

Keeping a finger on the pulse of pulse crop pathology

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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. Connors)

1929-2004 The Canadian Phytopathological Society
 75th Anniversary – Annual meeting June 13-16 2004, Crown Plaza, Ottawa

Building on the Past as We Shape the Future: Pioneering Prairie Plant Pathology
 A.D. Beattie, A.L. Breker, F.L. Dokken, J. Feng, D.L. Greenshields, M.E. Kuchuran, S.L. Vail, and T.L. Wagner
 University of Saskatchewan

Canada has become one of the most important crops on the prairies since the early 1970s. Many diseases cause significant losses in canola. In 1977, Saskatchewan Agriculture hired the first canola pathologist, L.J. Duczek, who provided consulting, advisory, extension and promotional services primarily on canola diseases. *Sclerotinia stem rot*, caused by *Sclerotinia sclerotiorum*, is common throughout western Canada. Much of the research on sclerotinia was done at the University of Saskatchewan led by R.A.A. Morill. They developed the leaf roll forecasting system which is currently the primary method of forecasting disease pressure. Blackleg, caused by *Leptosphaeria maculans*, infects leaves, cotyledons, and stems. The virulent strain of the fungus was first observed in Saskatchewan in 1975 by G.A. Patne, who made a significant contribution to the present knowledge of the pathogen's variability and epidemiology. Alternaria black spot (grey leaf spot) is caused by *Alternaria brassicae*. *A. alternata* and *A. raphani* on all above ground parts. At the University of Alberta, W.P. Skirjopad made significant contributions to the understanding of epidemiology, resistance breeding and control mechanisms for this disease. Also at the University of Alberta, J.P. Tewart conducted much of the research on the host-parasite interaction. At the Saskatchewan Agriculture and Agri-Food Canada Research Centre, L.J. Duczek was involved in determining the economic cost of Alternaria.

1916, a severe rust epidemic devastated wheat production in Canada. In 1916, the government opened a laboratory of plant pathology to assist in studying the rust pathogen in Saskatchewan. W.P. Fraser and M. Newton identified some 14 physiological races of stem rust on cereals crops in the early 1920s. At the 1924 Rust Conference, a decision was made, and in 1925, rust research was transferred to the Dominion Rust Research Lab in Winnipeg, making Saskatoon the centre for cereal rust research as well as diseases of forage crops, oilseeds, and cereal smuts. Early research was initiated by well-known pathologists R.C. Russel (bark-rot in wheat) and P.M. Simmonds along with W.P. Fraser (common root rot/brownish root rot).

Rust Conference (1924)

Flax was originating through by pioneer farmers to western Canada. Demands for linseed oil brought on by World War I saw flax production increase dramatically, and with it a corresponding increase in disease pressure, in particular wilt (*Fusarium oxysporum*). A wilt nursery was established at the University of Saskatchewan in the 1920s. This eventually led to the release of the first variety with combined resistance to wilt and rust (*Melangouza* line), developed by J.B. Harrington. In 1928, T.C. McIntosh joined the Department of Biology staff as a researcher and professor. As flax acreage grew, he pioneered the first studies on flax diseases. From 1942 to 1950, he produced numerous extension bulletins and conducted flax disease surveys to monitor the important diseases of the day including rust, root rot (*Phytophthora* spp.) and stem break (*Polydora* line). Through the release of resistant genetics and extension work, wilt and rust have become inconspicuous diseases of flax.

Leifseed was first grown in Canada in the late 1960's and was relatively disease free until the late 1970's. In 1978, the University of Saskatchewan's R.A.A. Morill identified an *Ascochyta* species from foliar lesions on leifseed plants from the field of the late Earl Puhars, a Leifseed area farmer. By 1980, *ascochyta blight* had become the major leifseed disease of the prairies, and focused research by Saskatchewan pathologists and breeders has since yielded resistant cultivars and effective control strategies. In 1990, a new problem faced leifseed producers in Saskatchewan: leifseed anthracnose was found 100 km southwest of Saskatoon. Anthracnose-resistant leifseed cultivars have been developed at the Crop Development Centre, particularly in the red cogwheel varieties. The challenge now is to produce the popular large-seeded yellow cotyledon cultivars that are resistant to anthracnose and *ascochyta* blight.

References
 Connors, I.L. 1972. Plant Pathology in Canada. Canadian Phytopathological Society, Central Duplicating Service, University of Saskatchewan, S. 89. 1986. Saskatchewan Research Council, Research Series No. 20, Agriculture Canada.
 Information on specific crops and their diseases were taken from various publications in the Canadian Journal of Plant Pathology.
 Information on leifseed derived with permission from Morill, R.A.A. (1998). Evaluation of seed disease rot in leifseed. University of Saskatchewan, S. 107-108.

Acknowledgements
 The book is the work of S. Barvitz, J. Thomson, A.M. Minak, A. Skirjopad, J.P. Tewart, G. Rowland, L.J. Duczek, G.A. Patne, R. Copman for their kind and generous support. Thanks also to R. Skirjopad for his support and assistance, and D. Dyck (Winnipeg portrait). Disease pictures were supplied by R.A.A. Morill (leaf roll, stem, sunflower), field rust, and R.C. Russel (bark-rot).

Plant pathology laboratory, Saskatoon (1925)

Of 8 pathology research group under R.A.A. Morill (1928)

Sunflowers are native to North America and were grown in western Canada by Aborigines and early Métis people settlers. Sunflower production began to increase around the time of World War II, and has been considered an economically important crop for the last 40 years. Sunflower, Sunola and Sunmehar are chosen as alternative cash crops for several reasons, including their resistance to blackleg, *Sclerotinia* wilt and head rot are major diseases on sunflower in Saskatchewan and Alberta. Much of the research into disease occurrence and control of sclerotinia has been conducted at Agriculture and Agri-Food Canada in Lethbridge and Lacombe, Alberta.

Saskatoon have become increasingly popular as a commercial fruit crop on the prairies. **Saskatoon juniper rusts** (*Gymnosporangium* spp.) can affect both leaves and berries of saskatoons, however, infection of the berries with even one spot will spoil them. *Entomosporium* berry and leaf spot (*Entomosporium mespilii*) occurs under warm, humid conditions and can lead to defoliation of berry bushes. These diseases, along with several others, were investigated by J.G.N. Davidson of Agriculture and Agri-Food Canada in Beaverlodge, AB.

Chickadee from the west, teaching on canola, comely pollen test, leaf roll with anthracnose, leaf leaves with *ascochyta* blight, *Sclerotinia* wilt on flax

Plant pathology laboratory, Saskatoon (2004)

R.C. Russel conducting a plant disease survey (1925)



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

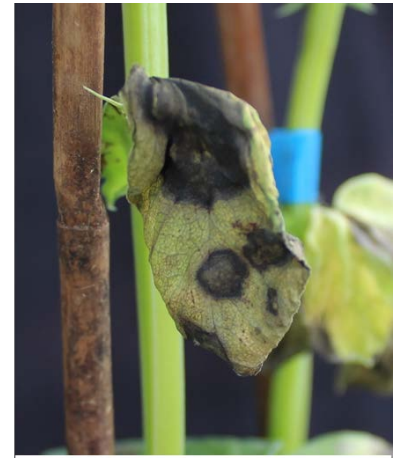
Root rots



Alternaria leaf spot on faba



Mycosphaerella blight of pea



Stemphylium blight on faba

Ascochyta blight of lentil



Anthracnose of bean



Halo blight of bean



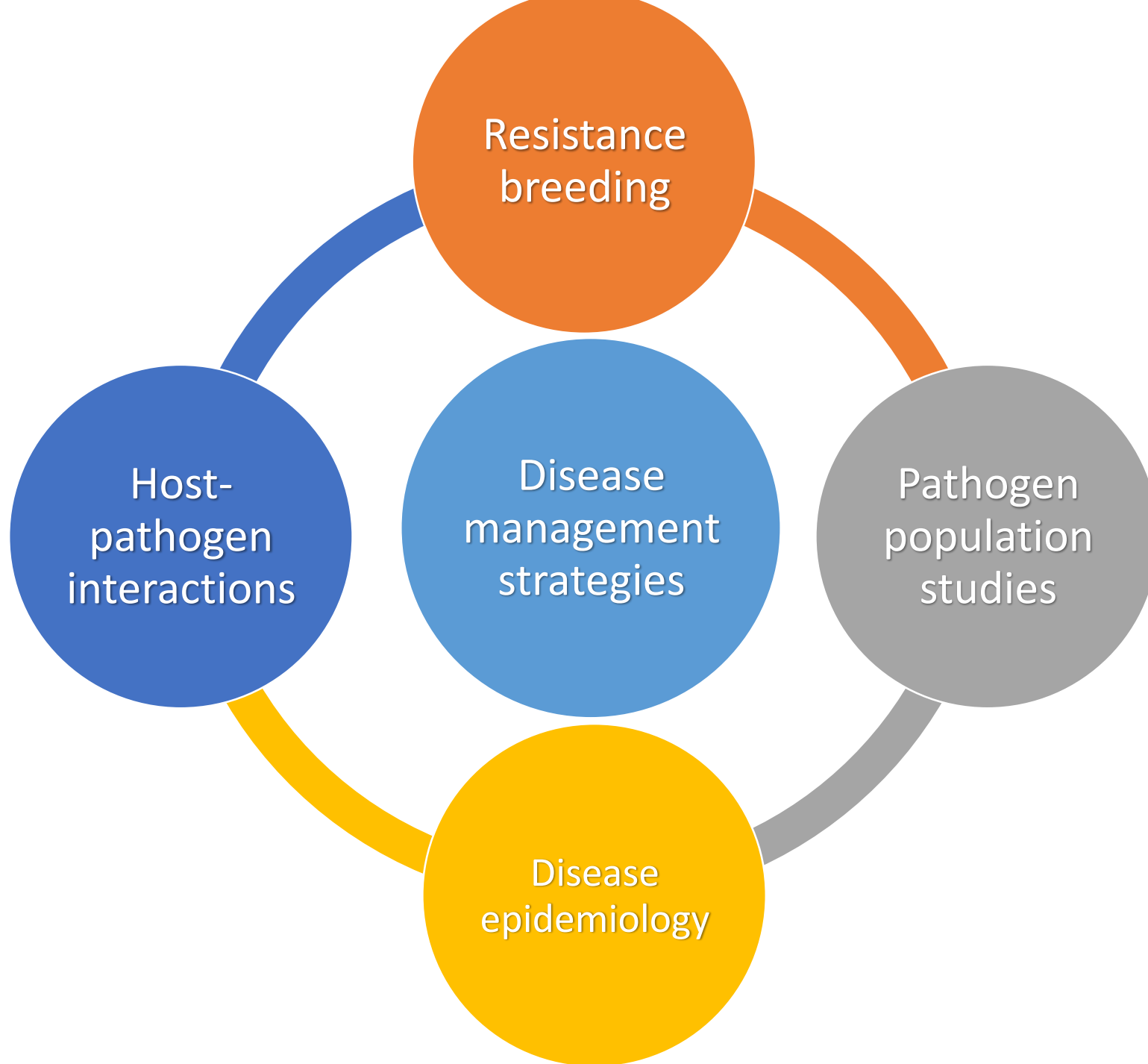
Anthracnose of lentil



Common bacterial blight of bean



Blossom blight





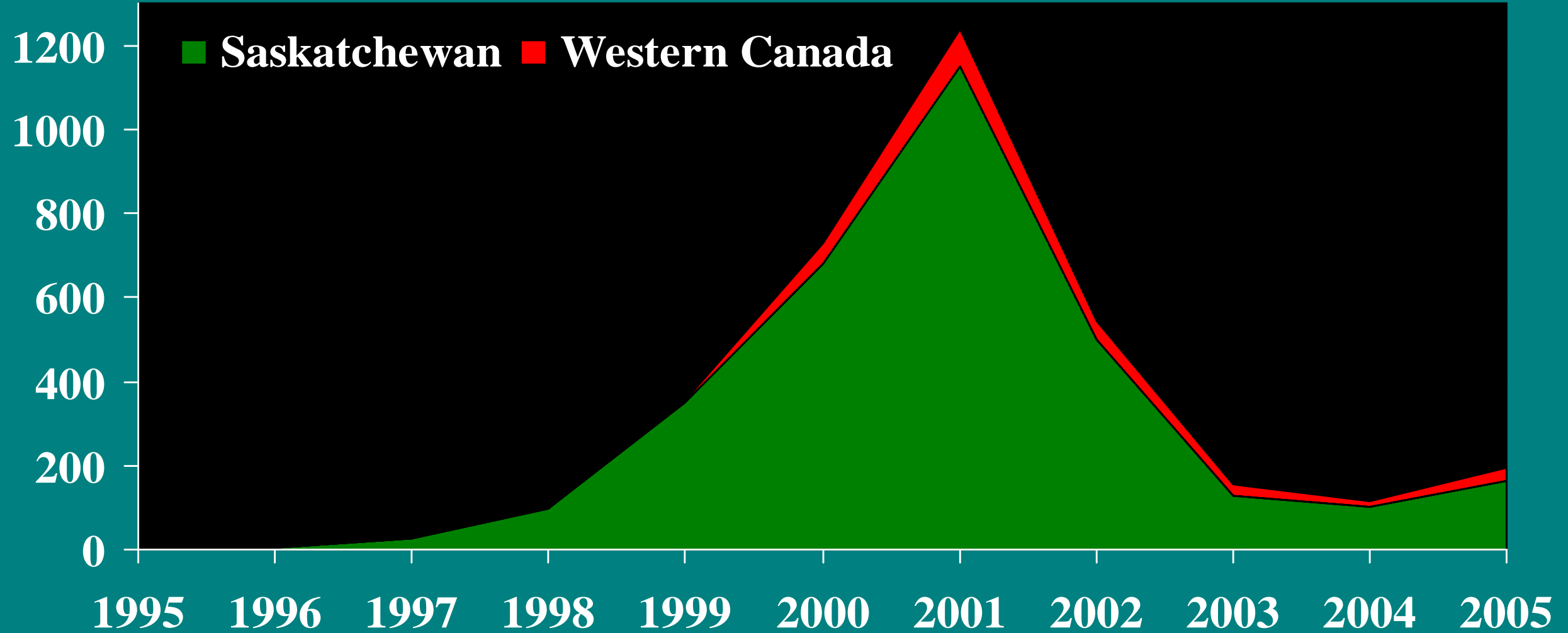
Management of ascochyta blight in chickpea in Canada

with Tom Wolf and Yantai Gan, AAFC

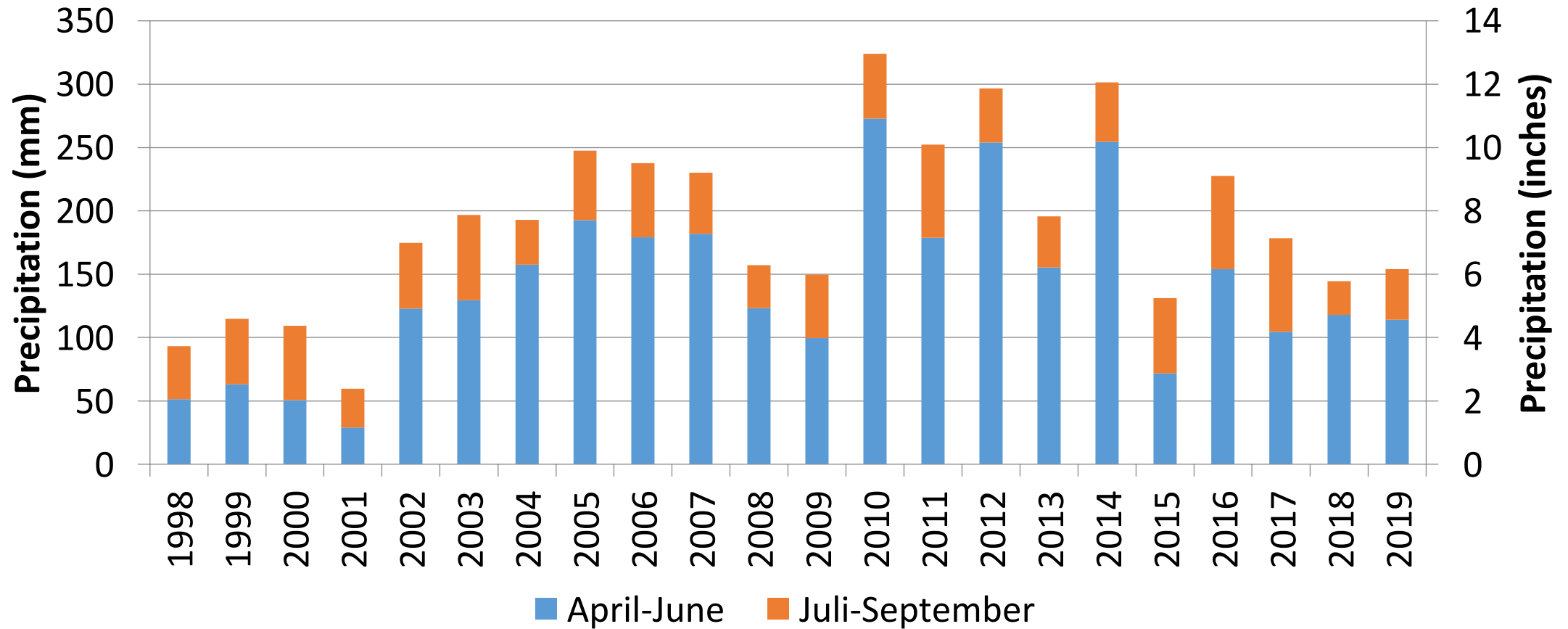
Chickpea area (seeded acres)

Source: Ray McVicar, SAF

Thousands



Epidemics of asochyta blight in chickpea after 2001



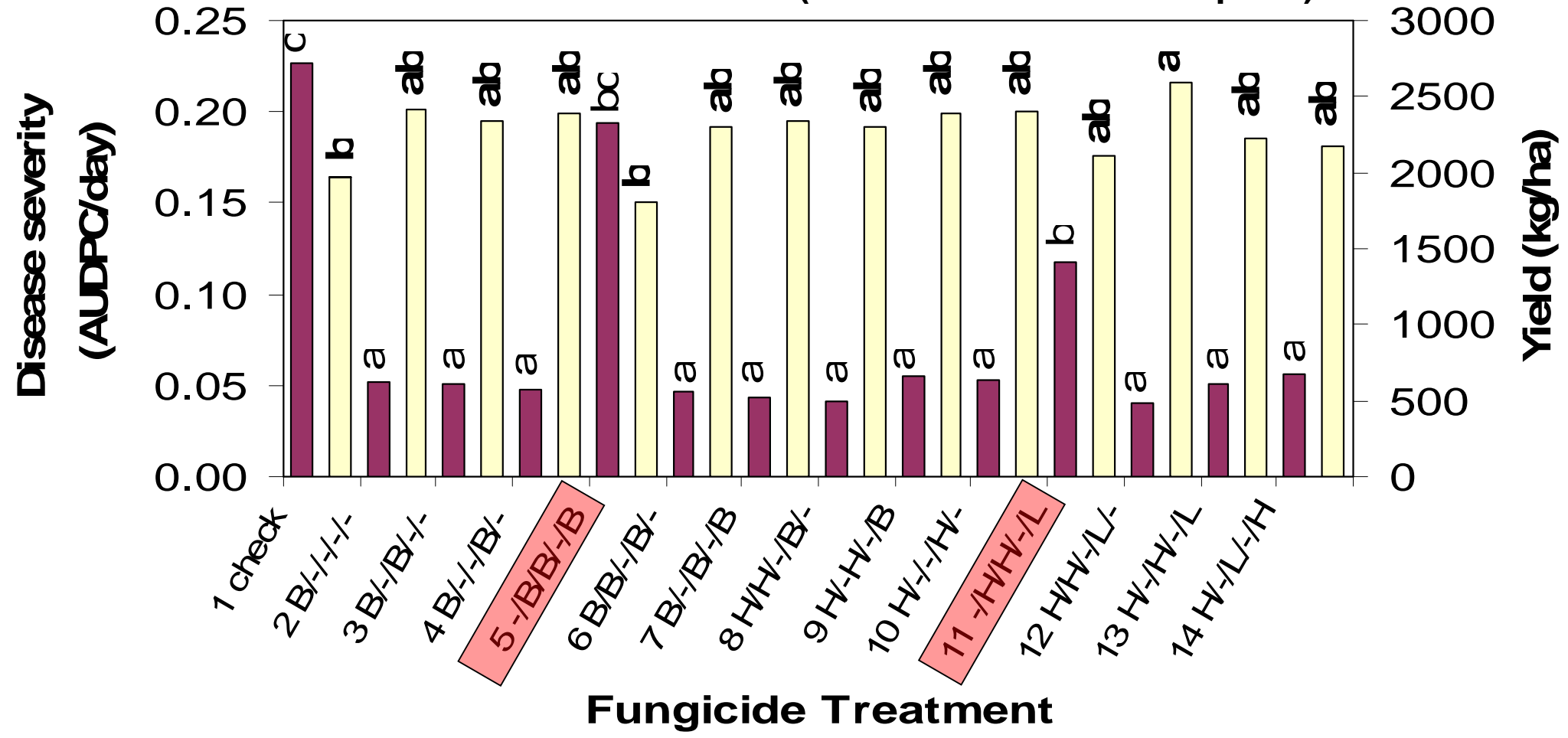


Timing of fungicide applications (Round 1)



■ Disease ■ Yield

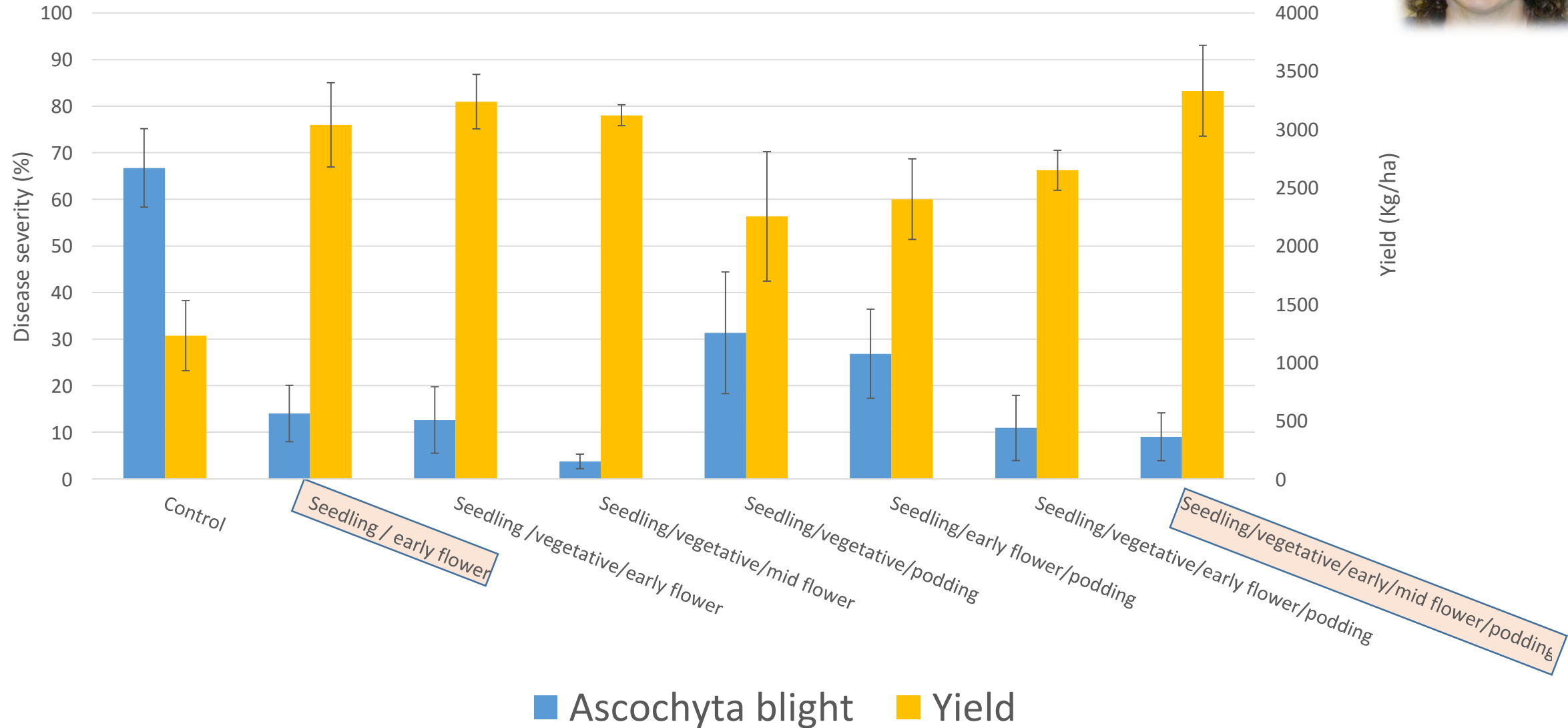
Saskatoon 2003 CDC Yuma (44% disease in control plots)





TIMING OF FUNGICIDE APPLICATIONS (Round 2)

CDC Yuma, Saskatoon, SK, 2008

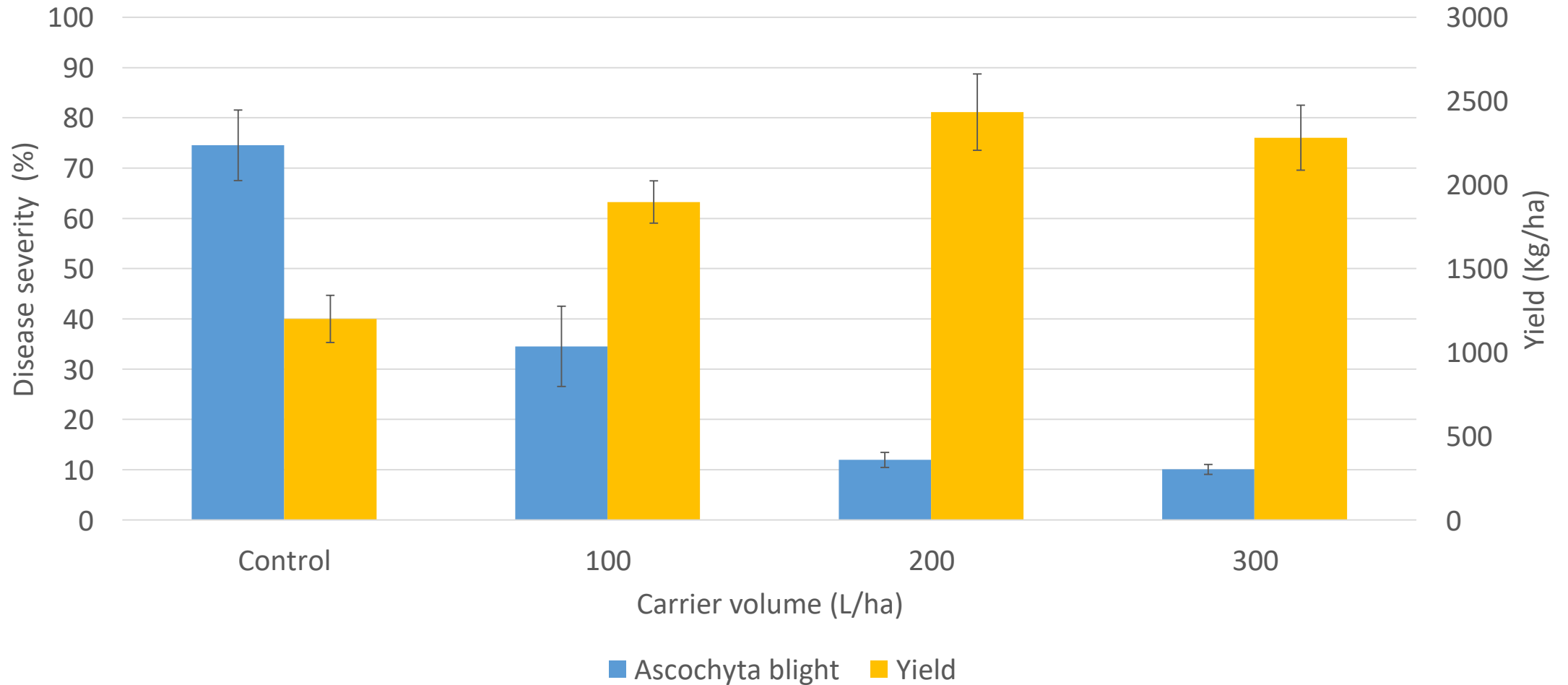




EFFECT OF CARRIER VOLUME

CDC Yuma, Outlook, SK, 2001

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

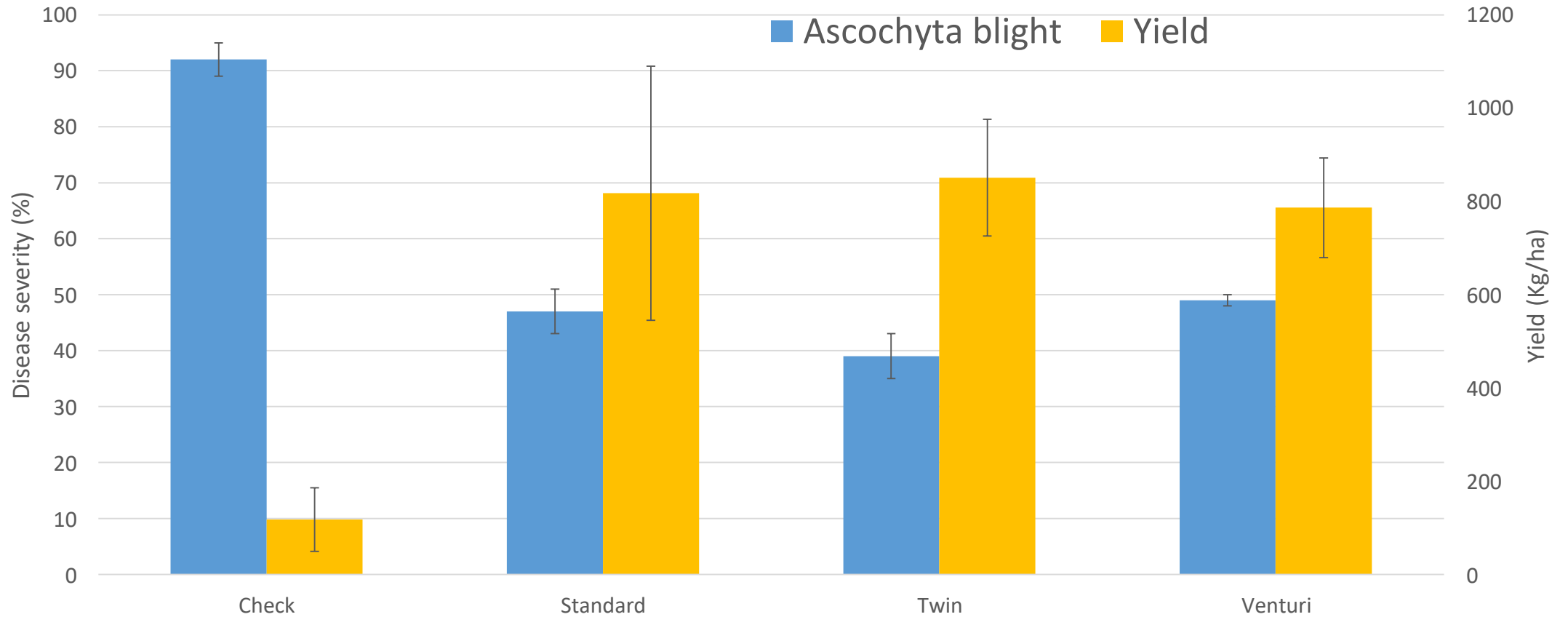




EFFECT OF DROPLET SIZE

Saskatoon, SK, 2002

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



Scouting and Management of

Ascochyta Blight in Chickpea

Symptoms

Scouting

Disease Risk Ratings

Disease Cycle & Infection Process

Fungicide & Resistance Management

Fungicide Application Technology

Economic Thresholds

Determining your Risk Rating:

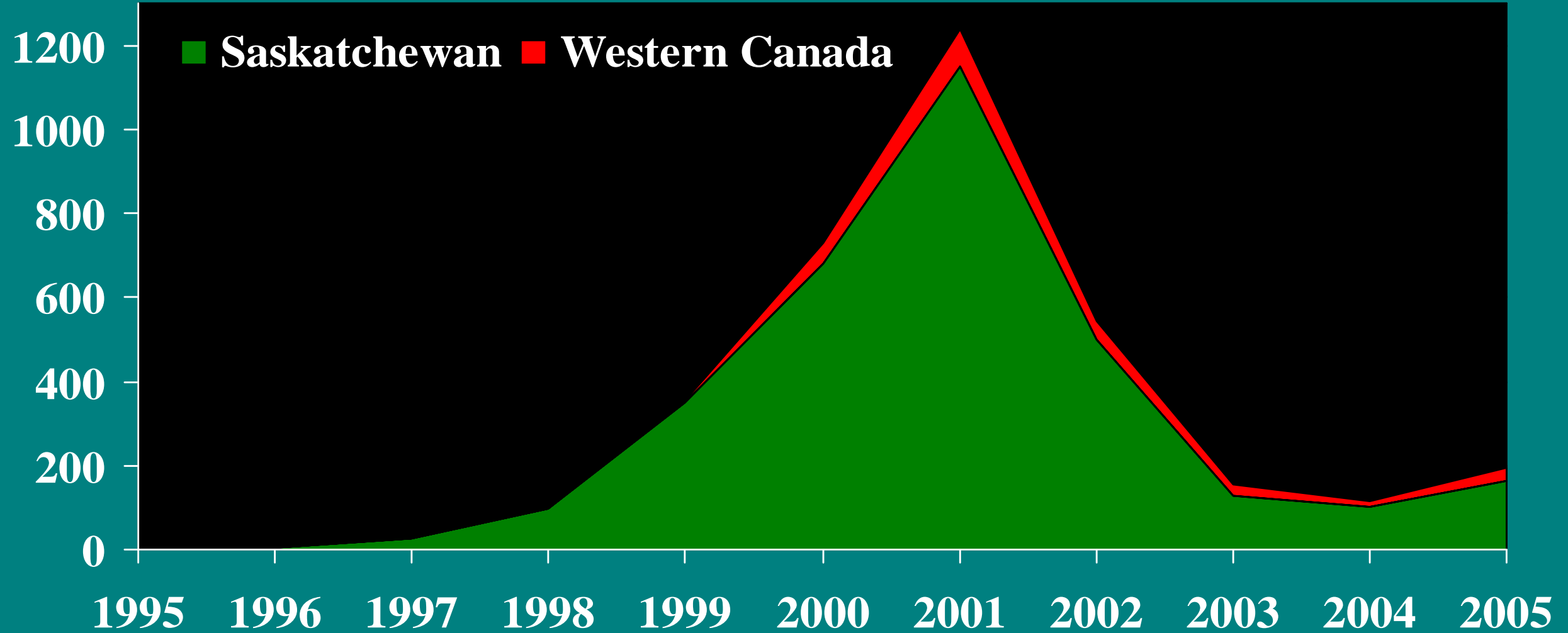
- Review the following six considerations and assign a risk value to each
- Add up the risk values to create a total risk value
- Use the total value to compare to the risk rating scale on the following page

| | Risk Value |
|---|------------|
| 1. Field History and Crop Rotation <ul style="list-style-type: none"> a. Crop is being grown in a region that has never had chickpea production <input type="checkbox"/> 0 b. Crop is planted on land that has not had chickpea for at least 3 years <input type="checkbox"/> 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 <input type="checkbox"/> 10 | |
| 2. Chickpea Variety <ul style="list-style-type: none"> a. Desi variety OR kabuli variety rated as "fair" resistance to ascochyta blight (e.g. B-90 or Amit, CDC Frontier) <input type="checkbox"/> 5 b. Kabuli variety that is rated as "poor" <input type="checkbox"/> 10 c. Kabuli variety that is rated as "very poor" <input type="checkbox"/> 20 | |
| 3. Level of Seed-borne Disease and Use of Seed Treatment <ul style="list-style-type: none"> a. Seed test indicated no seed-borne ascochyta AND used a registered seed treatment for ascochyta blight control <input type="checkbox"/> 0 b. Seed test indicated low levels of ascochyta (< 1%) AND used a registered seed treatment for ascochyta blight control <input type="checkbox"/> 5 c. Seed test indicated significant levels of ascochyta blight (5-10%) AND used a registered seed treatment for ascochyta blight control <input type="checkbox"/> 10 d. The seed quality is unknown, OR I am not using a seed treatment <input type="checkbox"/> 20 | |
| 4. Presence of Disease Symptoms since last Fungicide Application <ul style="list-style-type: none"> a. No new disease lesions have developed since last fungicide application <input type="checkbox"/> 0 b. Disease lesions have developed on new crop growth since last fungicide application <input type="checkbox"/> 10 c. Leaf and/or stem lesions have developed and no fungicide has been applied this season <input type="checkbox"/> 20 | |
| 5. Weather Conditions <ul style="list-style-type: none"> a. No rainfall in the past week and short-term forecast is for continued dry weather <input type="checkbox"/> 5 b. Weather conditions are unknown <input type="checkbox"/> 10 c. Rainfall or heavy dew has occurred during past week <input type="checkbox"/> 20 d. Weather is unsettled; thunderstorms are likely <input type="checkbox"/> 20 | |
| 6. Other Crop Health Considerations <ul style="list-style-type: none"> a. Crop emerged well in the spring and there has been no significant weather/injury to crop <input type="checkbox"/> 0 b. Crop was seeded very early and was slow to emerge <input type="checkbox"/> 5 c. Crop was damaged by early herbicide application or soil-residue <input type="checkbox"/> 10 d. The crop has received a light to moderate hail shower in the past 24 hours <input type="checkbox"/> 10 | |
| TOTAL RISK VALUE (1 + 2 + 3 + 4 + 5 + 6) = | |

Chickpea are (seeded acres)

Source: Ray McVicar, SAF

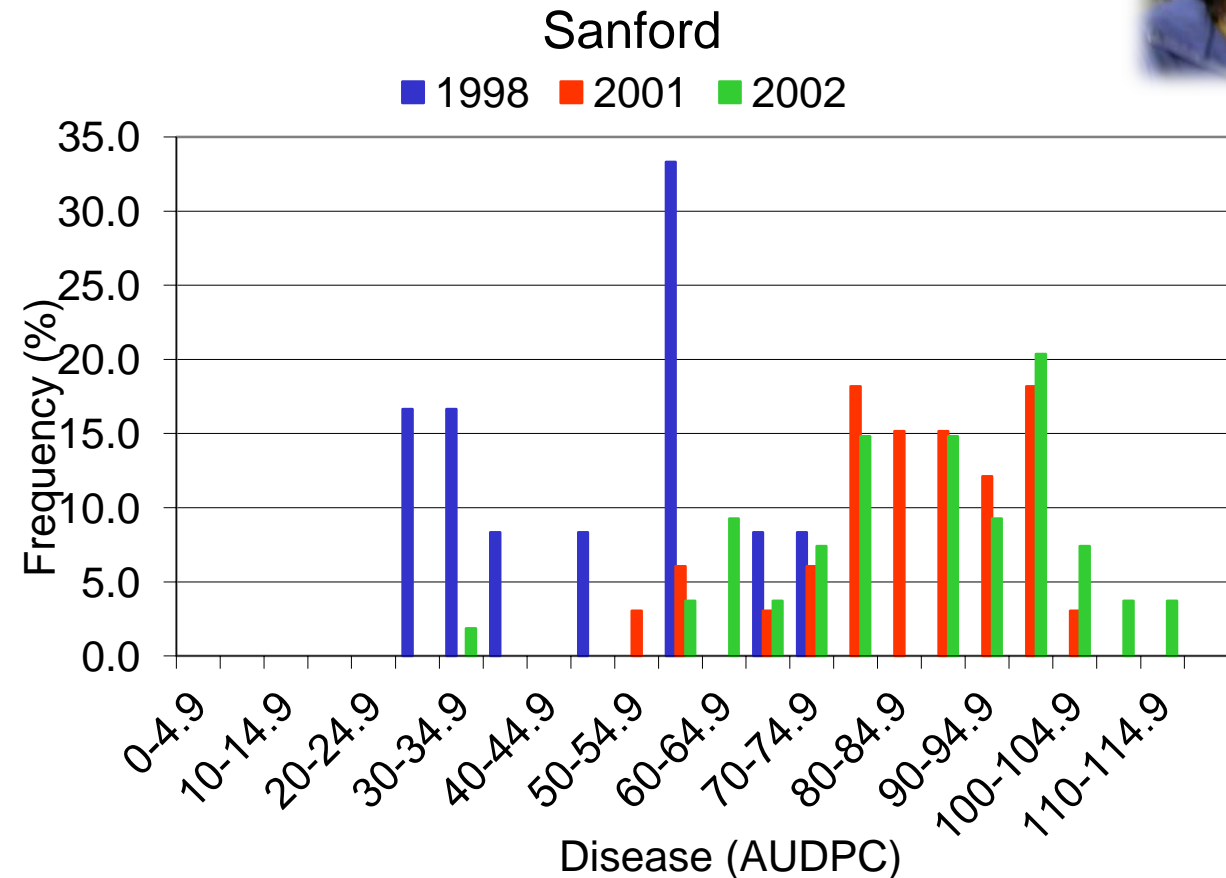
Thousands



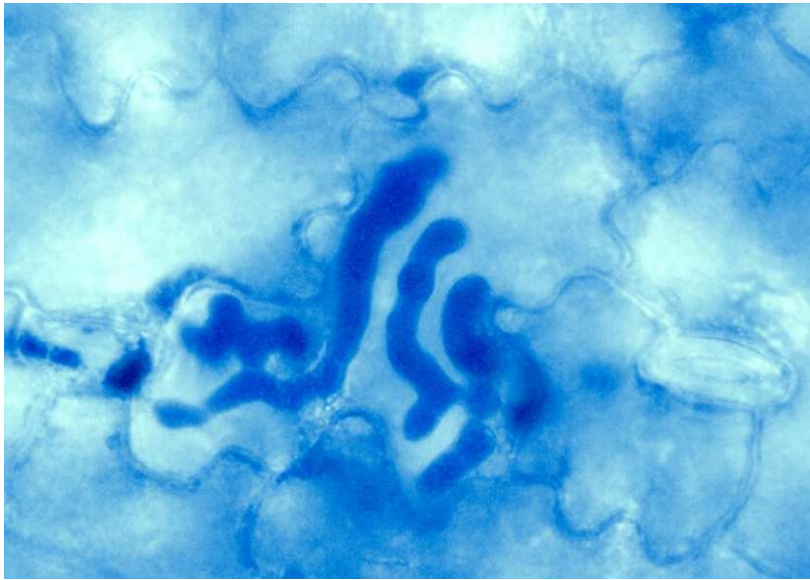


Resistance breakdown in chickpea

- 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.



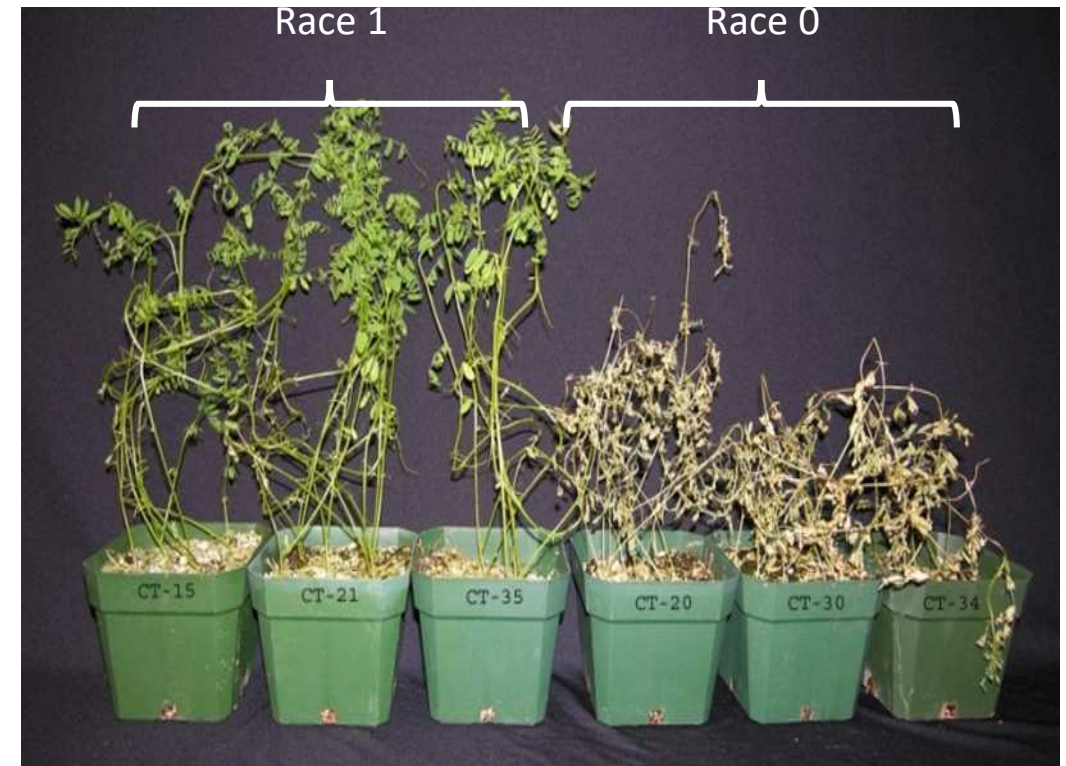
Understanding virulence in *Colletotrichum lentis* and anthracnose resistance in lentil

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.

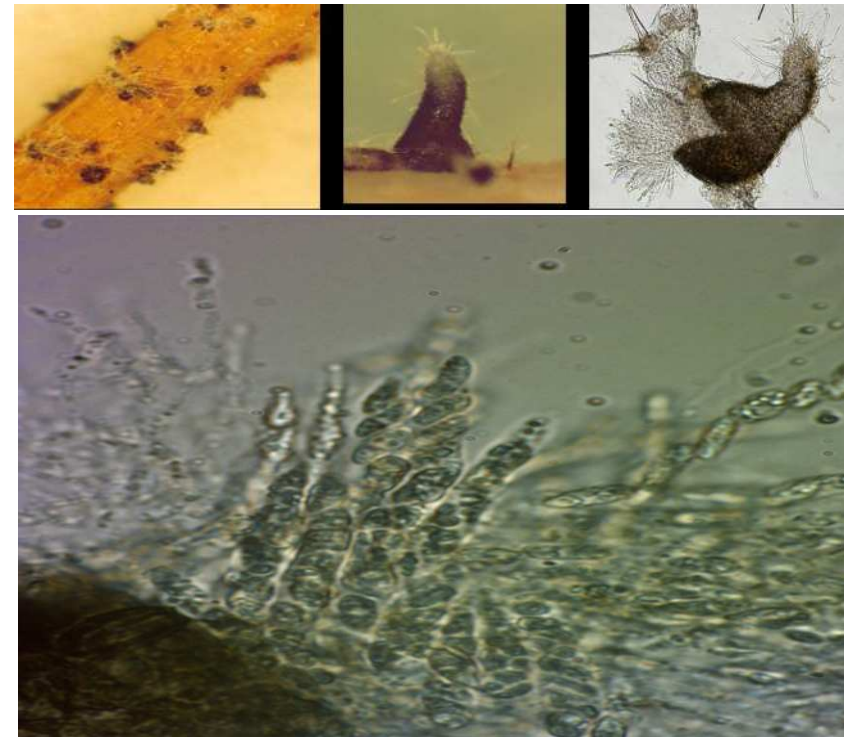




Sexual phase of *Colletotrichum lentis*



- Sexual phase induced in the laboratory
- Two sexual incompatibility groups (IG)
- F₁ segregates in a 1:1 ratio for IG
- IG-2 more common in the field
- Both IGs on the same plant

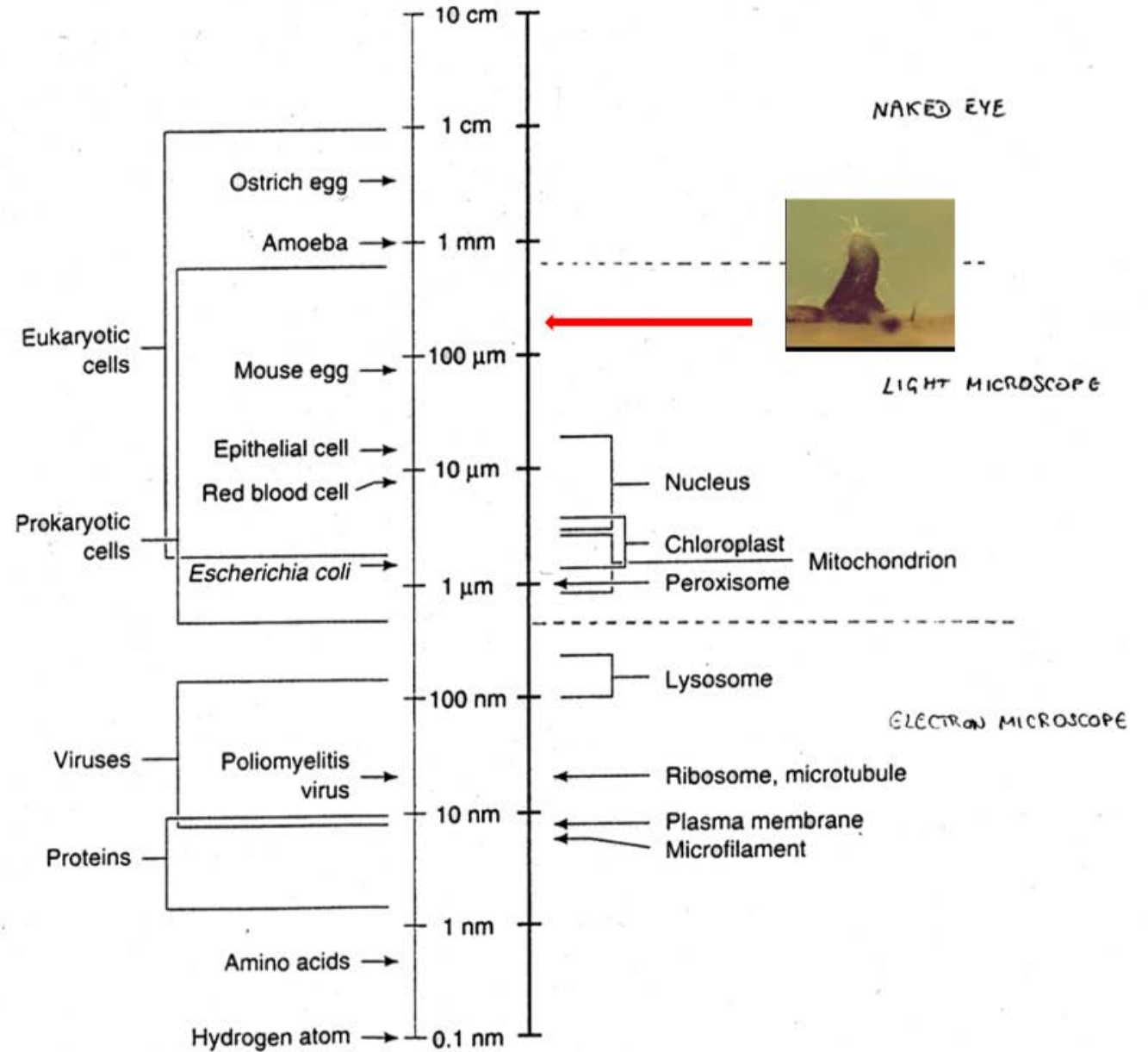


Menat et al. 2015. Fungal Ecology, in press.
Menat & Banniza 2012. Mycologia 104, 641-649.
Menat 2012. PhD thesis, University of Saskatchewan.
Armstrong-Cho & Banniza 2006. Mycological Research 110, 951-956.

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



mashable.com

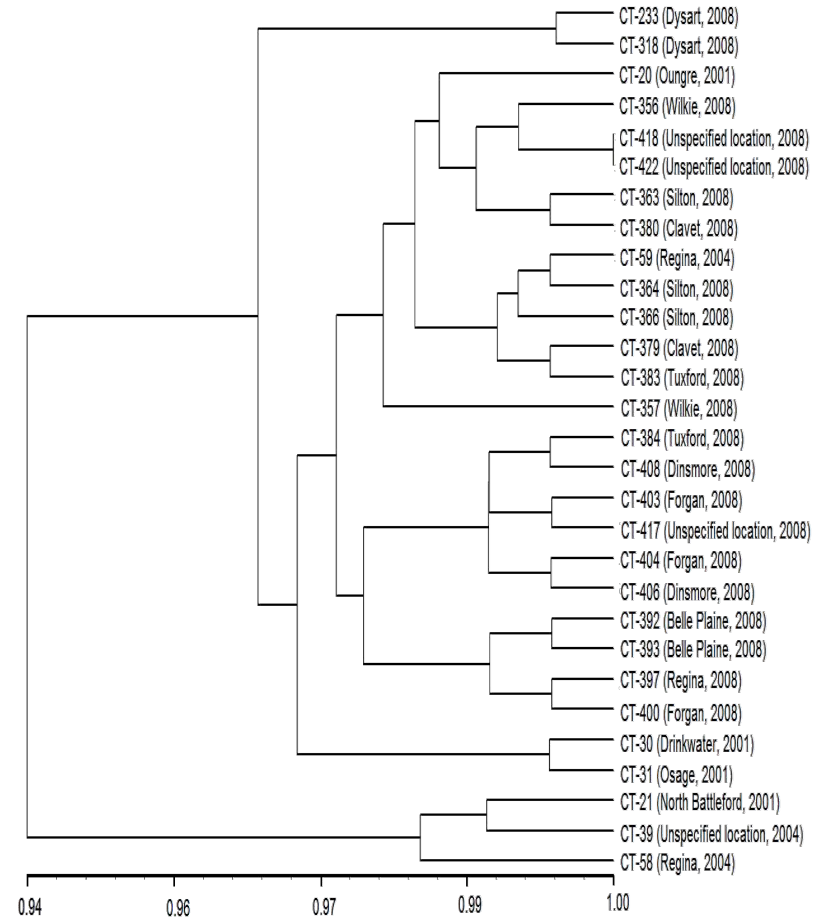




Does *Colletotrichum lentis* have sexual reproduction in the field?

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

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..



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



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..



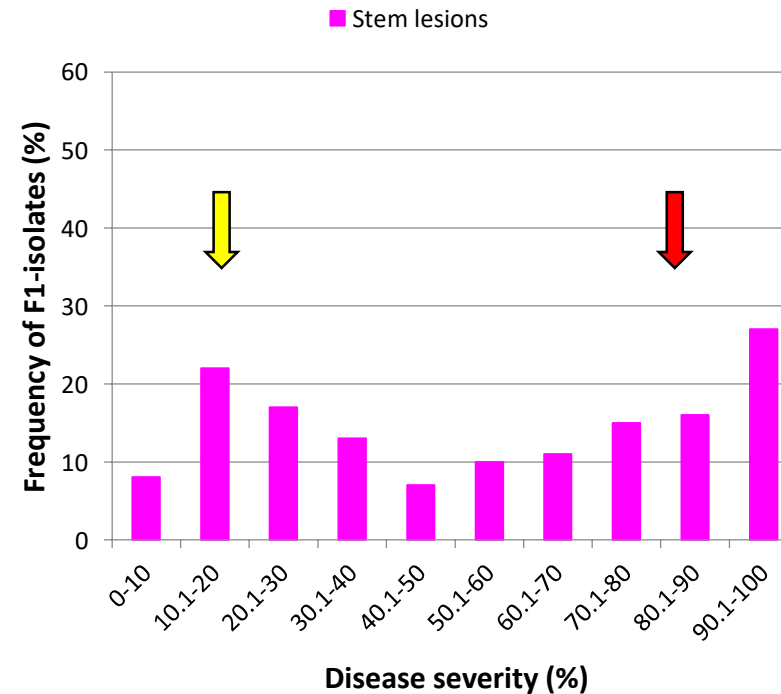
Breeding fungi: *Colletotrichum lentis* race 1 x race 0 population



- CT-21 (race 1/IG2) × CT-30 (race 0/IG1)
- Phenotyping of 142 asco-spore derived F₁-isolates and parental isolates
- Potential major gene / QTL effect

Bhadoria, 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

Virulence of F₁ isolates of
Colletotrichum lentis on
CDC Robin

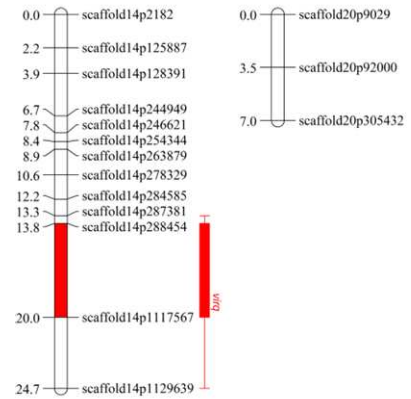
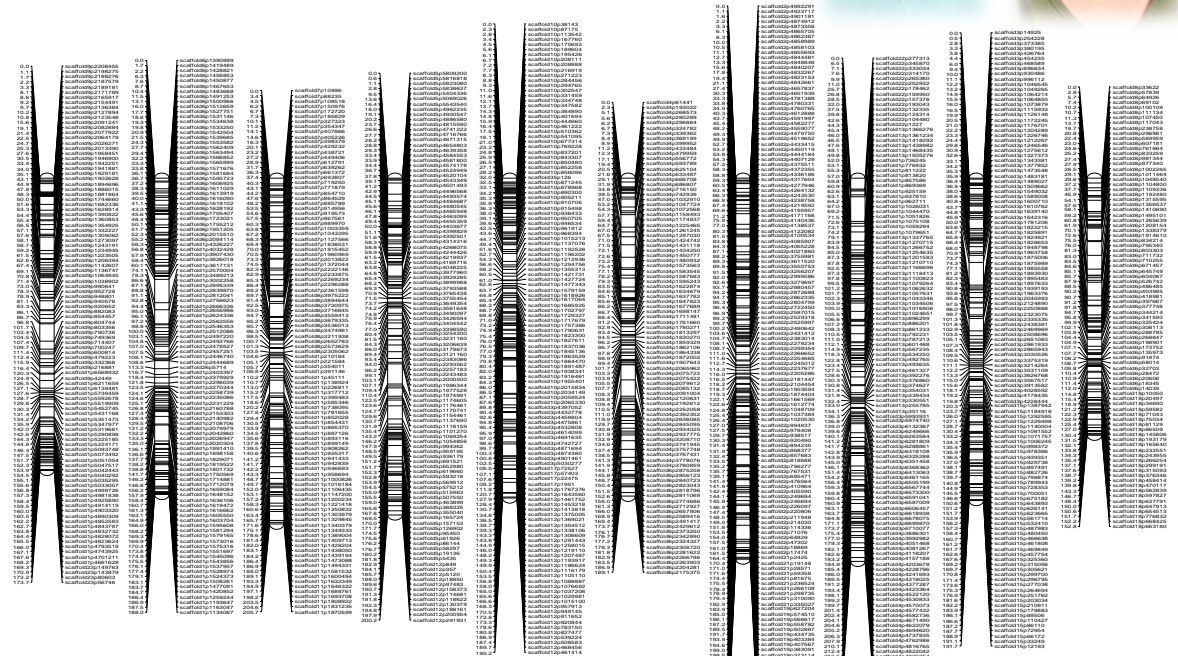


↓ race 1 parent ↓ race 0 parent

Sequencing and mapping of *Colletotrichum lentis*



- 56.10 Mbp genome assembly
- SNP-based map with 10 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



**NSERC
CRSNG**

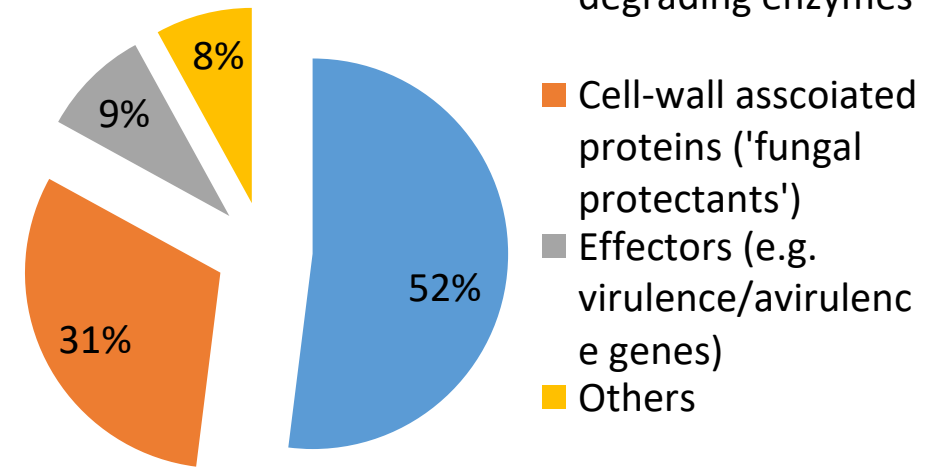




Virulence of *C. lentis* races

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





Finding the receptor for ClToxB in lentil



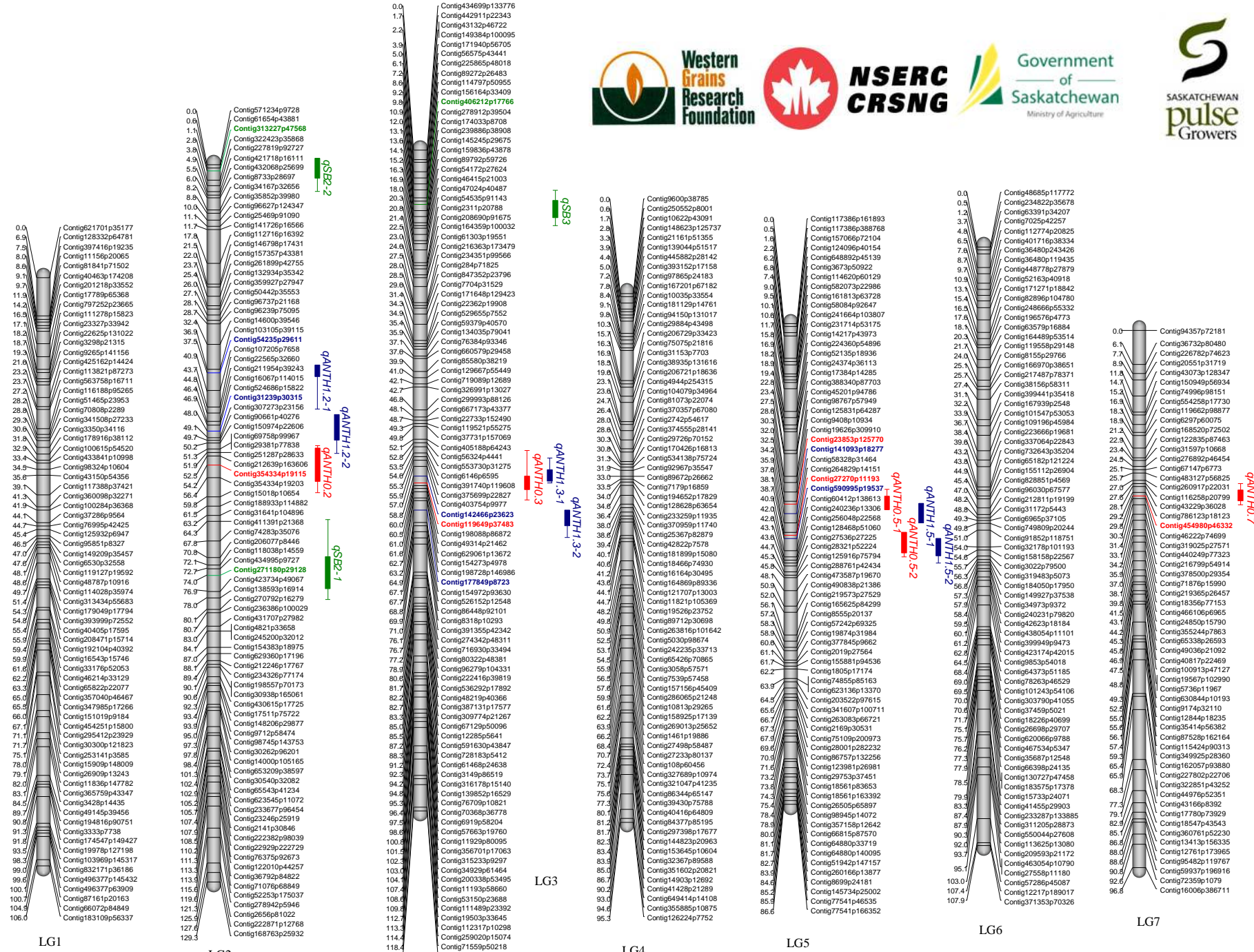
- *In vitro* pull-down assay identified 43 putative interactors with ClToxB of interest
- Infiltration of purified ClToxB induces necrosis in lentil





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

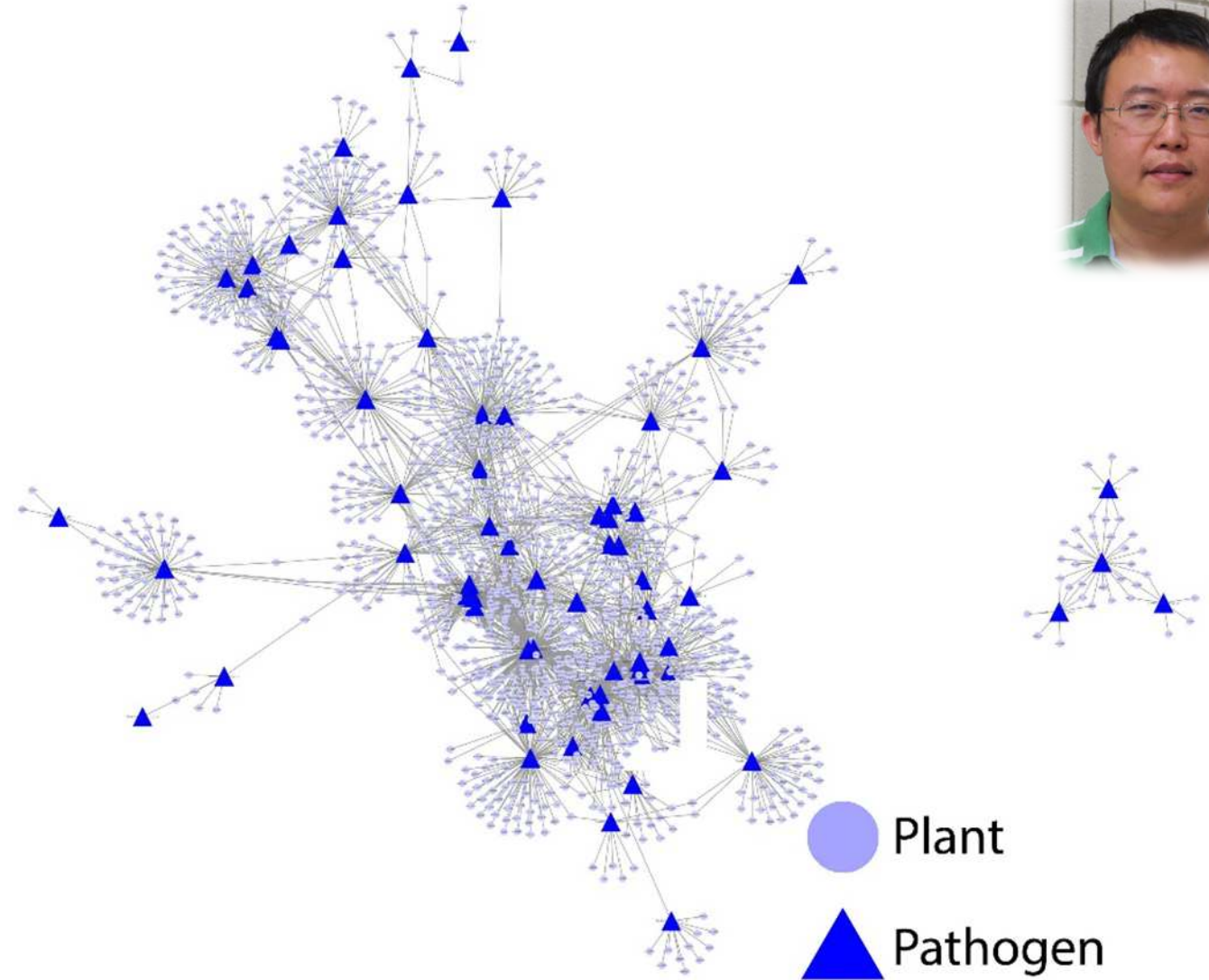
Green: stemphylium blight resistance QTL
Blue: anthracnose race 1 resistance QTL
Red: anthracnose race 0 resistance QTL



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:

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²Crop Protection Laboratory, 346 McDonald Street, Regina, SK S4N 6P6

³Department of Biology, University of Saskatchewan, 112 Science Place, Saskatoon, SK S7N 5E2

TITLE: FIRST REPORT OF APHANOMYCES EUTEICHES IN SASKATCHEWAN

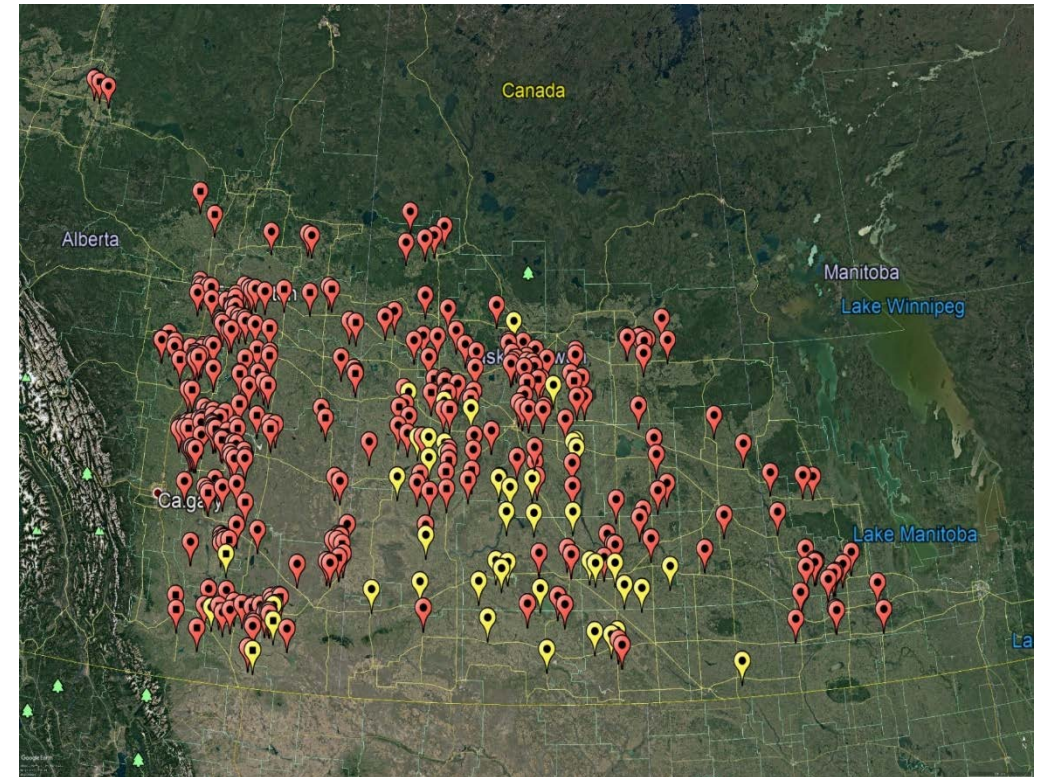
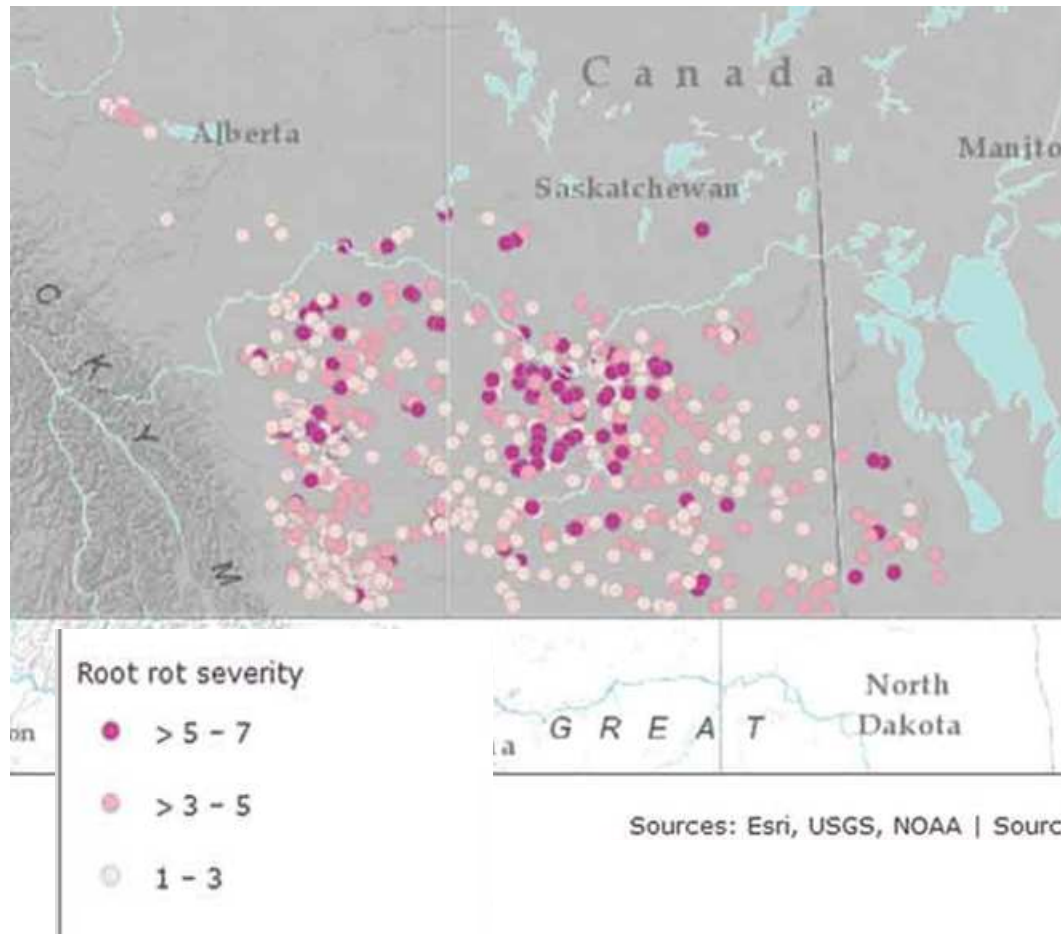
ABSTRACT: *Aphanomyces euteiches* was identified in samples from three diverse Saskatchewan locations using probe-based quantitative PCR. Wet conditions in several areas in 2012 and in preceding seasons have favored root rot and exacerbated symptom development. *Aphanomyces euteiches* is probably widespread 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.

/cgi-bin/rbaccess/rbunxcgi?F6=1&F7=IB&F21=IB&F22=IB&REQUEST=ClientSignin&LANGUAGE=ENGLISH&_ga=2.263379208.583740149.1538261856-1740749555.15382618

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



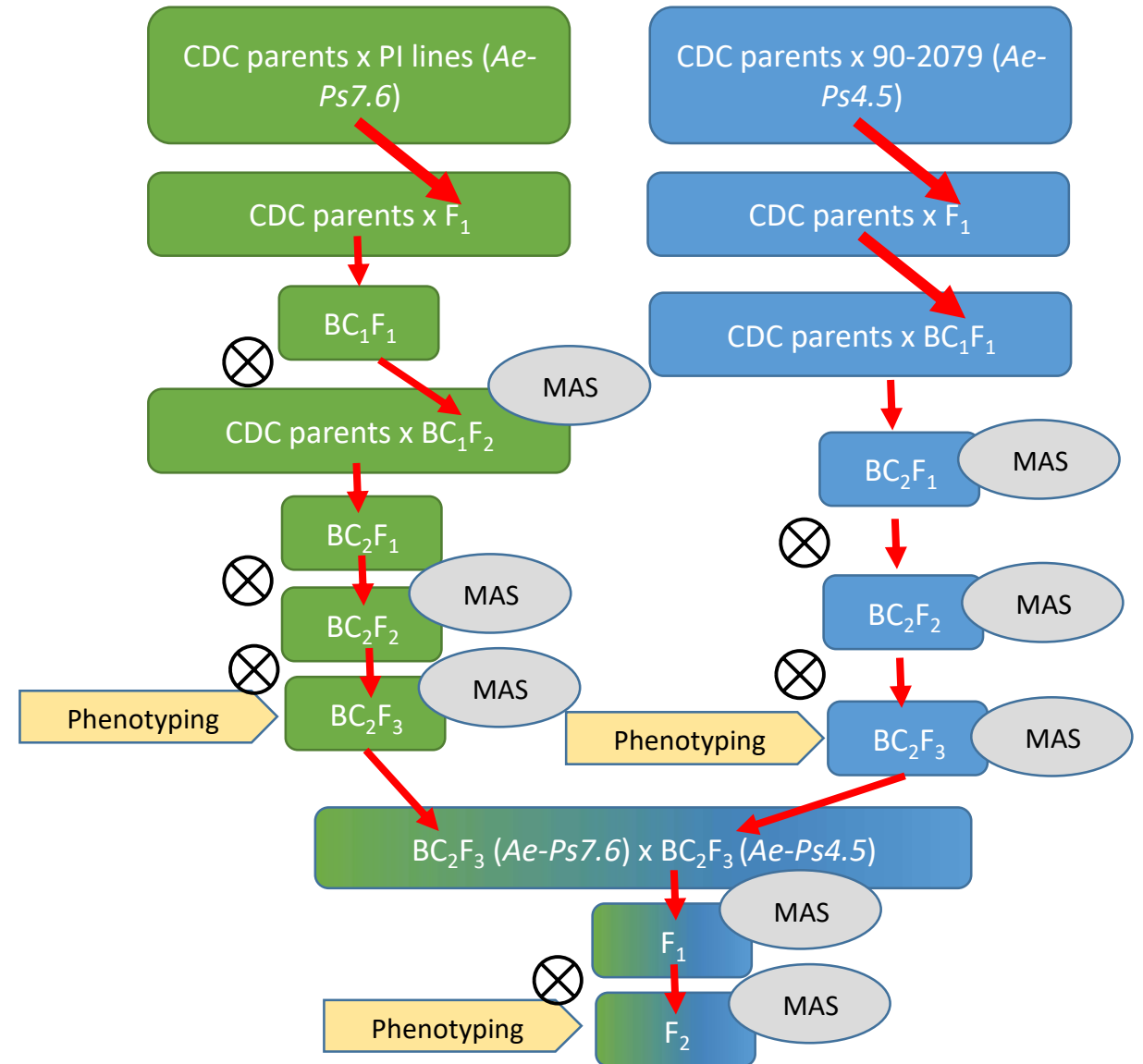
- Aphanomyces root rot in pea fields
- Aphanomyces root rot in lentil fields



Remember the
Western
Interior
Seaway?

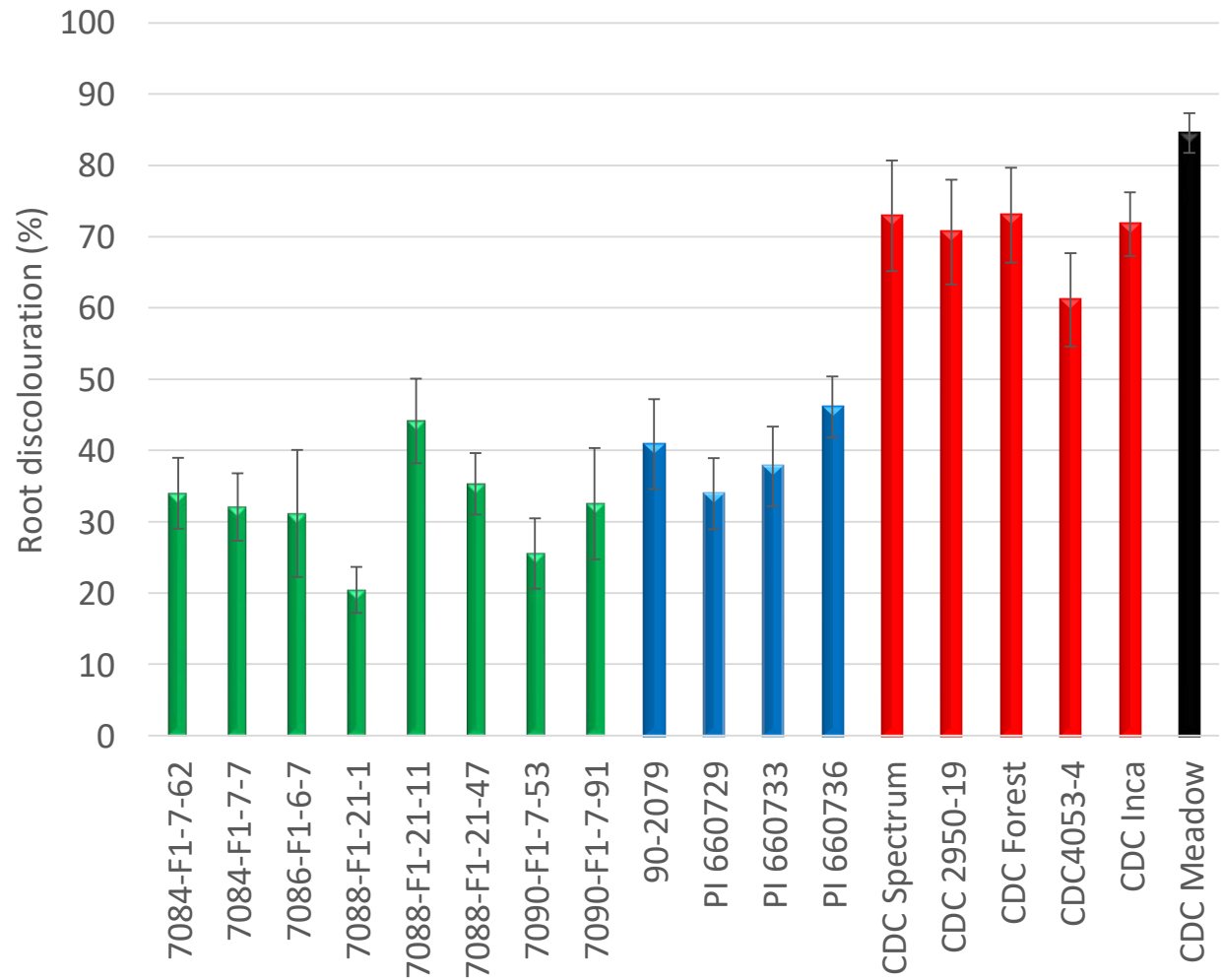
PEA: Backcrossing breeding for improved *Aphanomyces* resistance (Banniza & Warkentin)

- 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



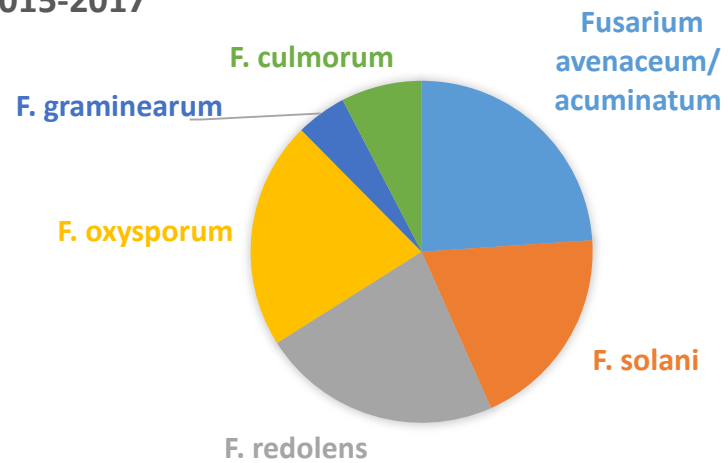
PEA: Some CDC lines carrying QTLs *Ae-Ps4.5* and *Ae-Ps7.6*

- 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?

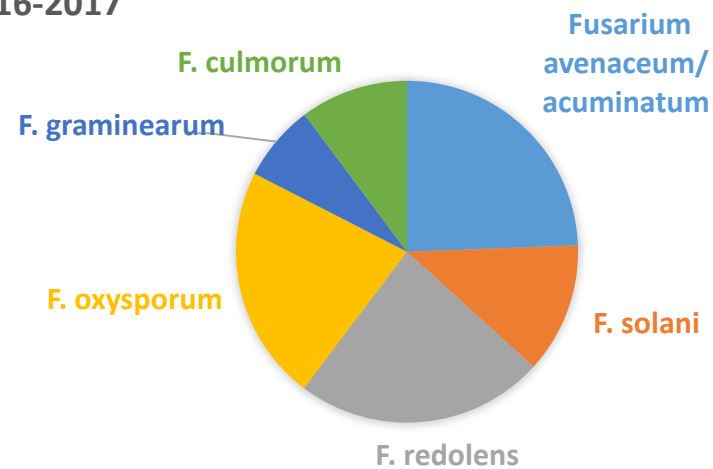


Fusarium species in pea, lentil and chickpea

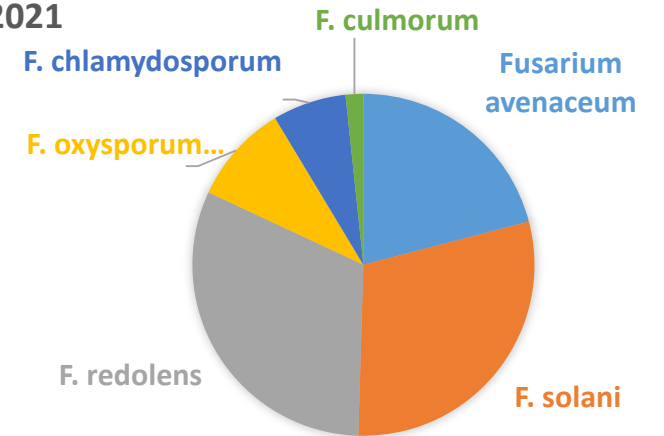
PEA
2015-2017



LENTIL
2016-2017



CHICKPEA
2020-2021

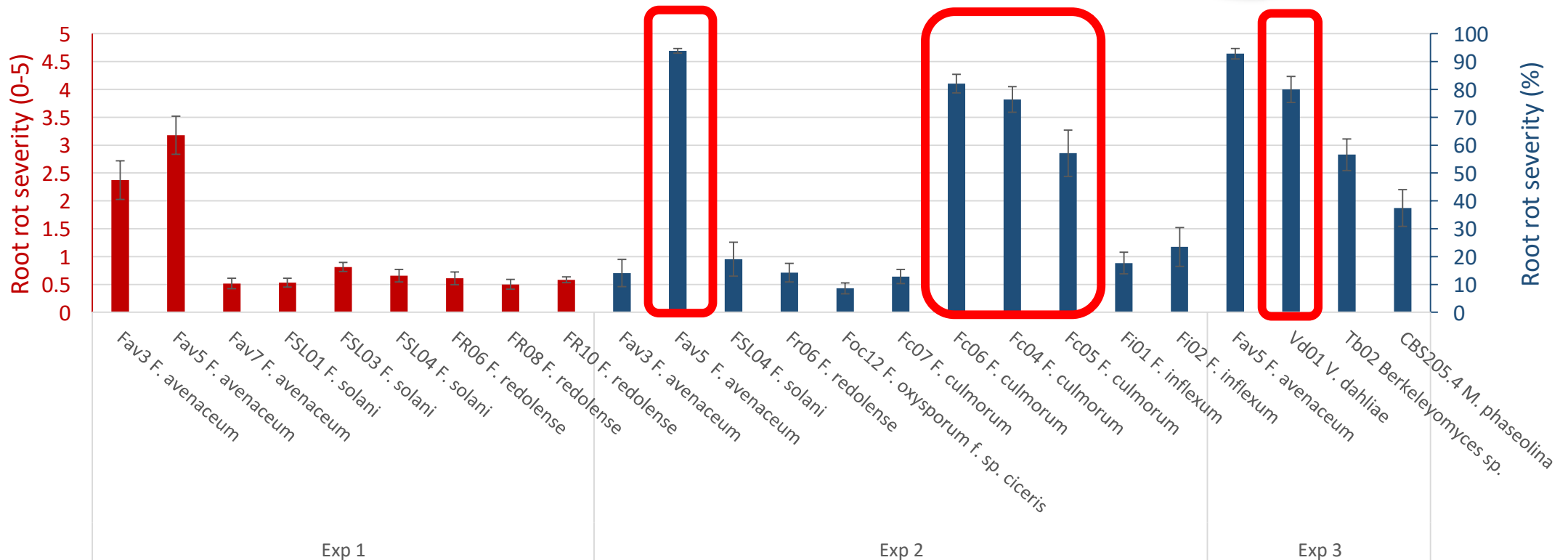
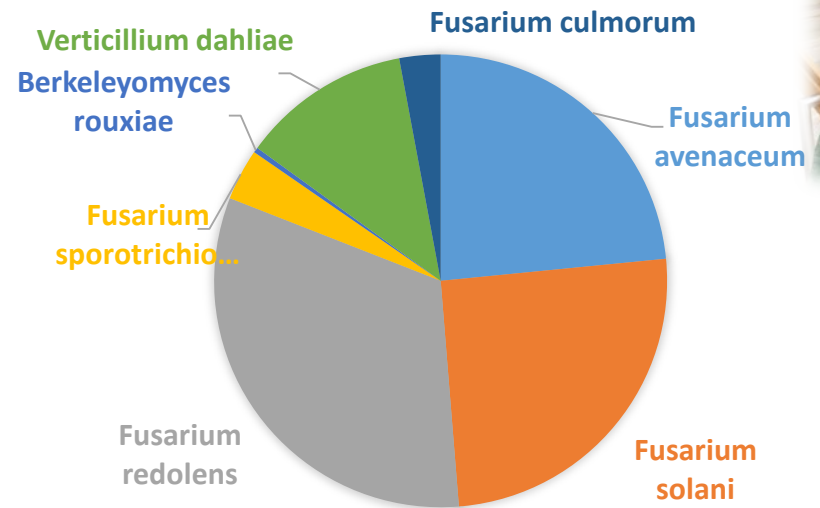


Chatterton et al. 2017. Can J Plant Pathol 41:98-114. <https://doi.org/10.1080/07060661.2018.1547792>

Armstrong-Cho et al., in press

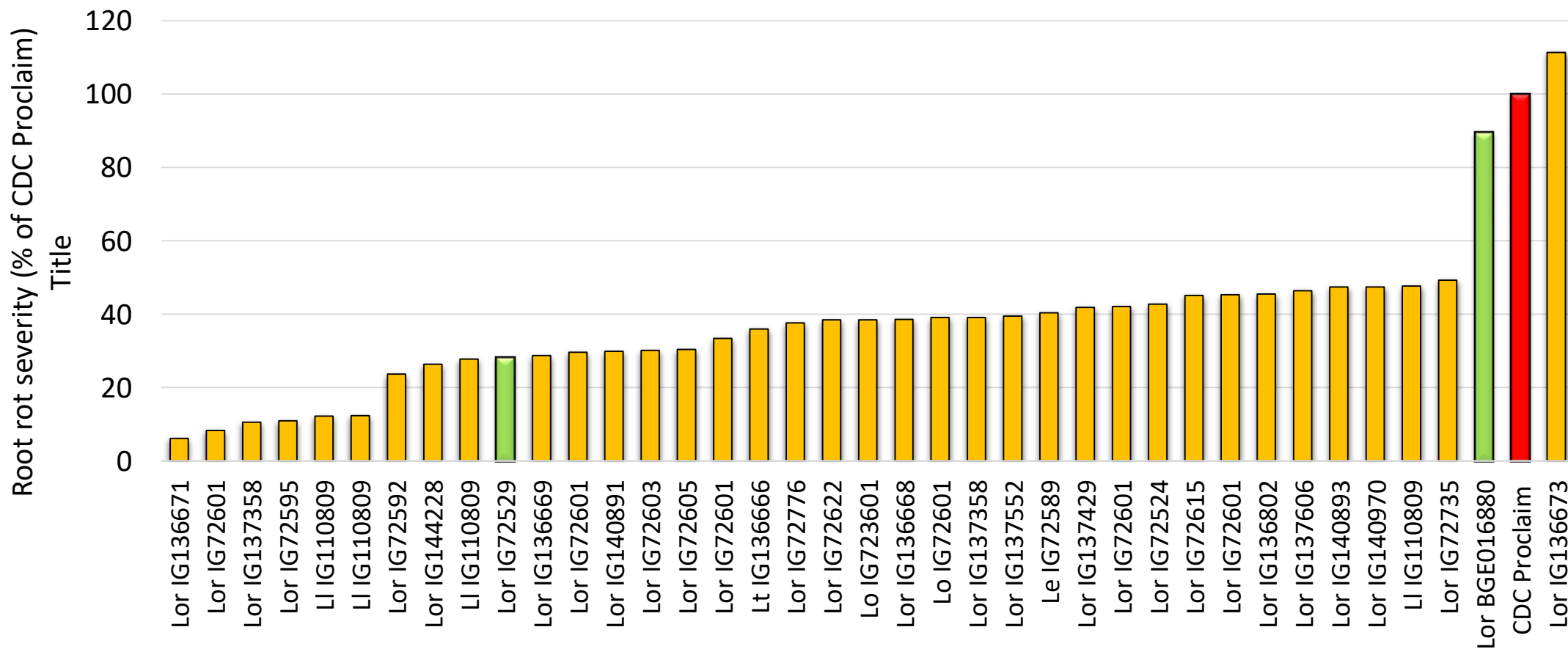


New pathogen in chickpea in 2021





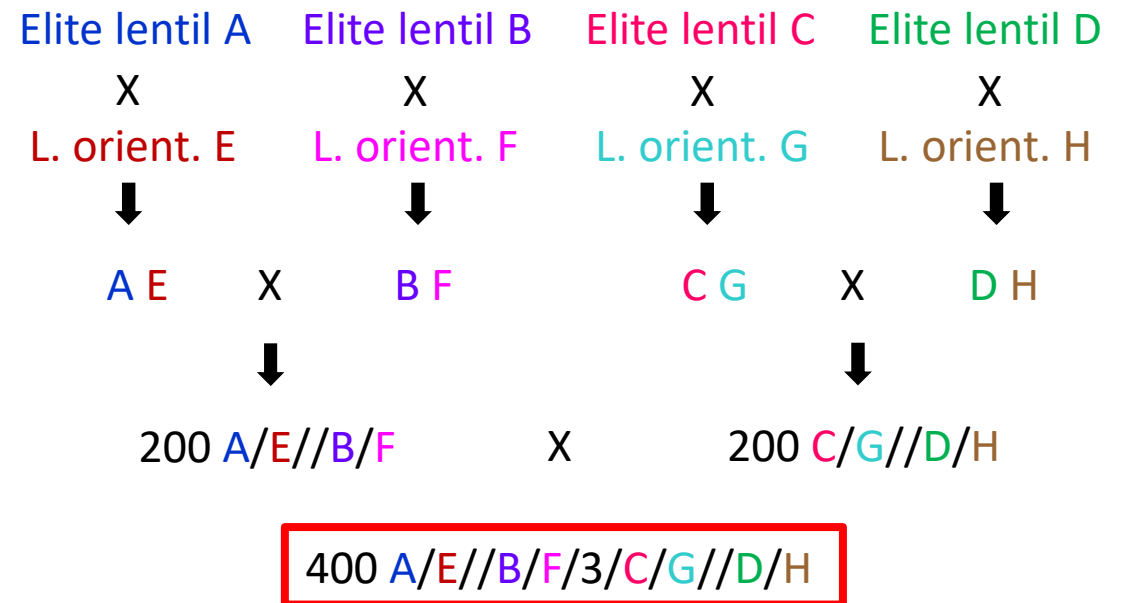
Aphanomyces root rot resistance in lentil



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)

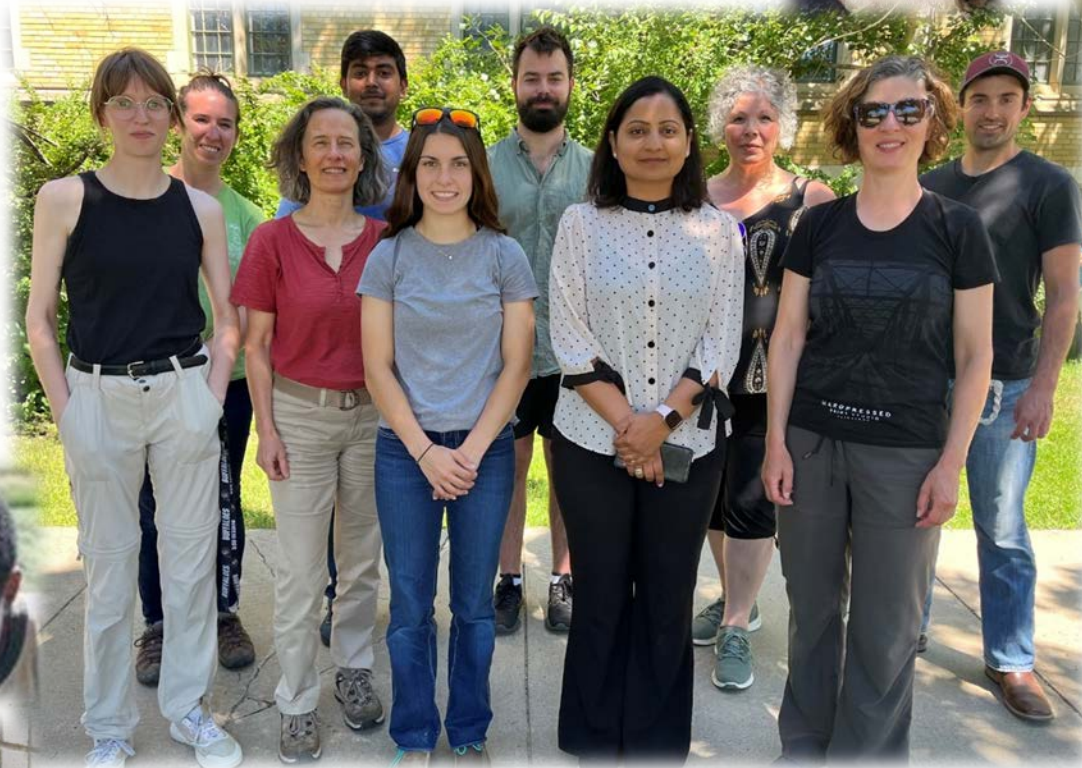
- Development of a multi-parent advanced generation inter-cross (MAGIC) population
- Identify lines with improved *Aphanomyces* and *F. avenaceum* resistance
- Determine effect of seed coat colour
- Develop markers for breeding



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



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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.