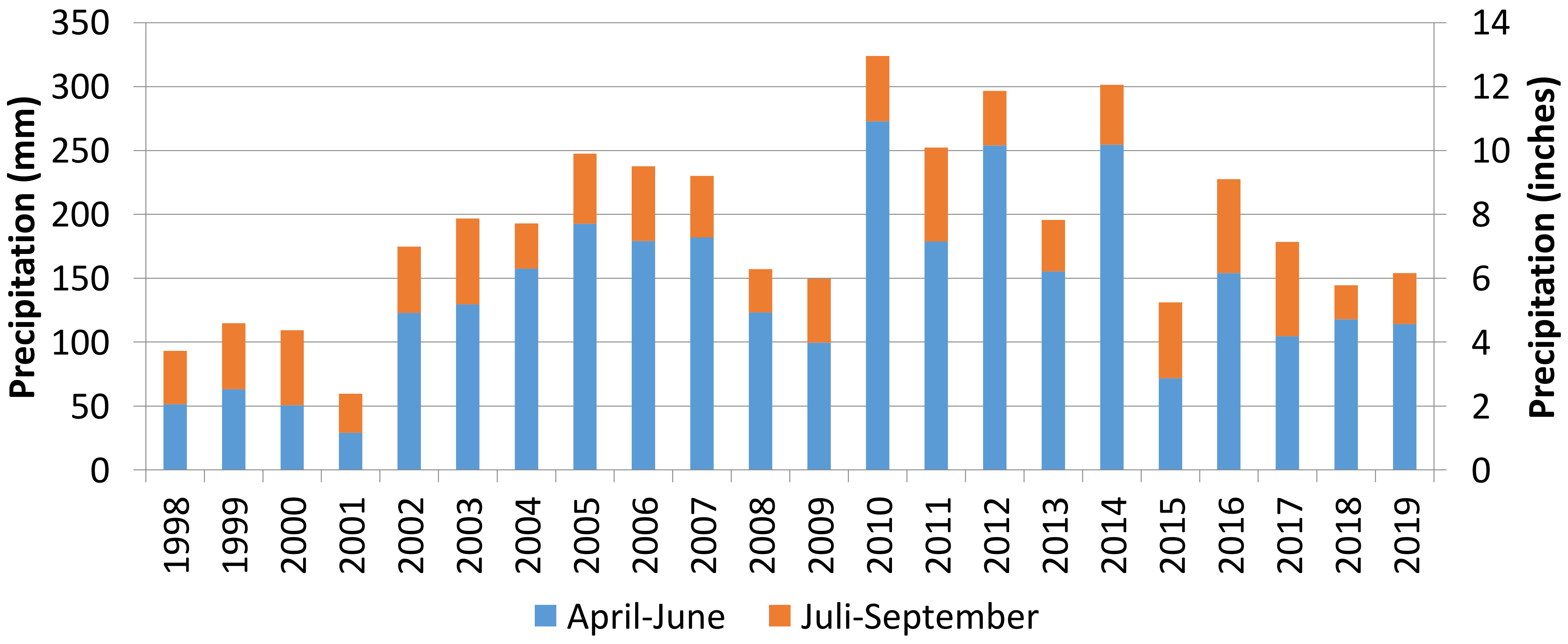
with Tom Wolf and Yantai Gan, AAFC

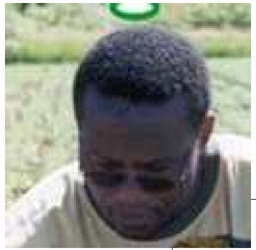
Chickpea area (seeded acres)

Source: Ray McVicar, SAF

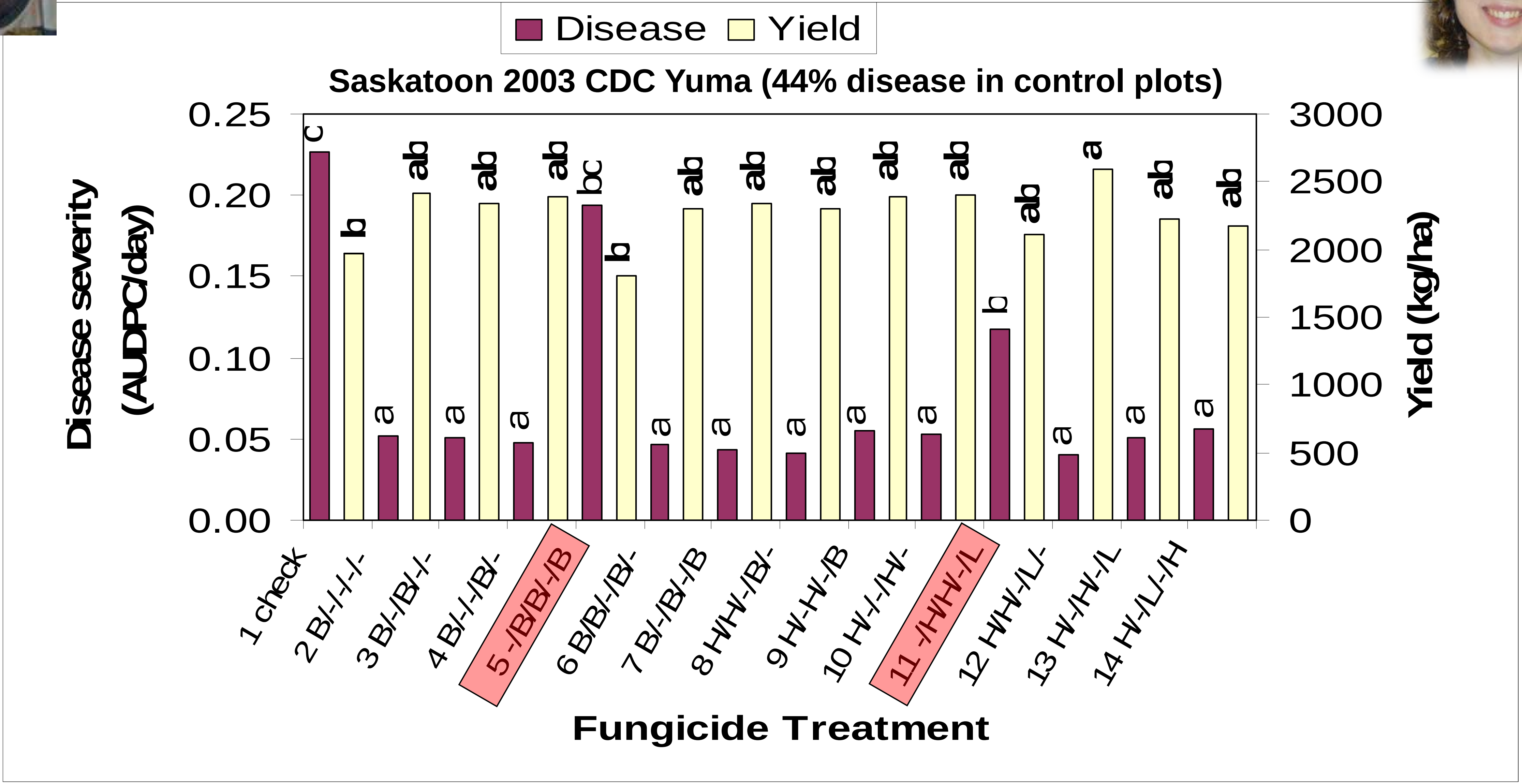


Epidemics of asochyta blight in chickpea after 2001



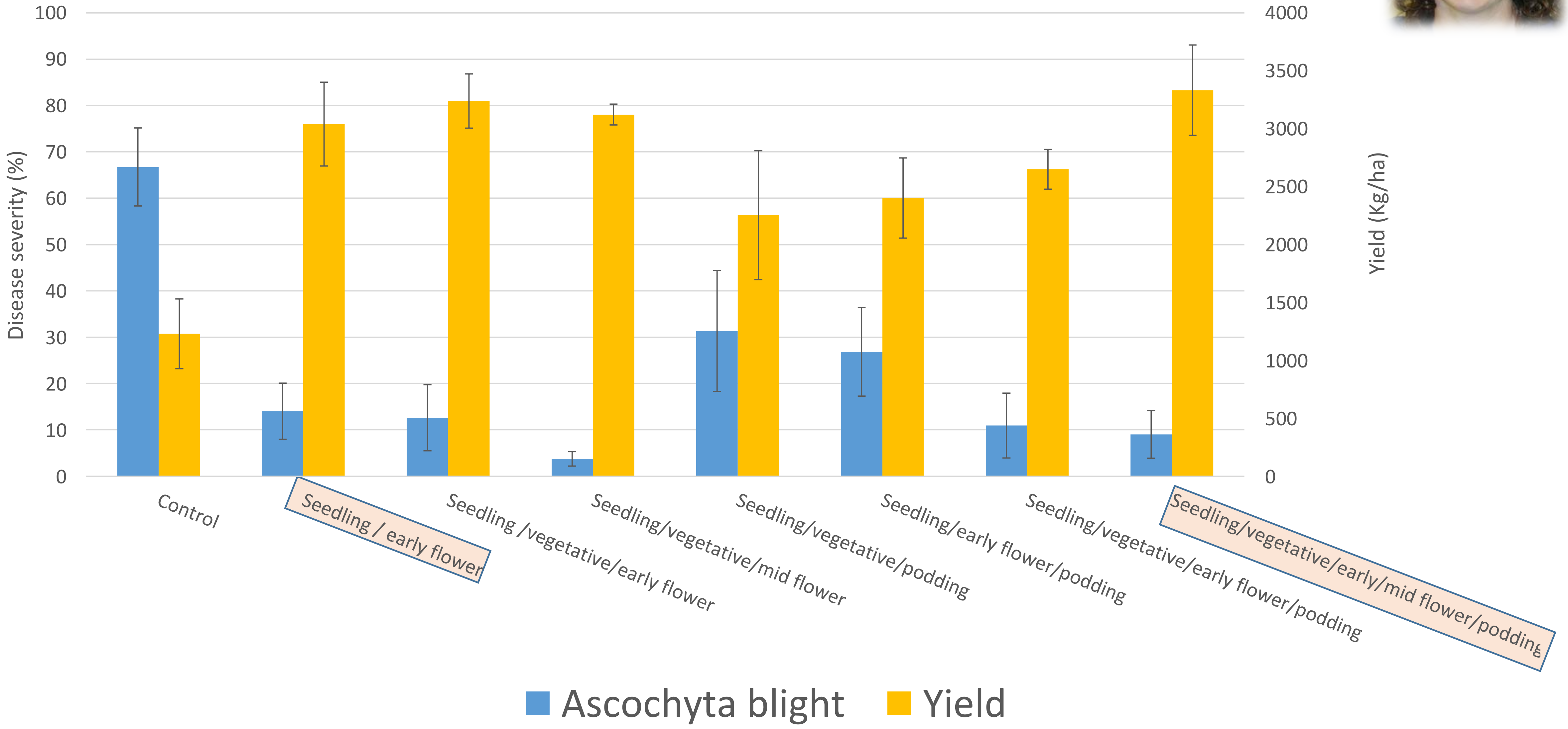


Timing of fungicide applications (Round 1)



TIMING OF FUNGICIDE APPLICATIONS (Round 2)

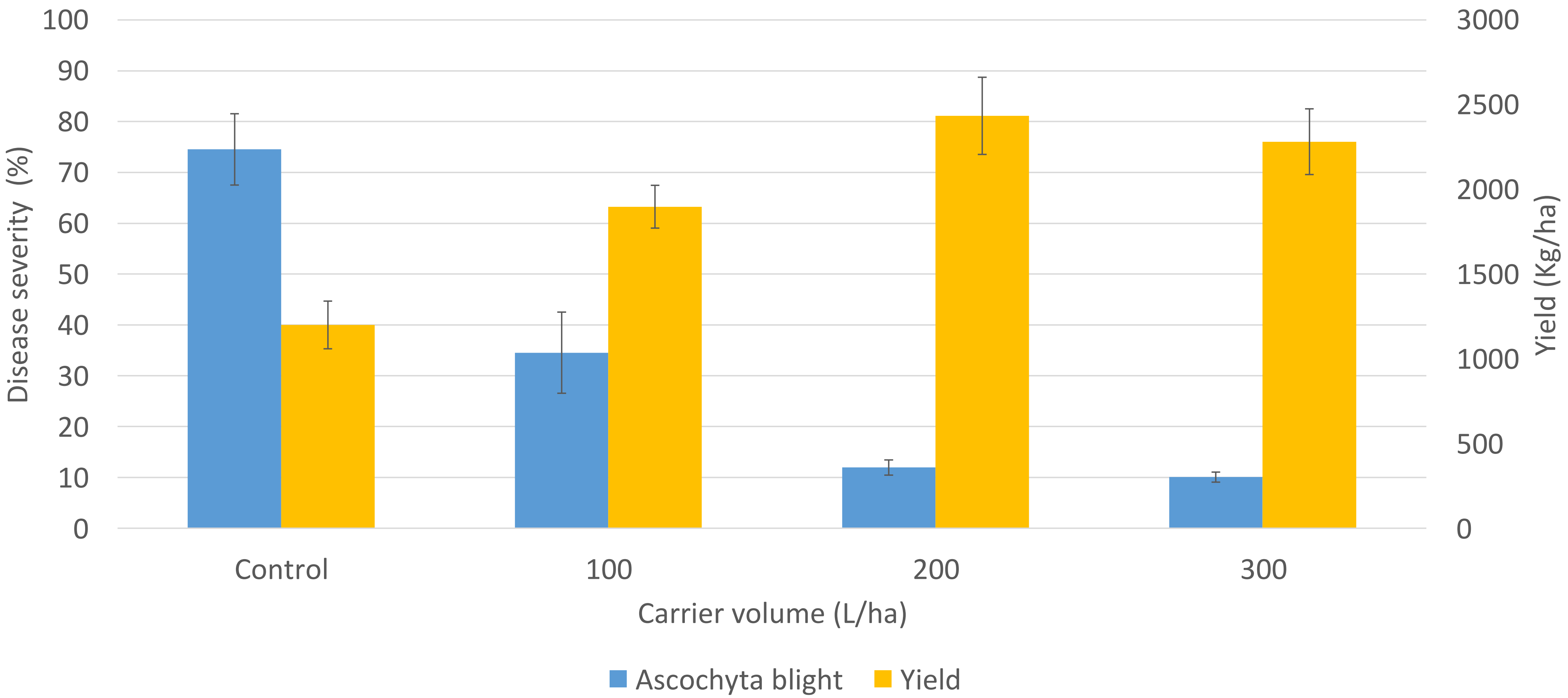
CDC Yuma, Saskatoon, SK, 2008



EFFECT OF CARRIER VOLUME

CDC Yuma, Outlook, SK, 2001

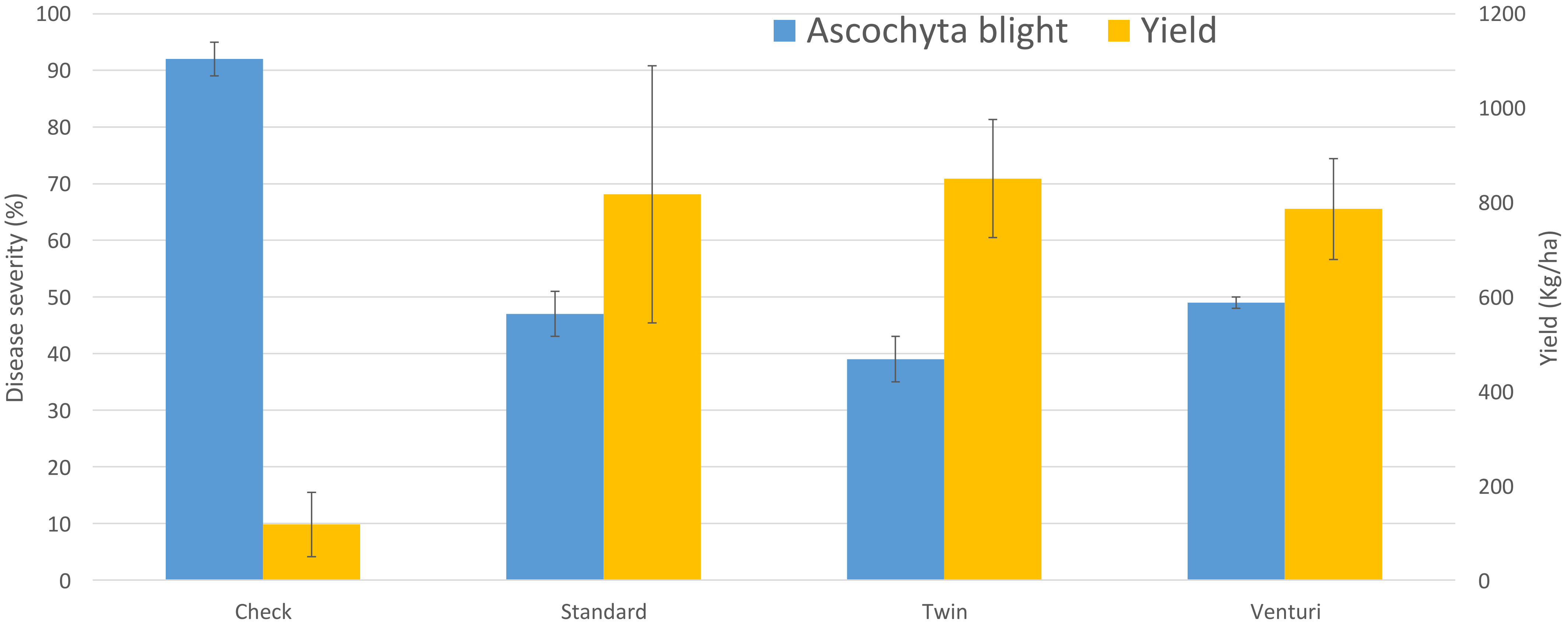
Armstrong-Cho et al.: Crop Protection 27 (2008), 1020-1030.

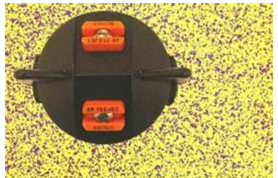


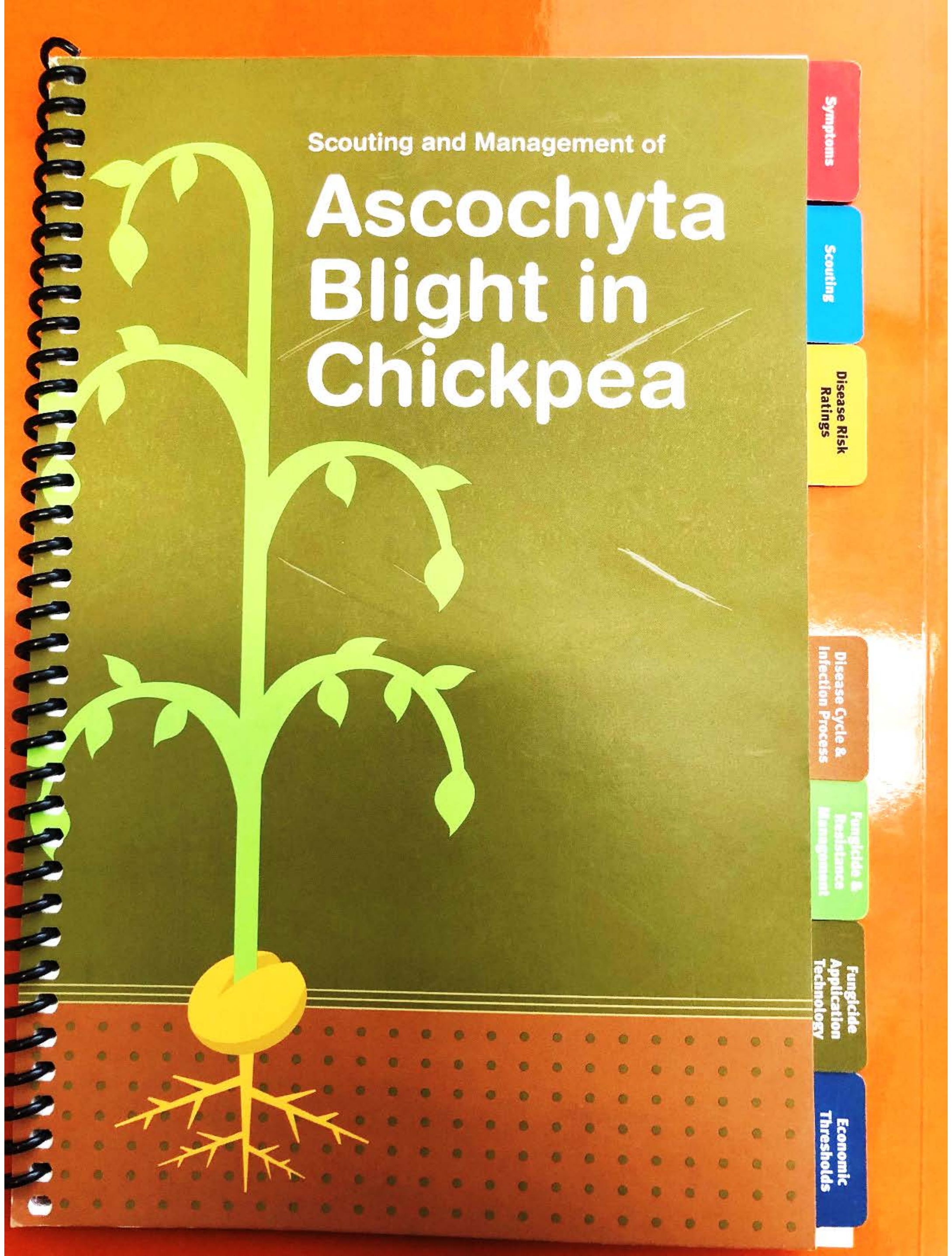
EFFECT OF DROPLET SIZE

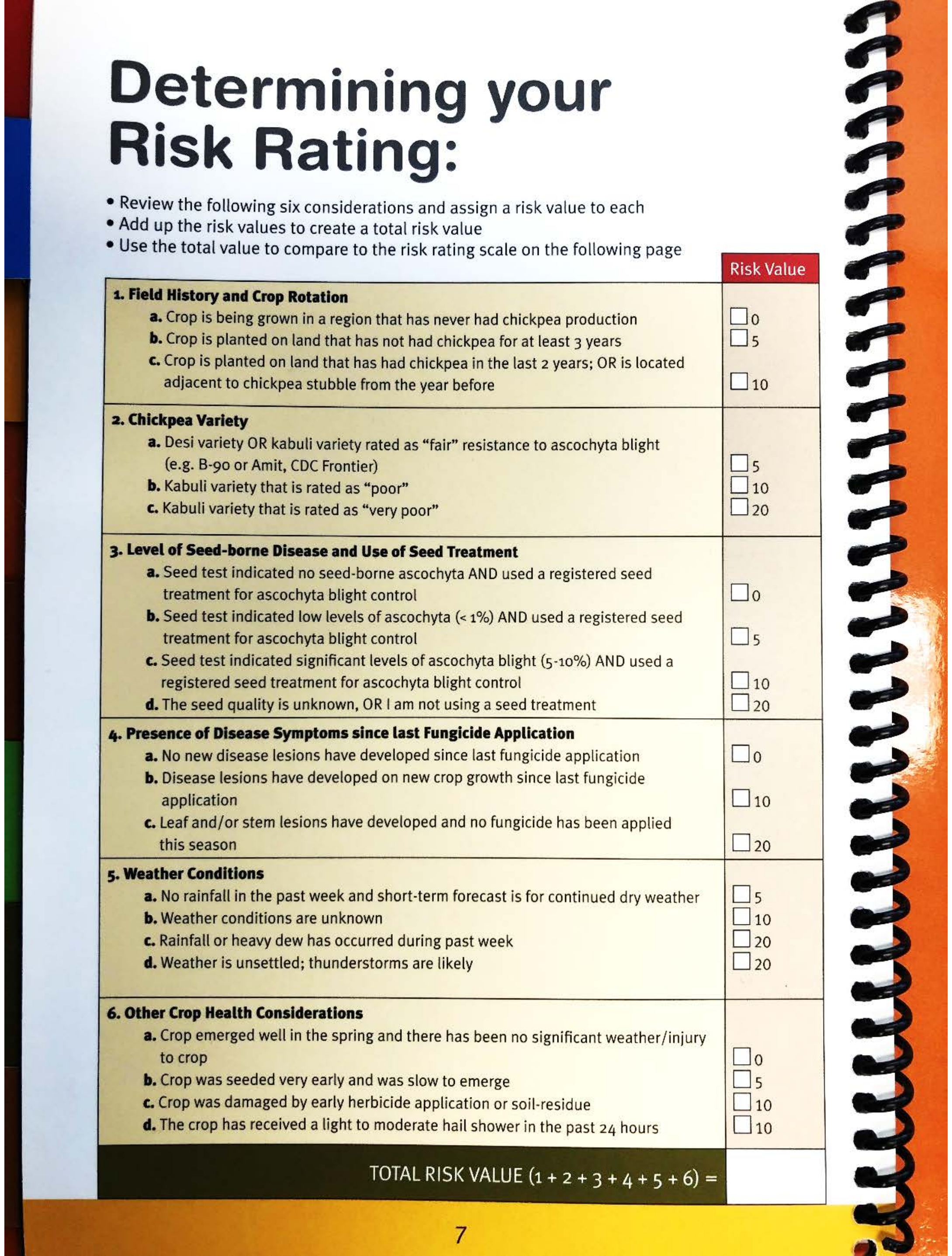
Saskatoon, SK, 2002

Armstrong-Cho et al: Crop Protection 27 (2008), 700-709.









Determining your Risk Rating:

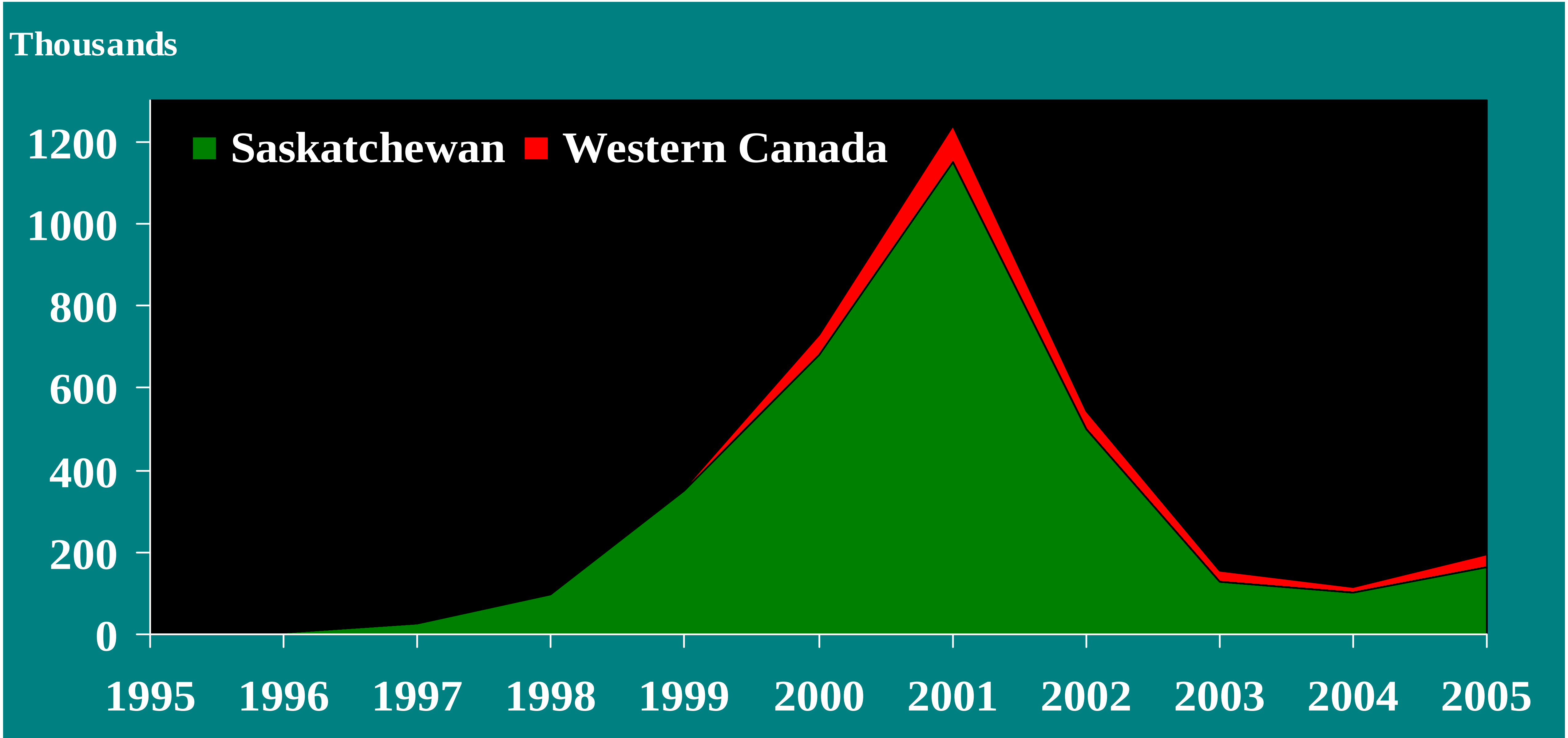
- Review the following six considerations and assign a risk value to each
- Add up the risk values to create a total risk value
- Use the total value to compare to the risk rating scale on the following page

	Risk Value
1. Field History and Crop Rotation	
a. Crop is being grown in a region that has never had chickpea production	☐ 0
b. Crop is planted on land that has not had chickpea for at least 3 years	☐ 5
c. Crop is planted on land that has had chickpea in the last 2 years; OR is located adjacent to chickpea stubble from the year before	☐ 10
2. Chickpea Variety	
a. Desi variety OR kabuli variety rated as "fair" resistance to ascochyta blight (e.g. B-90 or Amit, CDC Frontier)	☐ 5
b. Kabuli variety that is rated as "poor"	☐ 10
c. Kabuli variety that is rated as "very poor"	☐ 20
3. Level of Seed-borne Disease and Use of Seed Treatment	
a. Seed test indicated no seed-borne ascochyta AND used a registered seed treatment for ascochyta blight control	☐ 0
b. Seed test indicated low levels of ascochyta (< 1%) AND used a registered seed treatment for ascochyta blight control	☐ 5
c. Seed test indicated significant levels of ascochyta blight (5-10%) AND used a registered seed treatment for ascochyta blight control	☐ 10
d. The seed quality is unknown, OR I am not using a seed treatment	☐ 20
4. Presence of Disease Symptoms since last Fungicide Application	
a. No new disease lesions have developed since last fungicide application	☐ 0
b. Disease lesions have developed on new crop growth since last fungicide application	☐ 10
c. Leaf and/or stem lesions have developed and no fungicide has been applied this season	☐ 20
5. Weather Conditions	
a. No rainfall in the past week and short-term forecast is for continued dry weather	☐ 5
b. Weather conditions are unknown	☐ 10
c. Rainfall or heavy dew has occurred during past week	☐ 20
d. Weather is unsettled; thunderstorms are likely	☐ 20
6. Other Crop Health Considerations	
a. Crop emerged well in the spring and there has been no significant weather/injury to crop	☐ 0
b. Crop was seeded very early and was slow to emerge	☐ 5
c. Crop was damaged by early herbicide application or soil-residue	☐ 10
d. The crop has received a light to moderate hail shower in the past 24 hours	☐ 10
TOTAL RISK VALUE (1 + 2 + 3 + 4 + 5 + 6) =	

7

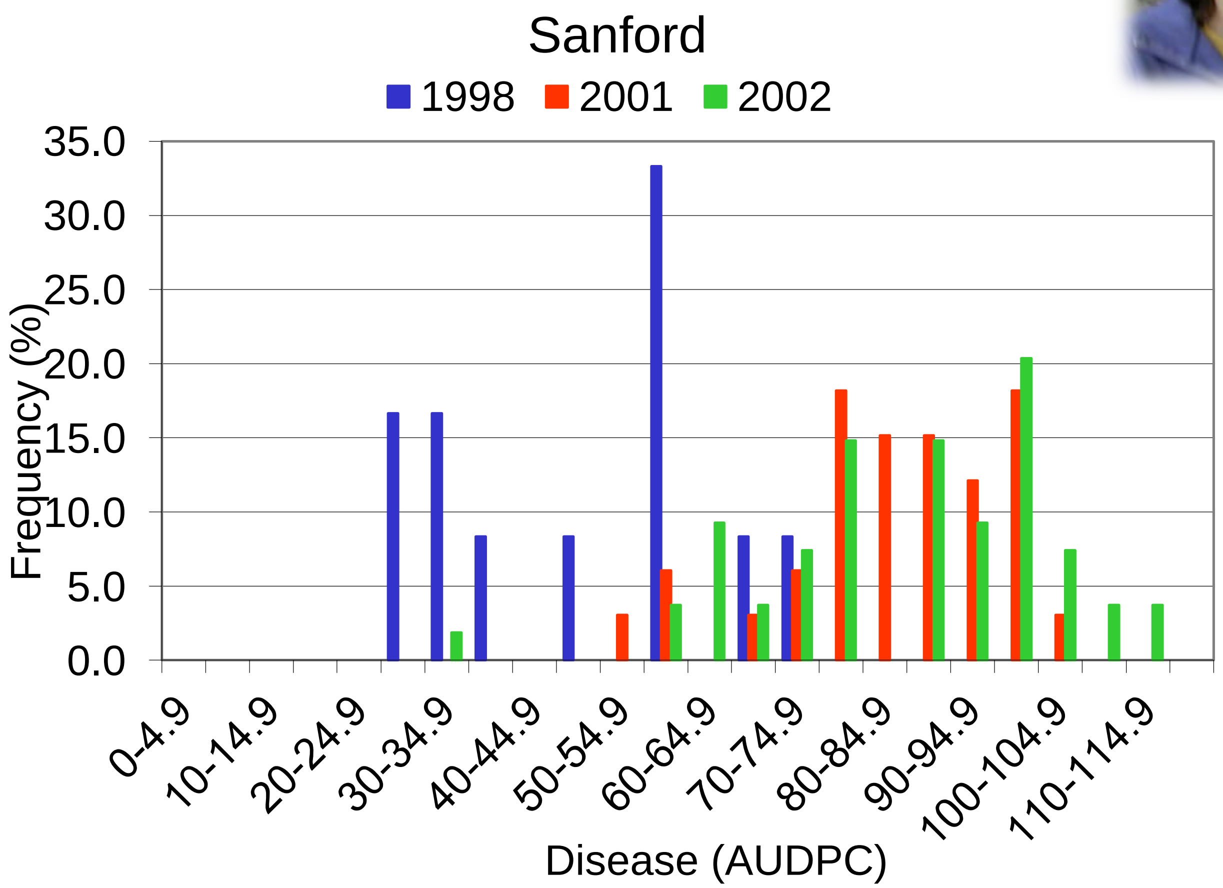
Chickpea are (seeded acres)

Source: Ray McVicar, SAF

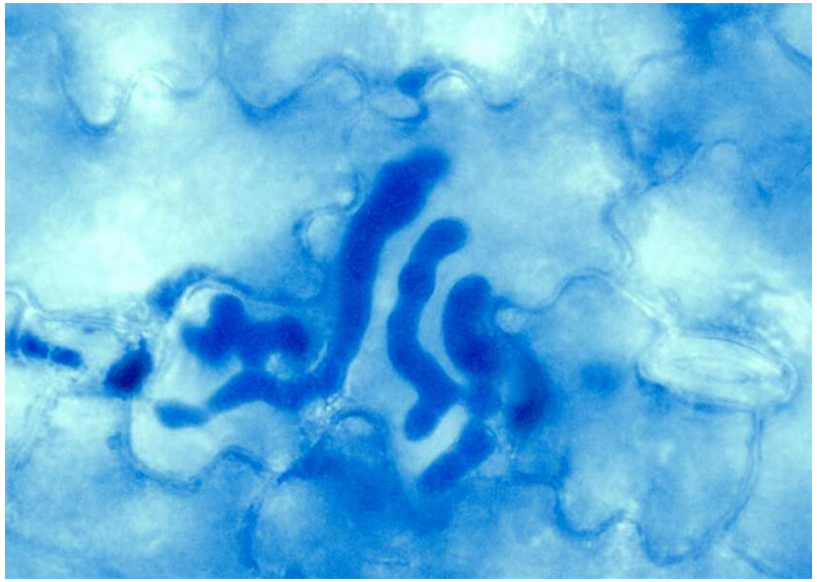


Resistance breakdown in chickpea

- Large kabuli chickpea Sanford considered partially resistant in 1998
- Dominated acreage because of premium price
- Rapid shift in virulence of *Ascochyta rabiei* within 3 years



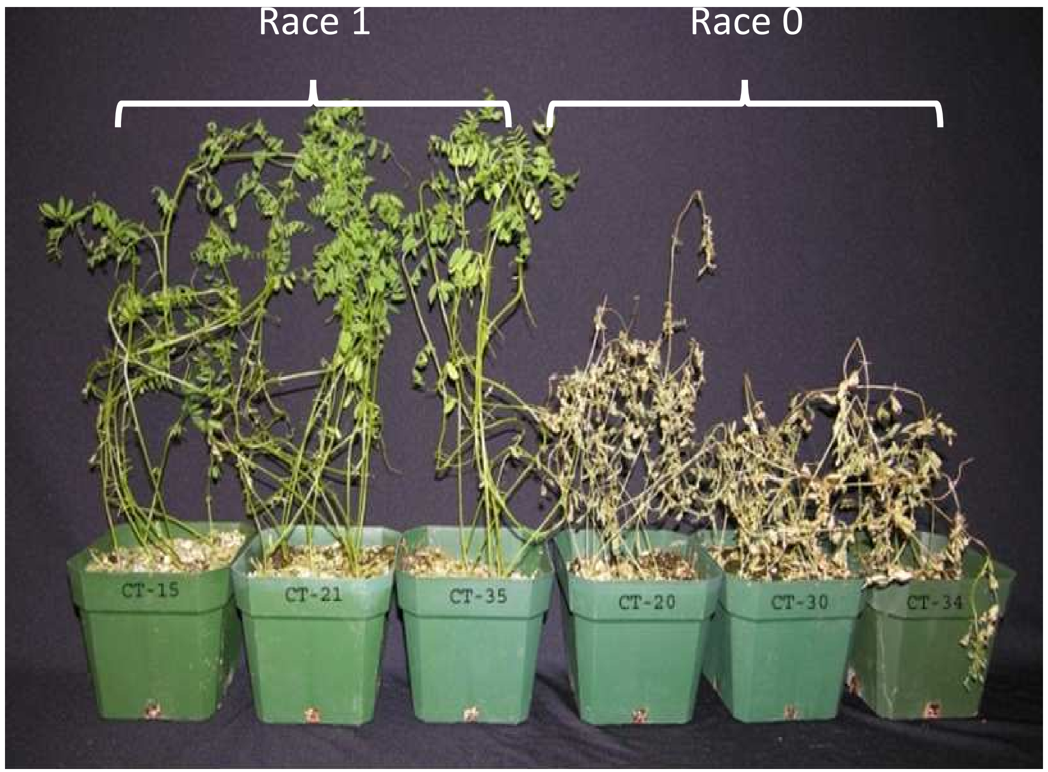
Vail, S. and Banniza, S., 2008. Structure and pathogenic variability in Ascochyta rabiei populations on chickpea in the Canadian prairies. Plant Pathology, 57(4), pp.665-673.



Understanding virulence in *Colletotrichum lentis* and anthracnose resistance in lentil

Colletotrichum lentis, the hemibiotrophic pathogen

- 2 **pathogenic** races previously described (Buchwaldt et al 2004)
- Both races undergo biotrophic phase before switching to necrotrophic phase
- Quantitative differences in the infection process between the two races

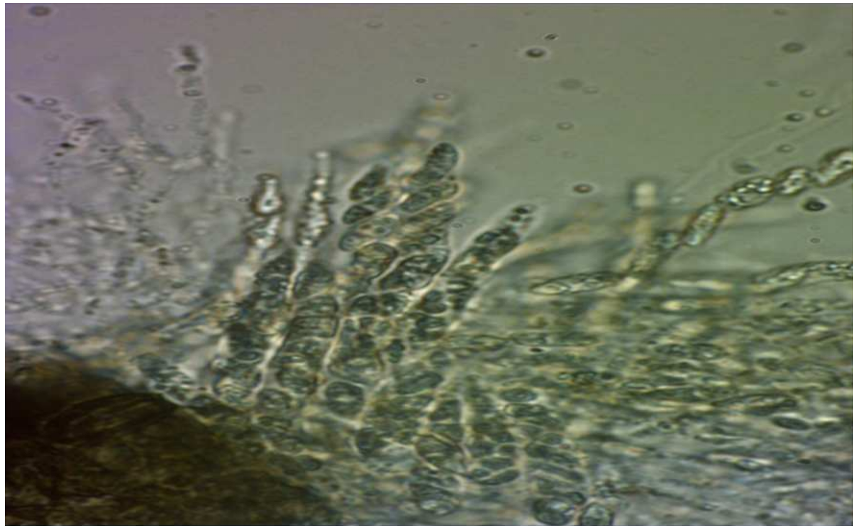


Armstrong-Cho, C., Wang, J., Wei, Y. and Banniza, S., 2012. The infection process of two pathogenic races of Colletotrichum truncatum on lentil. Canadian Journal of Plant Pathology, 34(1), pp.58-67.

NSERC CRSNG

Sexual phase of *Colletotrichum lentis*

- Sexual phase induced in the laboratory
- Two sexual incompatibility groups (IG)
- F_1 segregates in a 1:1 ratio for IG
- IG-2 more common in the field
- Both IGs on the same plant

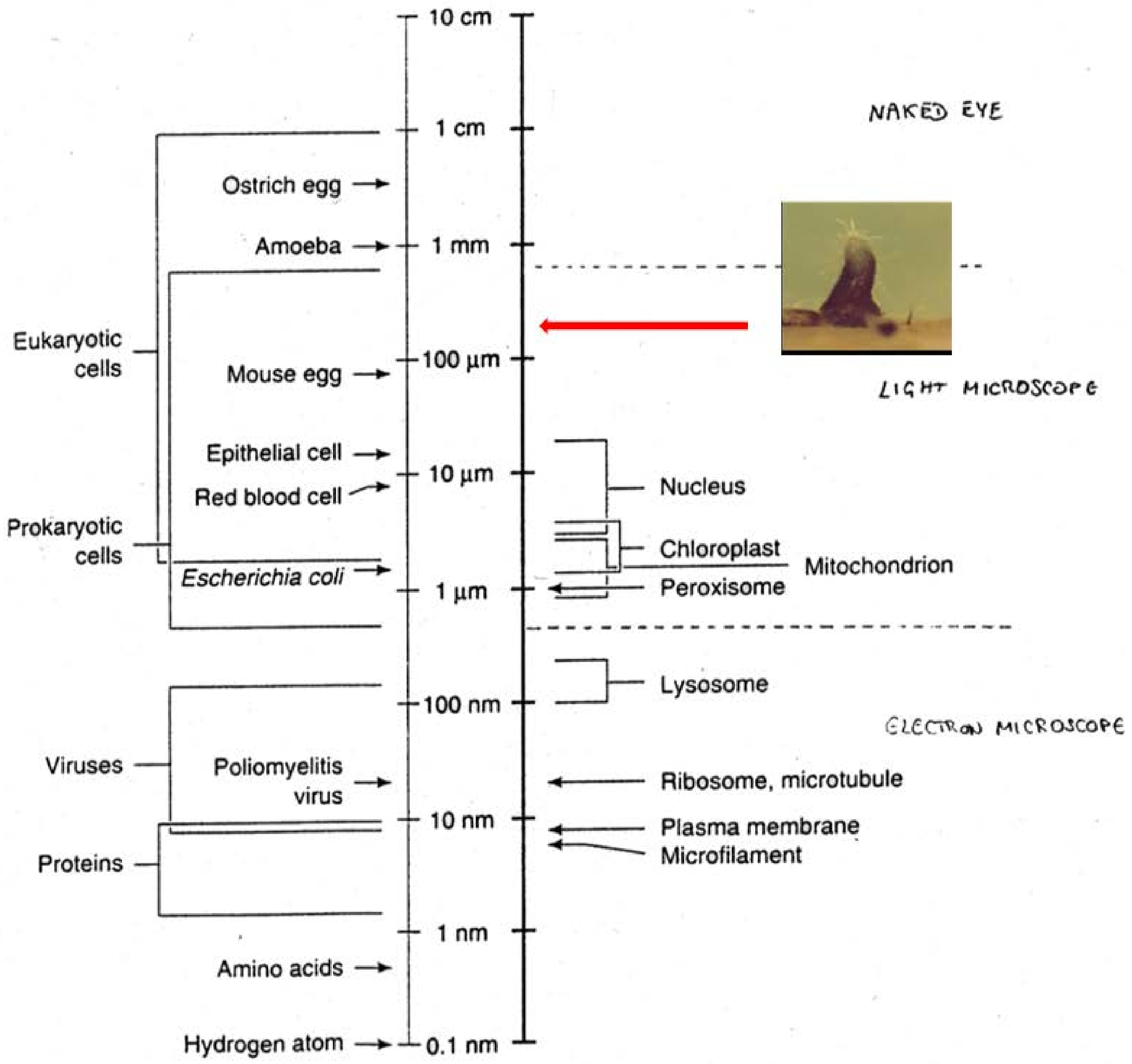


Menat et al. 2015. Fungal Ecology, in press.
Menat & Banniza 2012. Mycologia 104, 641-649.
Menat 2012. PhD thesis, University of Saskatchewan.
Armstrong-Cho & Banniza 2006. Mycological Research 110, 951-956.

NSERC CRSNG

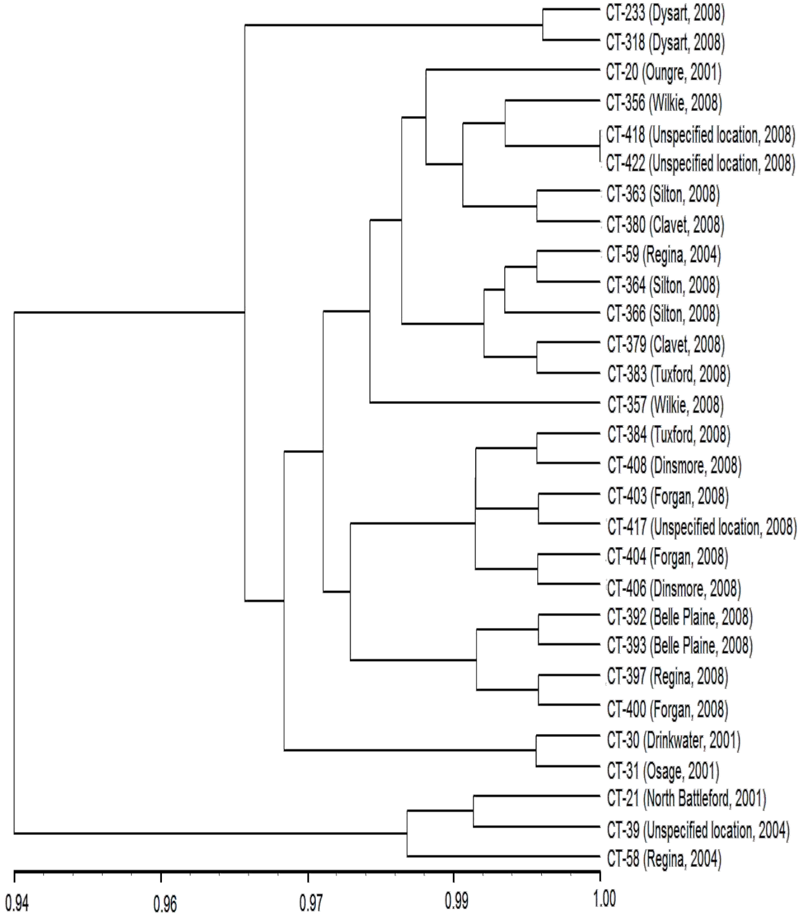
Does *Colletotrichum lentis* have sexual reproduction in the field?

mashable.com



Does *Colletotrichum lentis* have sexual reproduction in the field?

- High levels of genetic similarity (≥ 94% based on AFLP markers) in field population
- Same haplotype (n=131) in one lentil field
- Indication of linkage disequilibrium



Tree based on Dice genetic distance among 29 field isolates of *Colletotrichum sp.* representing distinct haplotypes obtained after clone correction.

Menat, J., Armstrong-Cho, C. and Banniza, S., 2016. Lack of evidence for sexual reproduction in field populations of Colletotrichum lentis. Fungal Ecology, 20, pp.66-74..

NSERC CRSNG

Does *Colletotrichum lentis* have sexual reproduction in the field?

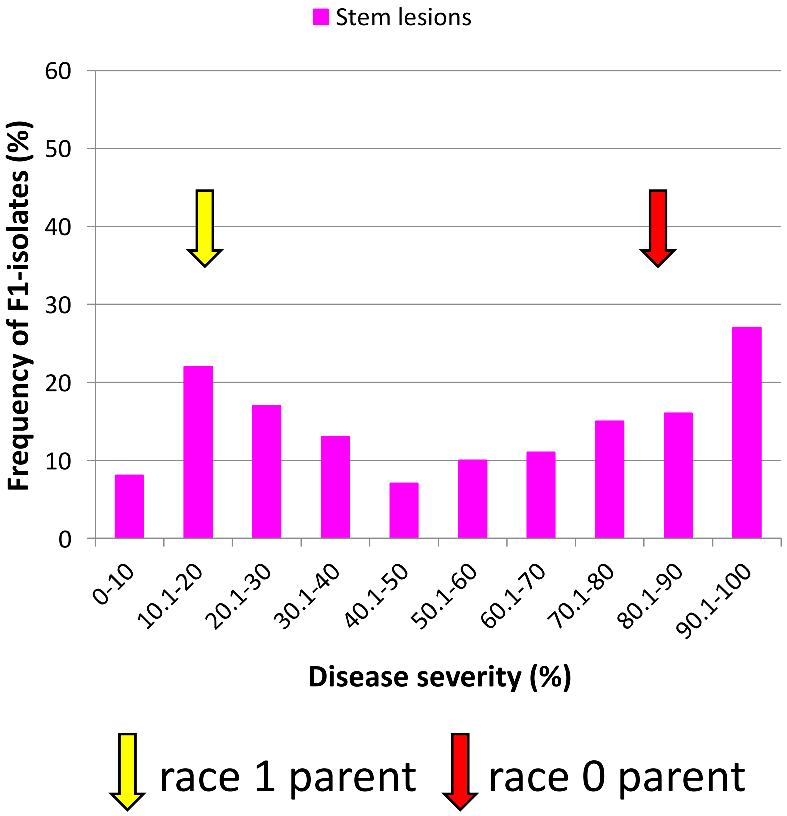
- Field isolates with combinations of
  - IG-1/race 0
  - IG-2/race 0
  - IG-2/race 1
  - never IG1/race 1
- Ascospore-derived F_1 isolates have all combinations at equal frequencies

Menat, J., Armstrong-Cho, C. and Banniza, S., 2016. Lack of evidence for sexual reproduction in field populations of Colletotrichum lentis. Fungal Ecology, 20, pp.66-74..

NSERC
CRSNG

Breeding fungi: *Colletotrichum lentis* race 1 x race 0 population

Virulence of F_1 isolates of *Colletotrichum lentis* on CDC Robin

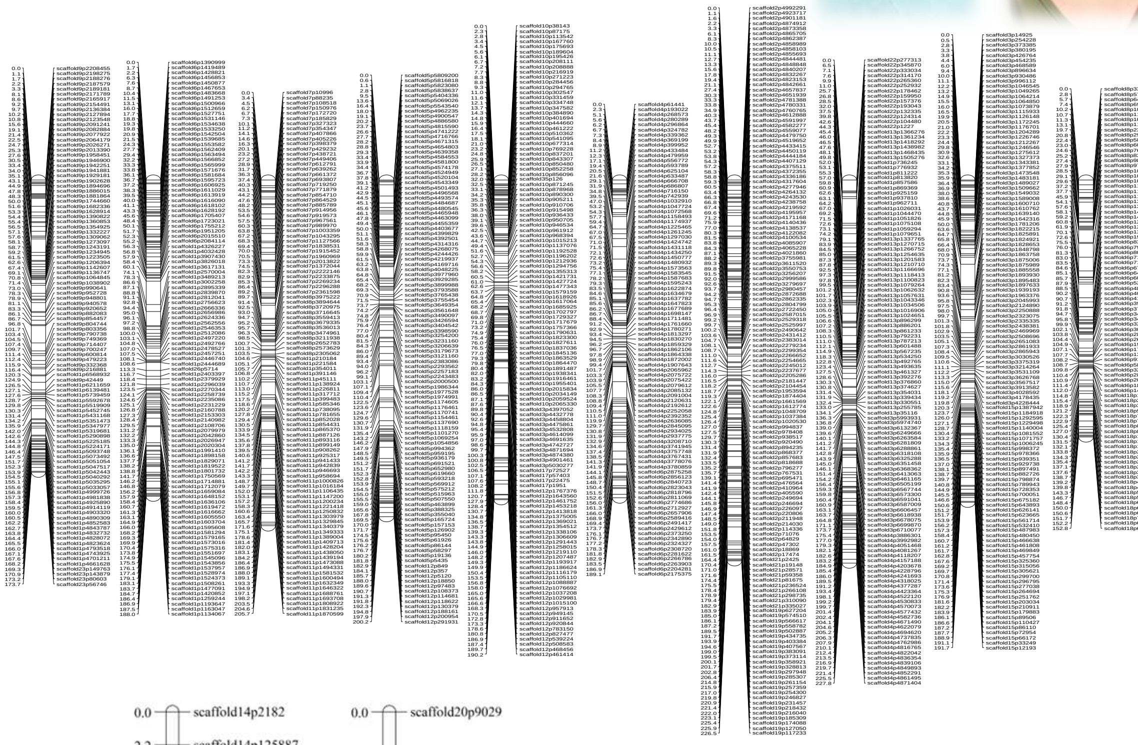


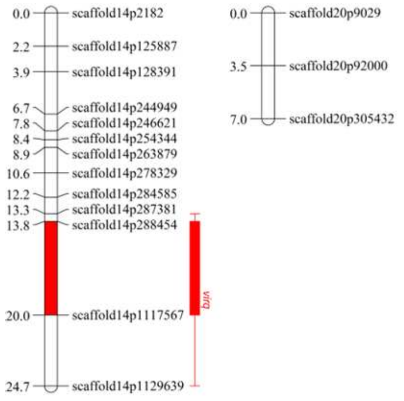
- CT-21 (race 1/IG2) × CT-30 (race 0/IG1)
- Phenotyping of 142 asco-spore derived F_1-isolates and parental isolates
- Potential major gene / QTL effect

Bhadauria, V., MacLachlan, R., Pozniak, C., Cohen-Skalie, A., Li, L., Halliday, J. and Banniza, S., 2019. Genetic map-guided genome assembly reveals a virulence-governing minichromosome in the lentil anthracnose pathogen Colletotrichum lentis. New Phytologist, 221(1), pp.431-445

Sequencing and mapping of *Colletotrichum lentis*

- 56.10 Mbp genome assembly
- SNP-based map with10 core chromosomes and 2 dispensable smaller chromosomes 98.27% of the genome
- QTL for virulence on LG/Chromosome 11





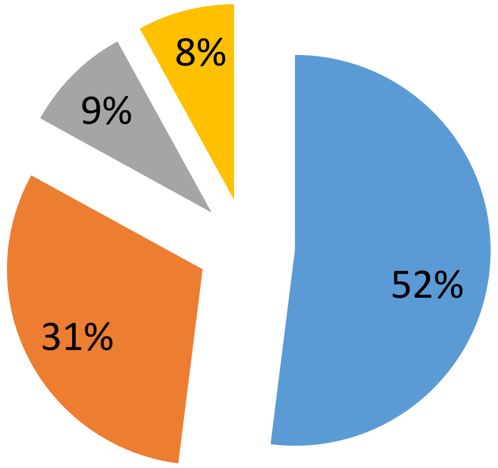
Bhadauria, V., MacLachlan, R., Pozniak, C., Cohen-Skalie, A., Li, L., Halliday, J. and Banniza, S., 2019. Genetic map-guided genome assembly reveals a virulence-governing minichromosome in the lentil anthracnose pathogen Colletotrichum lentis. New Phytologist, 221(1), pp.431-445

Western Grains Research Foundation
NSERC CRSNG
Government of Saskatchewan Ministry of Agriculture
Saskatchewan pulse Growers

Virulence of *C. lentis* races

Bhadauria et al 2013. Eukaryotic Cell 12, 31
Bhadauria et al 2011. BMC Genomics 12, 327
Bhadauria et al 2015 BMC Genomics 16, 628

- Expressed sequence tag libraries
- *CtNudix* likely elicits switch from biotrophy to necrotrophy by inducing host cell death
- Knock-down of virulence effector *ClToxB* reduced virulence on lentil



Western Grains Research Foundation
NSERC CRSNG
Government of Saskatchewan Ministry of Agriculture
Saskatchewan Pulse Growers

Finding the receptor for ClToxB in lentil

- *In vitro* pull-down assay identified 43 putative interactors with ClToxB of interest
- Infiltration of purified ClToxB induces necrosis in lentil

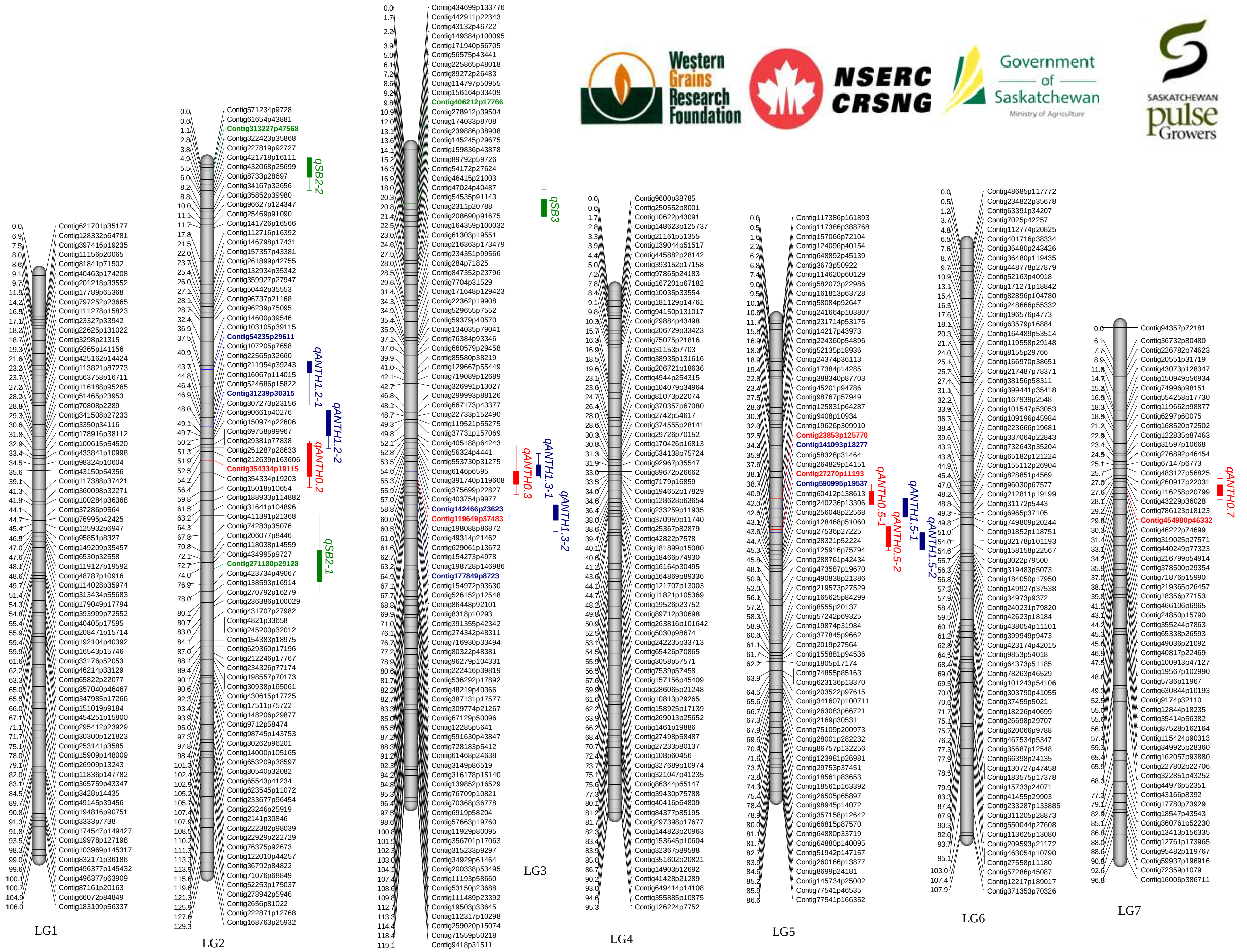
NSERC CRSNG

Resistance to anthracnose in *Lens ervoides* population LR-66

Green: stemphylium blight resistance QTL

Blue: anthracnose race 1 resistance QTL

Red: anthracnose race 0 resistance QTL

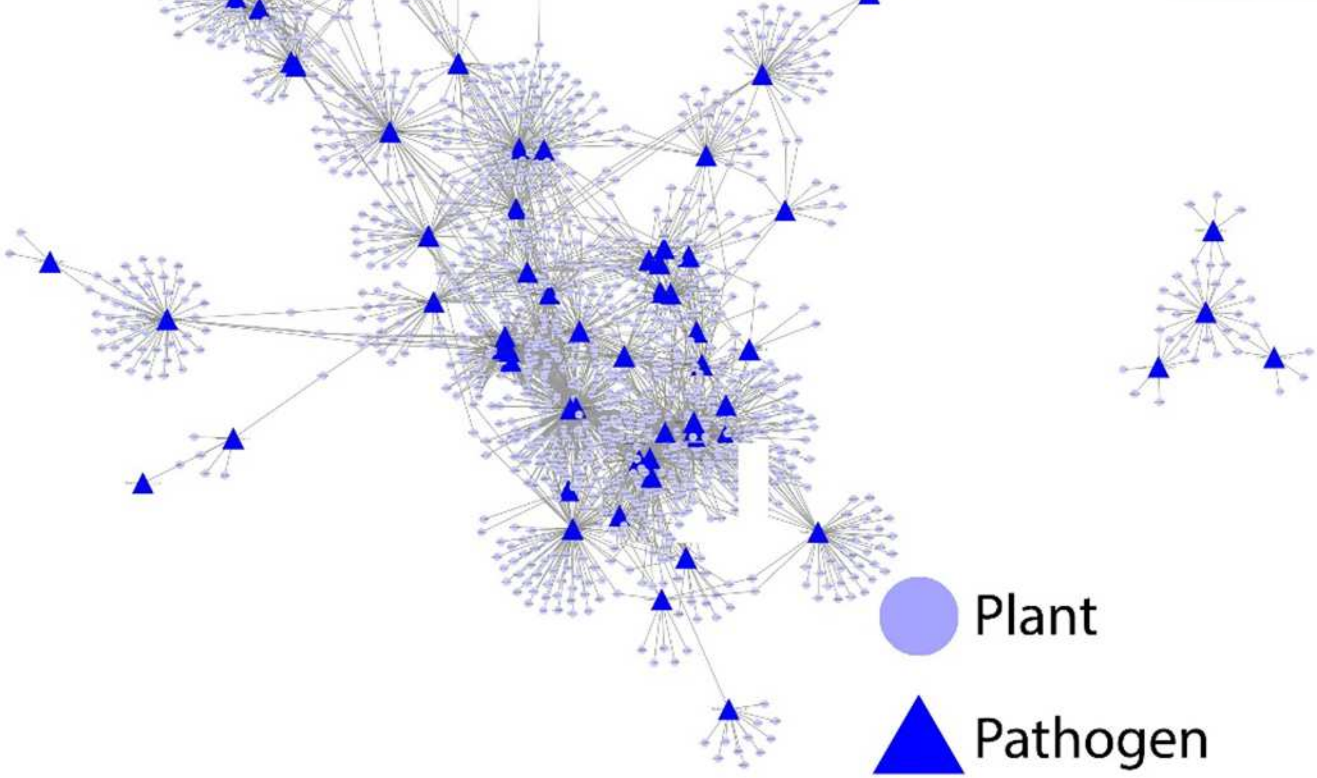


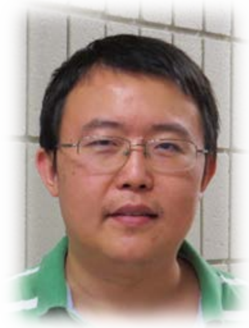
Badauria et al 2017. Scientific Reports 7, 3232

Can we now just edit genes to make lentil resistant?

- NOT YET
- Quantitative host-pathogen systems are highly complex
- Gene editing requires
  - Knowledge of gene function
  - Identification of major switches for resistance or susceptibility

TO BE CONTINUED





Cao, Zhe, and Sabine Banniza. "Cross-Kingdom Gene Coexpression Analysis Using a Stemphylium botryosum–Lens ervoides System Revealed Plasticity of Intercommunication Between the Pathogen Secretome and the Host Immune Systems." *Molecular Plant-Microbe Interactions* 34, no. 12 (2021): 1365-1377.



Root rots in pulse crops

Aphanomyces root rot

CROPS: Pea and lentil
LOCATION: Saskatchewan

NAMES AND AGENCIES:
S. Banniza[1], V. Bhadauria[1], C.O. Peluola[2], C. Armstrong-Cho[1], and R.A.A. Morrall[3]
[1]Crop Development Centre, University of Saskatchewan, 51 Campus Drive, Saskatoon, SK S7N 5A8
Telephone: 306-966-2619, **Facsimile:** 306-966-5015, **E-mail:** sabine.banniza@usask.ca
[2]Crop Protection Laboratory, 346 McDonald Street, Regina, SK S4N 6P6
[3]Department of Biology, University of Saskatchewan, 112 Science Place, Saskatoon, SK S7N 5E2

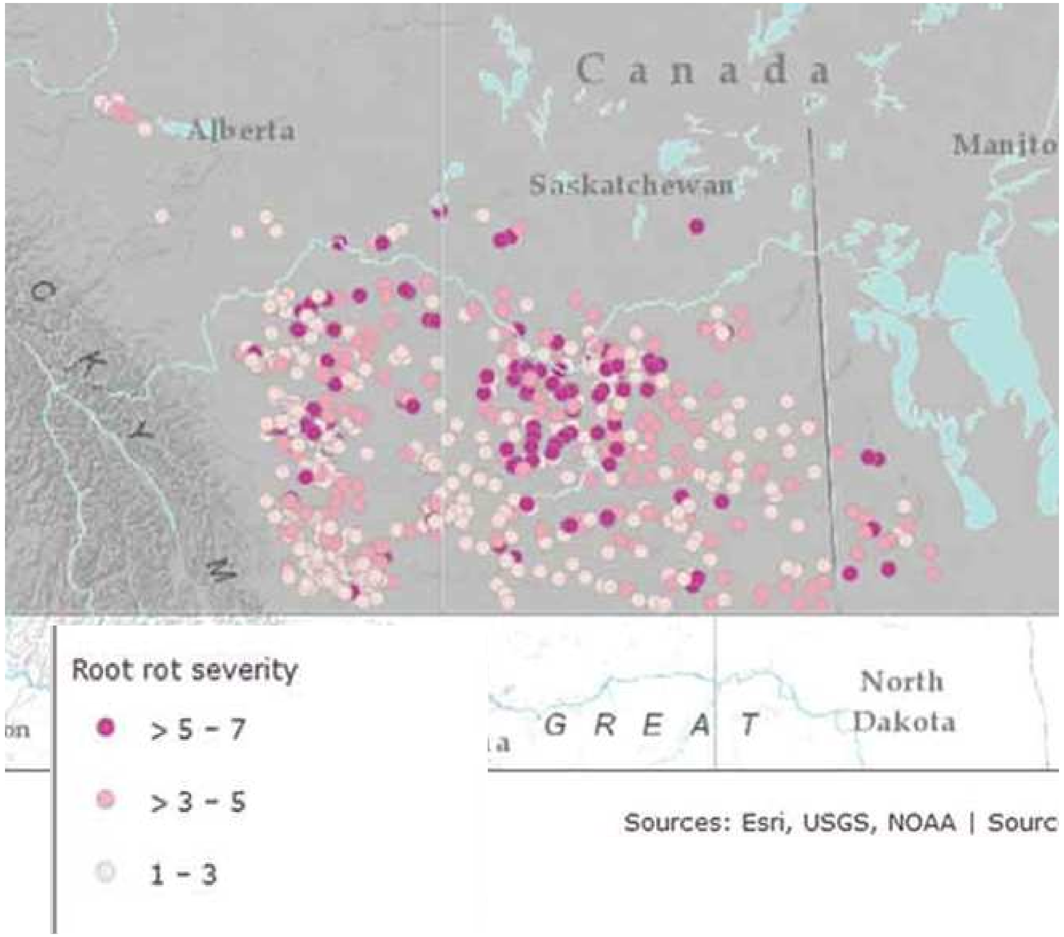
TITLE: FIRST REPORT OF APHANOMYCES EUTEICHES IN SASKATCHEWAN

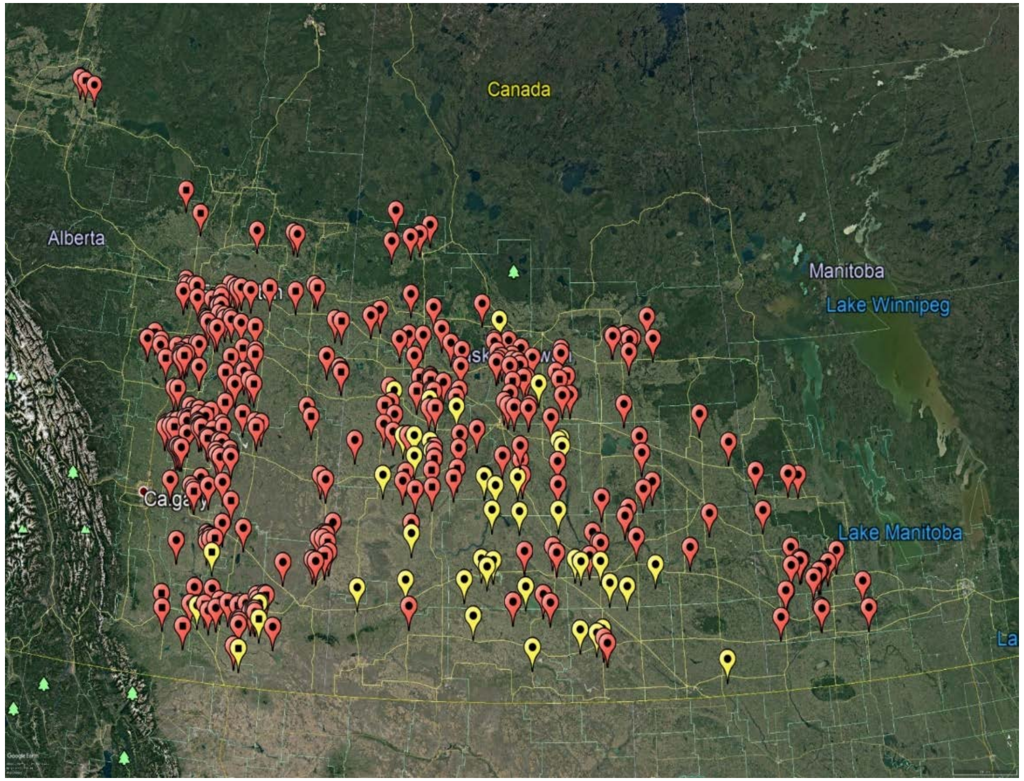
ABSTRACT: *Aphanomyces euteiches* was identified in samples from three diverse Saskatchewan locations using probe-based quantitative PCR. Wet conditions in several areas in 2012 and in preceding seasons have favored root rot and exacerbated symptom development. *Aphanomyces euteiches* is probably widespread and has been present for a long time, with recent conditions enabling its detection.

INTRODUCTION AND METHODS: Since 1948 there have been regular reports in the Canadian Plant Disease Survey (e.g. Vol.28 pp. 45; Vol. 34 pp. 69; Vol. 42 pp. 97; Vol. 56 pp. 23; Vol. 78. pp.12, 98; Vol.79, pp. 70) and elsewhere (Tu, 1985) of *Aphanomyces euteiches* or of "black root" diseases on pea and other legumes. These reports come from seven of Canada's ten provinces. Although it appears that *A. euteiches* is widespread in Canada and it is known to cause severe damage to pea crops in the U.S.A.

Banniza, S., Bhadauria, V., Peluola, C.O., Armstrong-Cho, C. and Morrall, R.A.A., 2013. First report of Aphanomyces euteiches in Saskatchewan. *Can. Plant Dis. Surv*, *93*, pp.163-164.

Pea and lentil root rot surveys 2014-2017





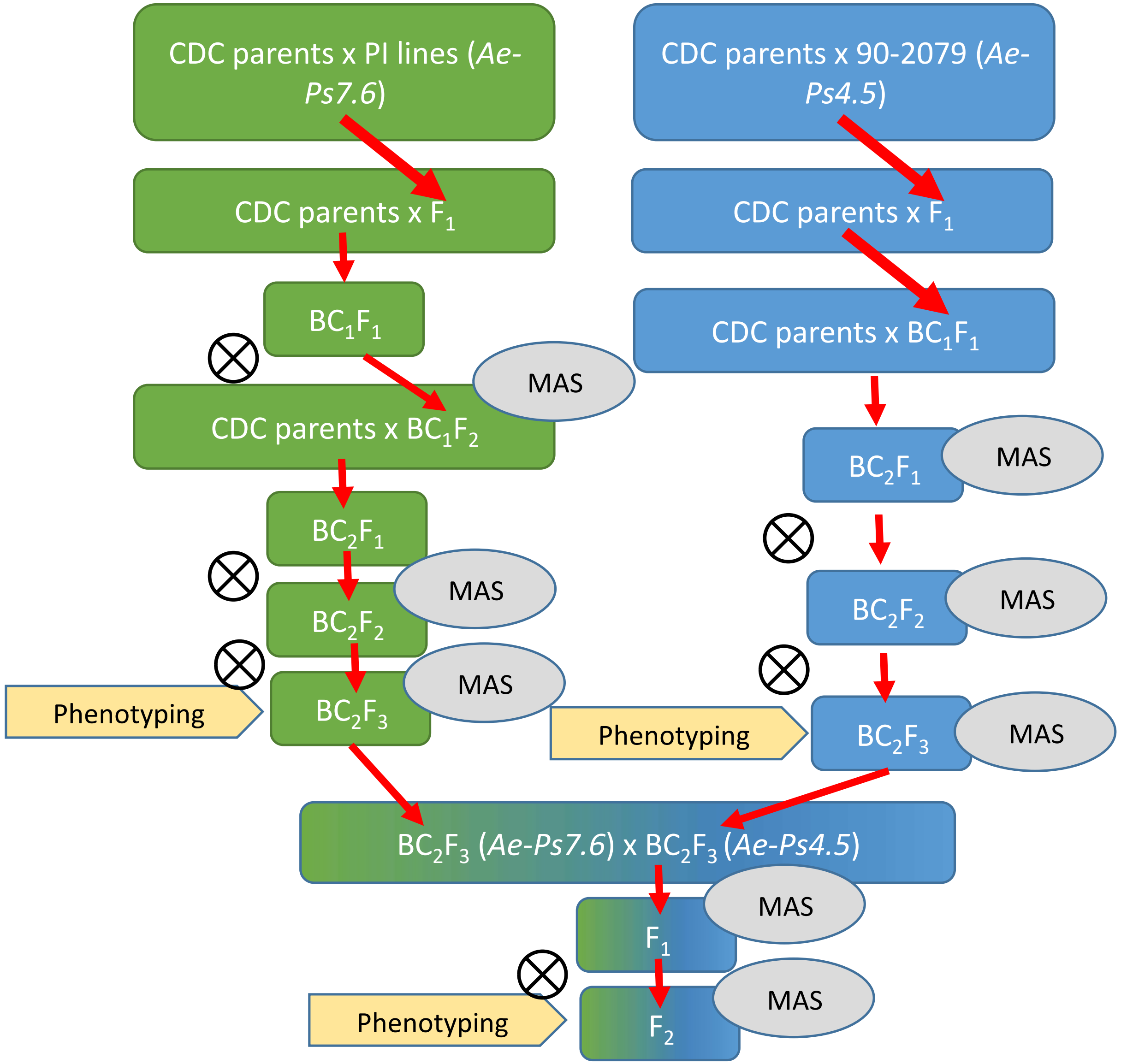
Aphanomyces root rot in pea fields
Aphanomyces root rot in lentil fields

Chatterton et al. 2017. Can J Plant Pathol 41:98-114. https://doi.org/10.1080/07060661.2018.1547792

Remember the Western Interior Seeway?

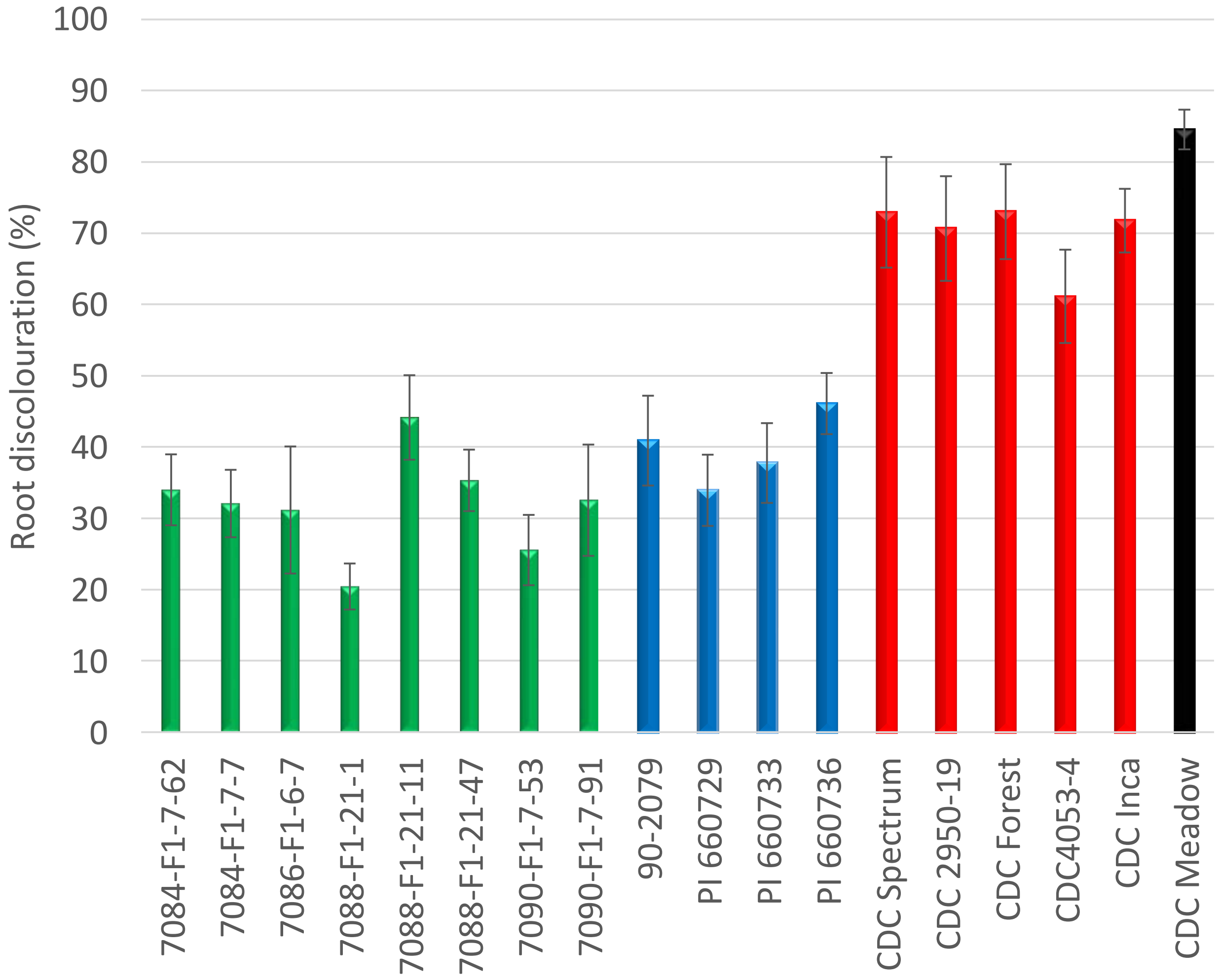
PEA: Backcrossing breeding for improved Aphanomyces resistance
(Banniza & Warkentin)

- Multiple CDC pea varieties
- Crossed with 2 sources of resistance (PI lines & 90-2079) to transfer
  - — 'Major' (*Ae-Ps4.5 & Ae-Ps7.6*)
  - — 'minor' QTLs

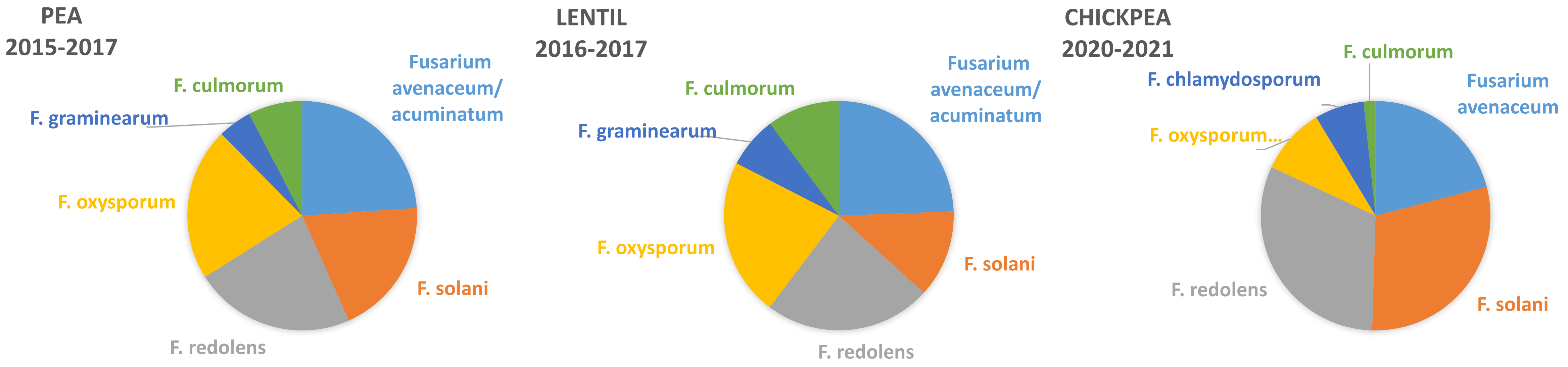


PEA: Some CDC lines carrying QTLs *Ae-Ps4.5* and *Ae-Ps7.6*

- Most promising lines arising were tested in
  - 2021 yield trials
  - 2021 field disease nursery
- 2022 pre-breeder seed development
- 2023 /2024 pea Co-op Test
- 2025 Registration?



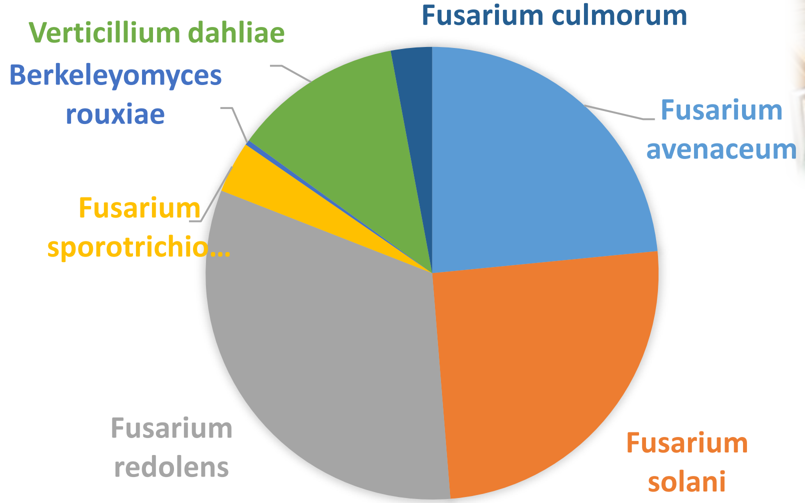
Fusarium species in pea, lentil and chickpea

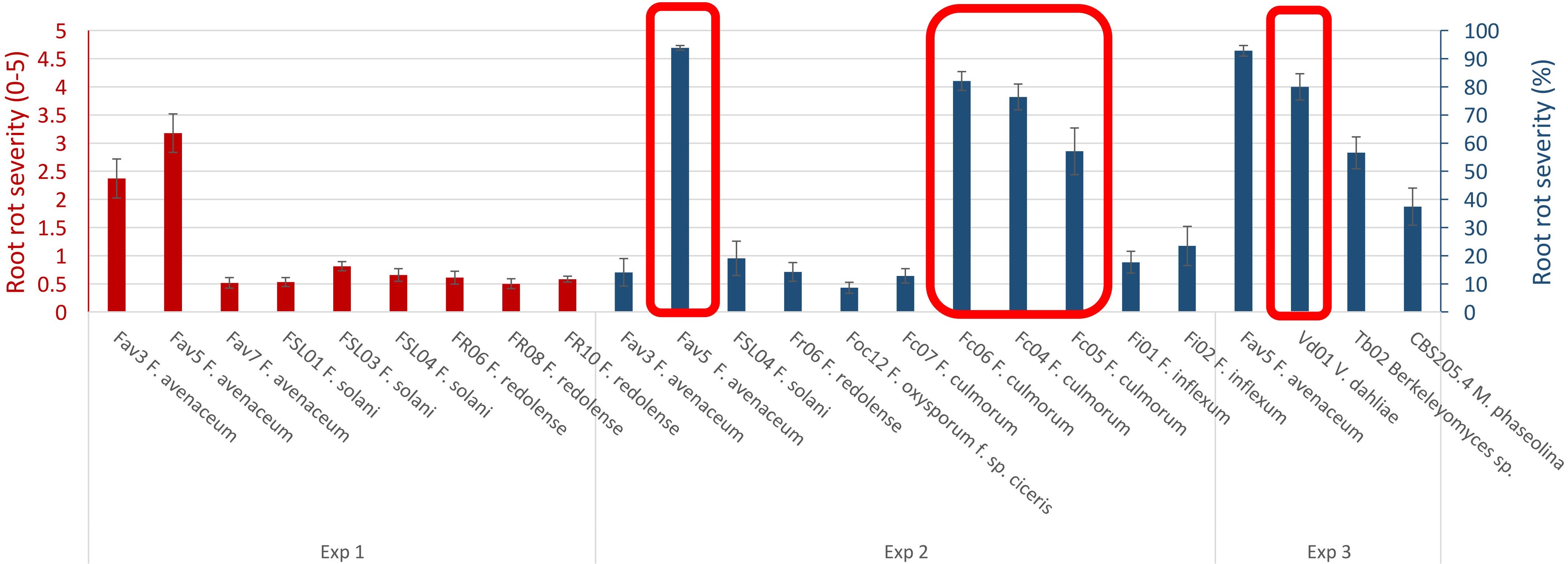


Chatterton et al. 2017. Can J Plant Pathol 41:98-114. https://doi.org/10.1080/07060661.2018.1547792

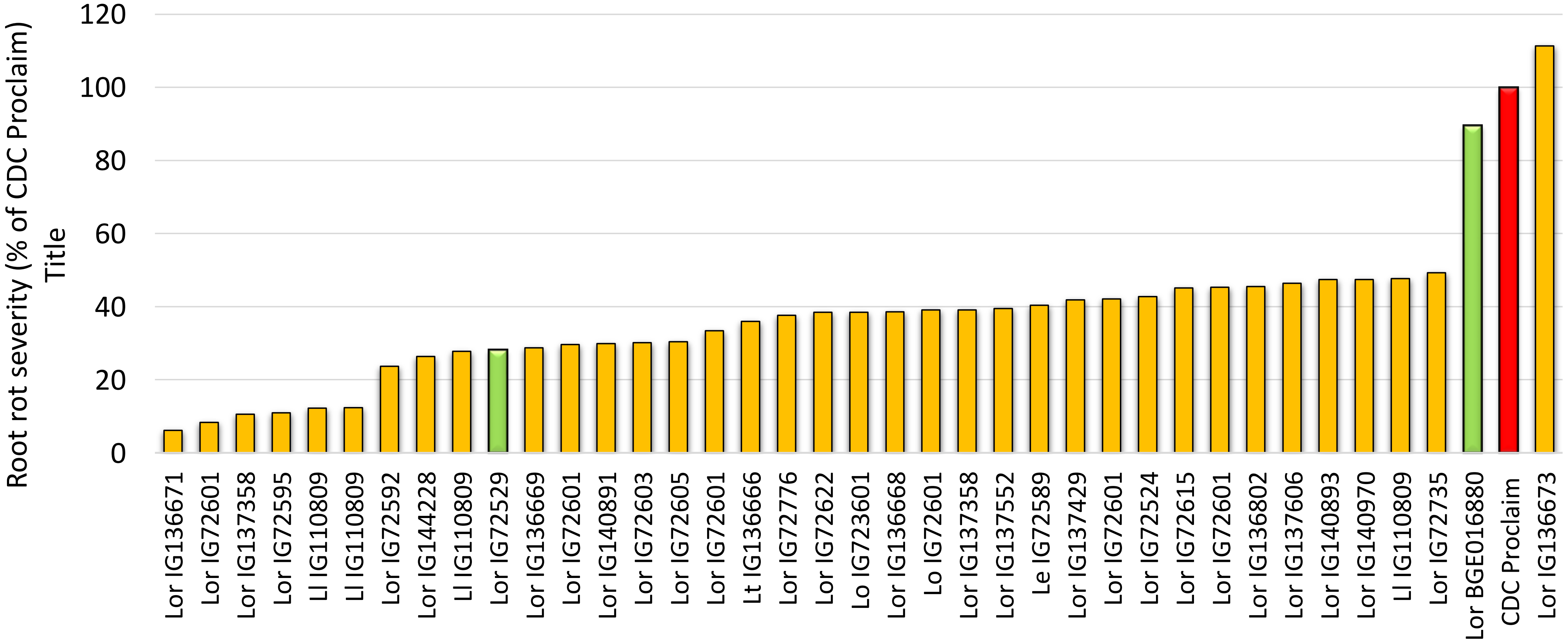
Armstrong-Cho et al., in press

New pathogen in chickpea in 2021





Aphanomyces root rot resistance in lentil



Lor: *Lens orientalis*, Ll: *L. lamottei*, Lt: *L. tomentosus*, Lo: *L. odemensis*, Le *L. ervoides*

New: Combining *Aphanomyces* and *F. avenaceum* resistance in lentil (Banniza & Bett)

- Development of a multi-parent advanced generation inter-cross (MAGIC) population
- Identify lines with improved *Aphanomyces* and *F. avenaceum* resistance
- Determine effect of seed coat colour
- Develop markers for breeding

Elite lentil A	Elite lentil B	Elite lentil C	Elite lentil D
X	X	X	X
L. orient. E	L. orient. F	L. orient. G	L. orient. H
⬇	⬇	⬇	⬇

A E X B F   C G X D H

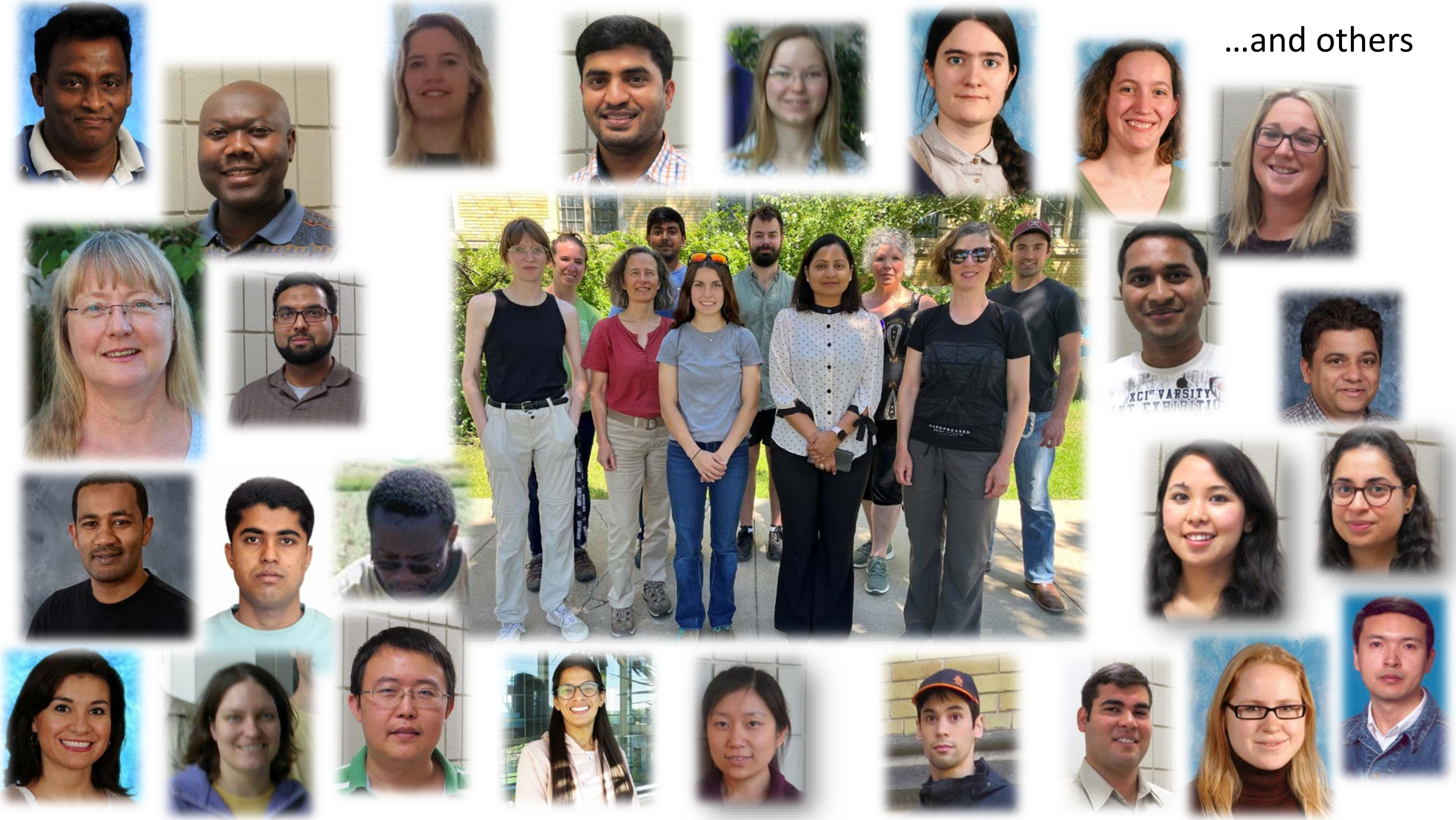
⬇   ⬇

200 A/E//B/F X 200 C/G//D/H

400 A/E//B/F/3/C/G//D/H

Going forward

- Root rot resistance in pea, lentil and chickpea
- *Colletotrichum lentis* race 0 (anthracnose) resistance in lentil
- Explore foliar fungal pathogens of faba bean
- Resistance screening to bacterial blights and anthracnose in bean
- Support provincial disease surveys through training



…and others

Incomplete list of formal and informal research collaborators

Bob Conner (AAFC Morden)
Randy Kutcher (AAFC Melfort)
Robin Morrall (Dpt. Of Biology, UofS)
Yangdou Wei (Dept. of Biology, UofS)
Bruce Gossen (AFFC Saskatoon)
Sue Boyetchko (AAFC Saskatoon)
Clarice Coyne (USDA, USA)
Rebecca McGee (USDA, USA)
Marie-Laure Pilet-Nayel (INRA, FRA)
Anne Moussart (INRA, FRA)
Bernard Tivoli (INRA, FRA)
Christophe Le May (Agrocampus Ouest, FRA)
Mary Burrows (Montana State University, USA)
Michael Harding (Government of Alberta)
Robyne Davidson (Lakeland College)
Syama Chatterton (AAFC Lethbridge)
Deborah McLaren (AAFC Brandon)
Hossein Borhan (AAFC Saskatoon)
Judith Lichtenzveig (University of Western Australia, AUS)
Rebecca Ford (University of Melbourne, AUS)
Jenny Davidson (SARDI, AUS)
Gopalan Selvaraj (NRC)
Julie Pasche (North Dakota State University, USA)
Axel Diederichsen (AAFC Saskatoon)
Anupa Hingane (IAEA, Vienna, AT)
Pedro Crous (Westerdijk FungalBio Diversity Institute, NL)
Tobin Peever (Washington State University, USA)
Weidong Chen (Washington State University, USA)
Yantai Gan (AAFC Swift Current)
Michelle Hubbard (AAFC Swift Current)
Tom Wolf (AAFC Saskatoon)
Terry Hogg (ICDC)
Keith Seifert (AAFC Ottawa)
Eric Johnson (AAFC Scott)
Art Davis (Dpt. of Biology, UofS)
Brianne McInnes (NARF Melfort)
Jessica Pratchler (NARF Melfort)
Diego Rubiales (CSIC, Cordoba, ES)
Roman Labuda (University of Veterinary Medicine Vienna, AT)
Many colleagues in the Dpt. Of PLSC, UoS

Acknowledgments

Government of Saskatchewan
Ministry of Agriculture

Crop Development Centre
USASK

Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada

Saskatchewan Pulse Growers

NSERC
CRSNG

RDAR
Results Driven Agriculture Research

WGRF
Advancing Agriculture through Research

SCIC
Saskatchewan Crop Insurance Corporation

ACIDF
Alberta Crop Industry Development Fund Ltd.

SARM
Saskatchewan Association of Rural Municipalities

University of Saskatchewan
College of Agriculture and Bioresources
AGBIO.USASK.CA

Alberta Pulse Growers

We acknowledge we are on Treaty 6 Territory and the Homeland of the Métis.
We pay our respect to the First Nations and Métis ancestors of this place and reaffirm our relationship with one another.