University of Guelph Bean Breeding Research

UNIVERSITY of GUELPH

ONTARIO AGRICULTURAL COLLEGE

DEPARTMENT OF PLANT AGRICULTURE

Breeding for Sustainable and Profitable Bean Production in Ontario

Objectives:

1) **Develop novel, high yielding, disease resistant, bean varieties for Ontario bean producers**

2) **Educate highly qualified personnel for the pulse industry in Canada**

3) **Create new knowledge about the genetic control of beneficial traits in beans**

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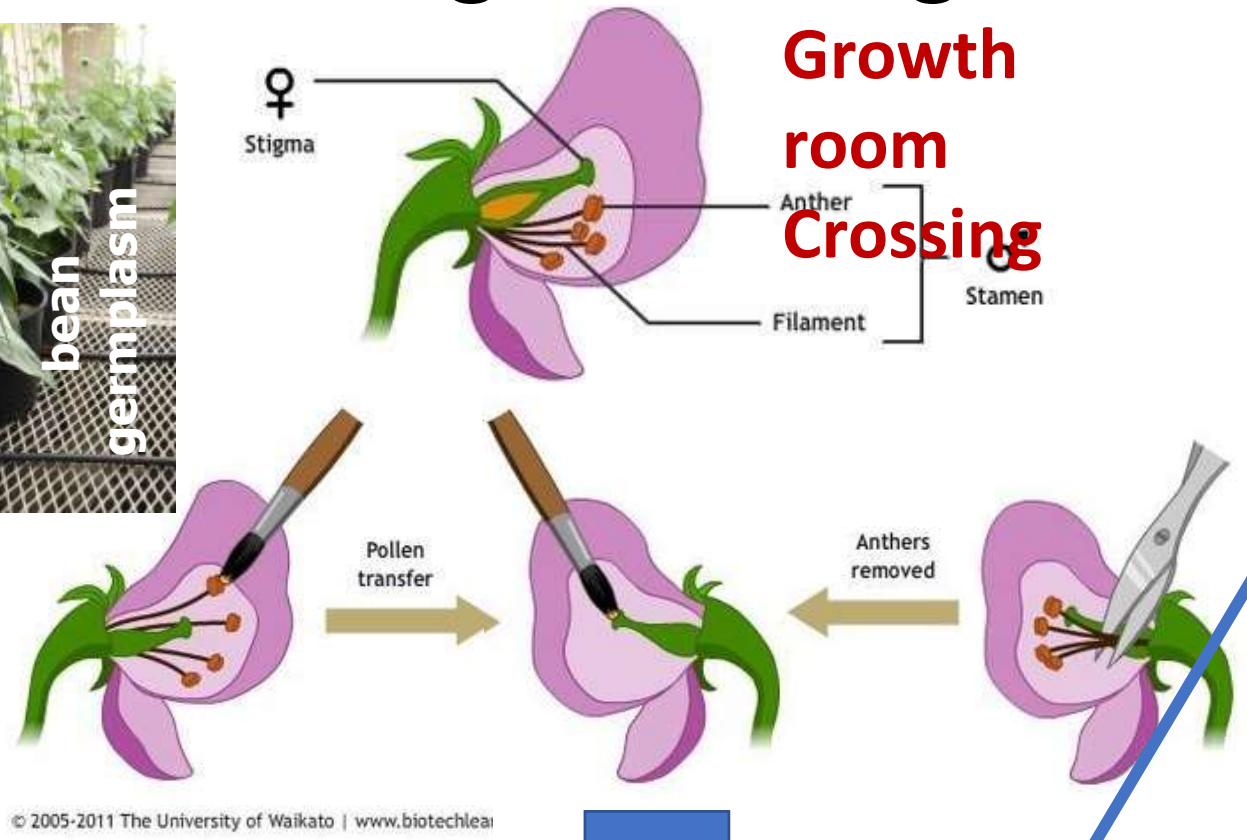
Plant breeding is a long-term, multistep process

Growth room

Crossing



F_1 seed to field

⊗

F_2 seed

U of G Bean Breeding Program

250 unique crosses

250 families selfed to F_5

3,000 to 5,000 headrow plots established from single plants selected from F_5 families

200 entries in preliminary yield trials established from lines selected from headrows

120 entries in advanced yield trials established from lines selected from PYTs

10 lines tested in registration trials

5 lines tested for a second year in registration trials

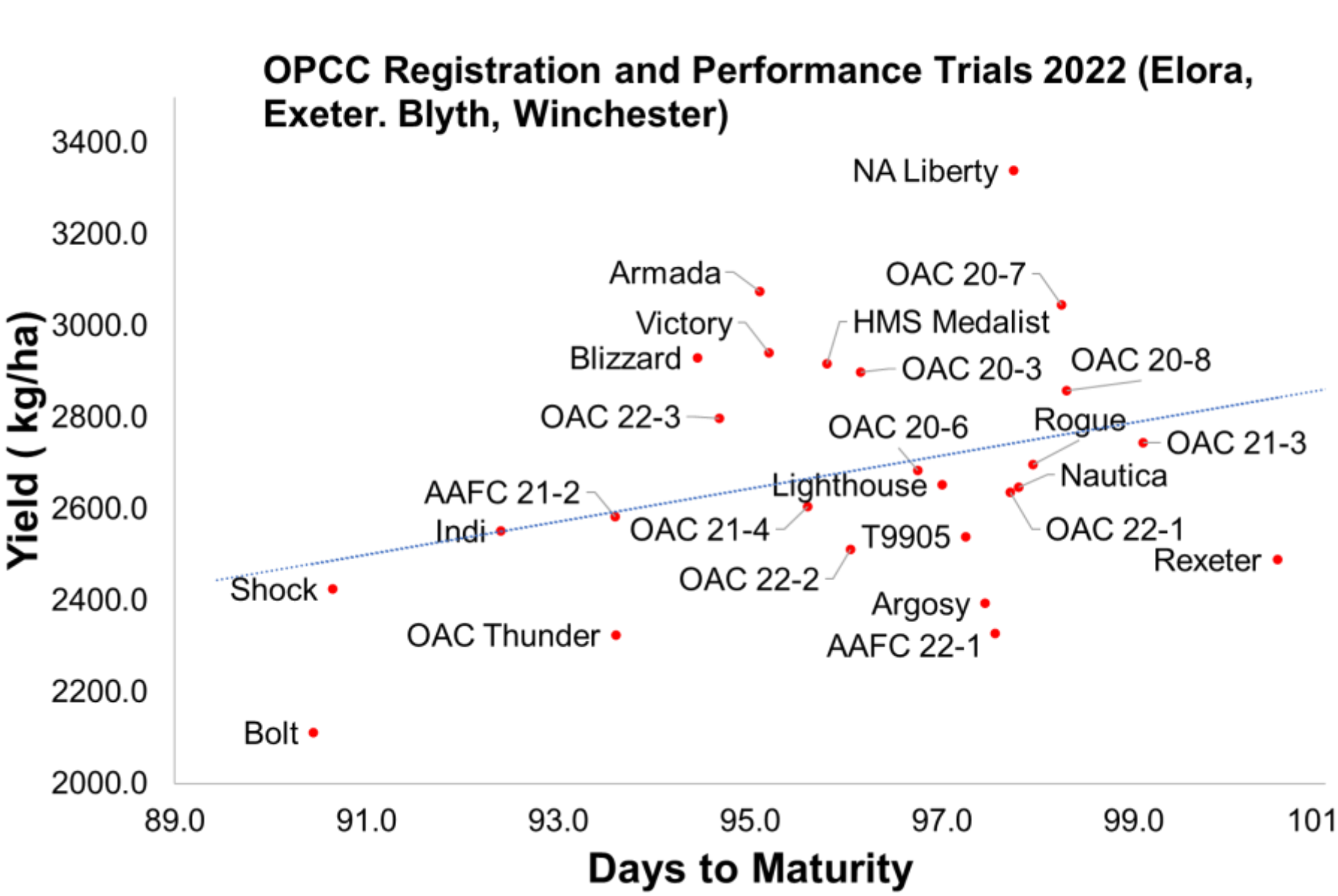
2-3 lines supported for registration

Plant breeding and variety development is a long-term, multistep process

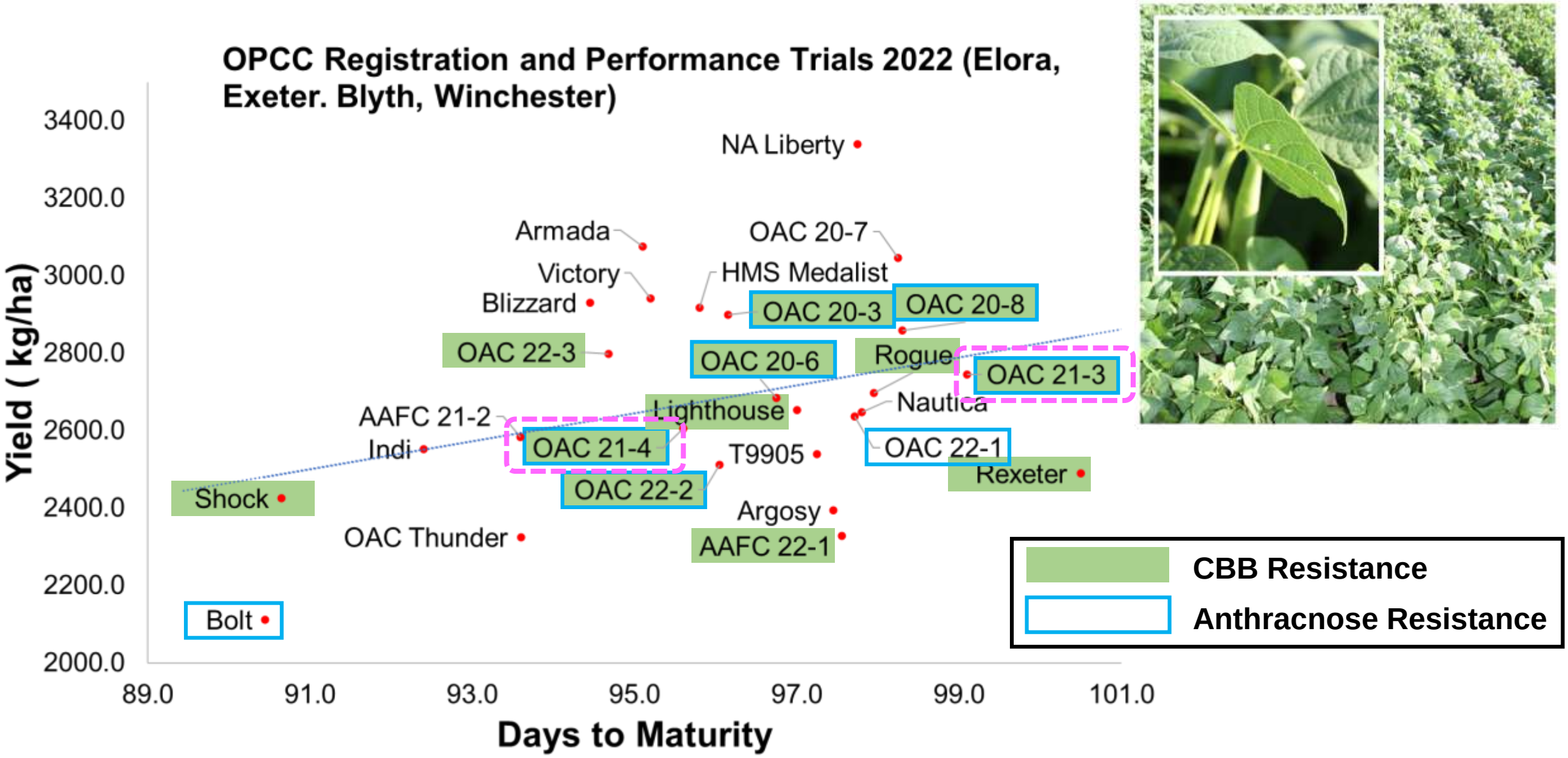
- 3,000 to 5,000 headrow plots established from single plants selected from F5 families
- 200 entries in preliminary yield trials established from selected headrows
- 120 entries in advanced yield trials selected PYT lines
- 10 OAC lines tested in provincial trials
  - including lines from previous year
- 2-4 lines supported

- From headrows to yield trials there is strong selection, based on:
  - plant architecture
  - seed morphology
  - yield
  - disease resistance

Registration and Performance Trials 2022



Registration and Performance Trials 2022

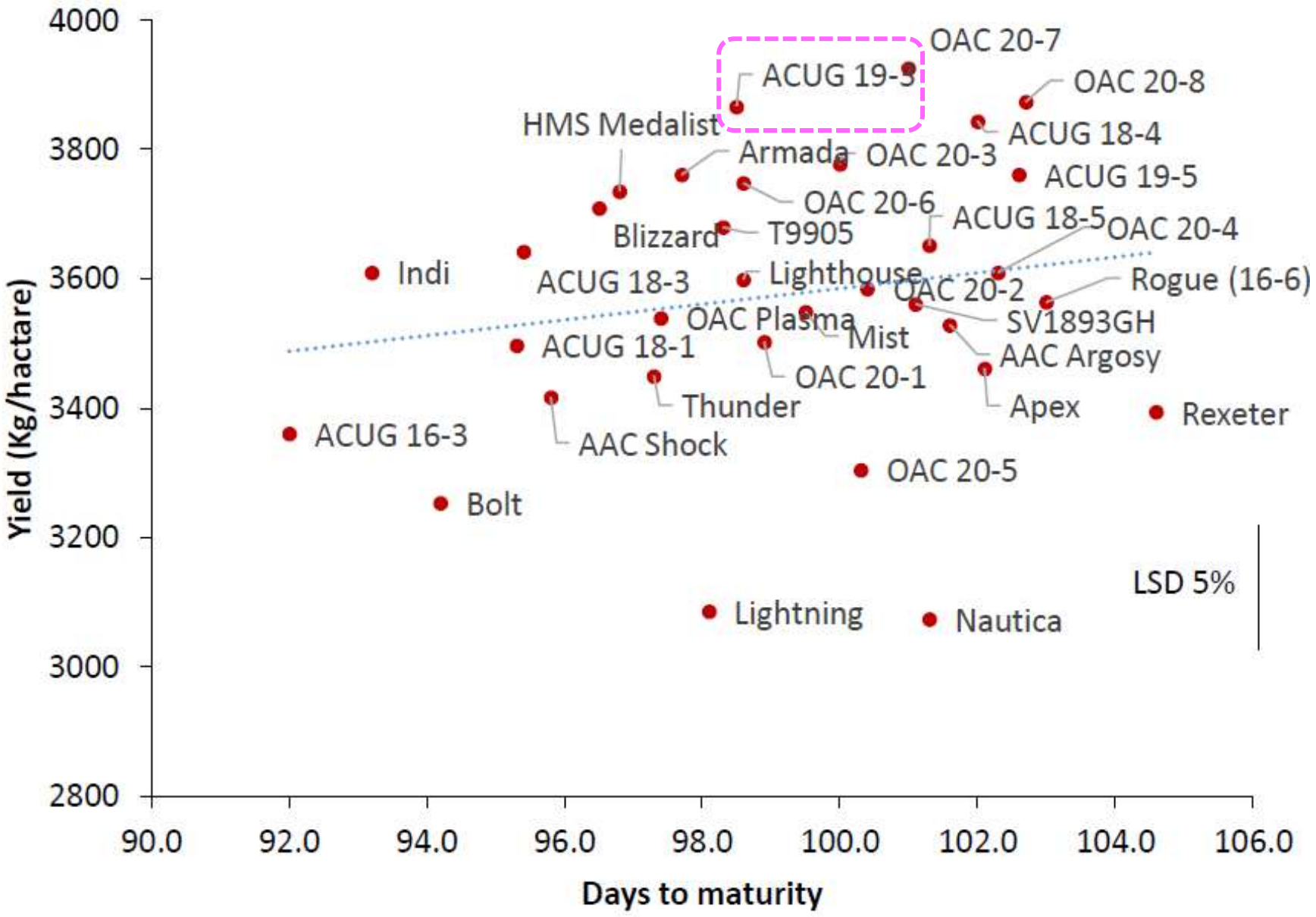


New varieties for Ontario growers -21 varieties in 5 years

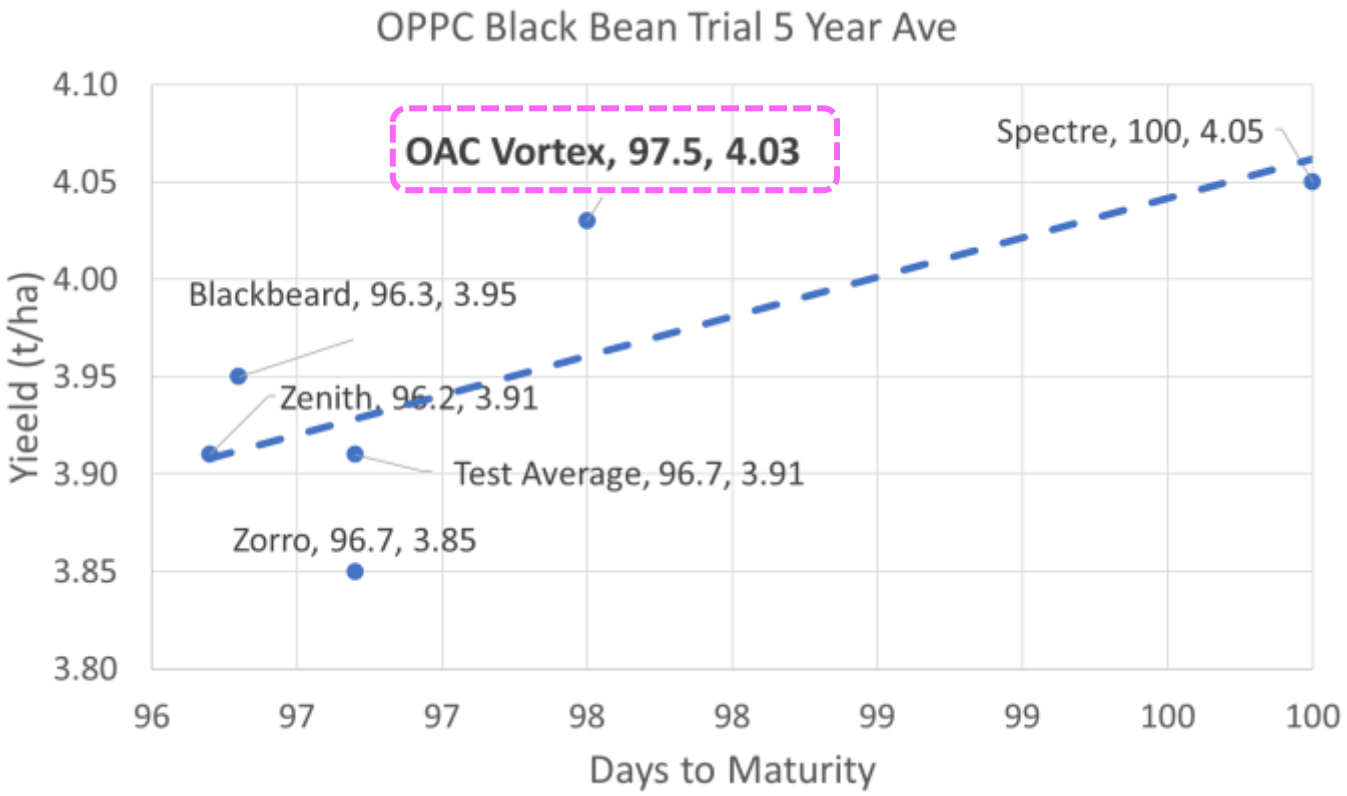
Year of Commercialization	Cultivar Type	Cultivar Name	Company
2022	Adzuki	A18HR064 (Gemstone)	Hensall Distr
2022	White Navy	20-3 (Blast)	Hensall Distric
2022	White Navy	20-7 (Steam)	Hensall District
2022	Pinto	P16HR025	Hensall District Co
2022	Black	**20-B5 (Umbra)**	Hensall District Co-oper
2022	Black	20-B4 (Bannock)	Hensall District Co-operative Inc.,
2022	Dark Red Kidney	20-D1 (OAC Tong)	Columbia Seed Co Ltd, Vauxhall, A
2022	nondarkening Pinto ME78	ME78 (Prairie Omega)	Columbia Seed Co Ltd, Vauxhall, Alb
2022	Cranberry Bean	ACUG 19-NCD1 (Prairie Omega)	Columbia Seed Co Ltd, Vauxhall, Albe
2022	White Navy	ACUG 19-3 (OAC Seal)	Jefferies Seeds, Glenborough Manitoba
2021	White Navy	ACUG 18-3 (OAC Charm)	Treasure Valley Seed Co., Denver Colora
2021	Kintoki	Kintoki (OAC Sunrise)	Crooked Creek Acres, Strathroy, Ontario
2021	White Navy	ACUG 18-4 (OAC Equinox)	Meridiian Seed, N Dakota, USA
2020	Cranberry Bean	ACUG 14-C2 (OAC Racer)	Plovgh, Viroqua, Wisconsin, USA
2020	Black	ACUG 15-B4 (OAC Vortex)	Plovgh, Viroqua, Wisconsin, USA
2020	White Navy	ACUG 16-3 (OAC Fusion)	Plovgh, Viroqua, Wisconsin, USA
2019	White Kidney	ACUG 17-W1 (OAC Snowshoe)	Treasure Valley Seed Co., Denver Colorado, USA
2019	Cranberry Bean	ACUG 17-C1 (OAC Navabi)	Treasure Valley Seed Co., Denver Colorado, USA
2019	Cranberry Bean	ACUG 17-C3 (OAC Firestripe)	Treasure Valley Seed Co., Denver Colorado, USA
2018	Dark Red Kidney	ACUG16-D2 (Gallantry)	Hensall District Co-operative Inc., Canada
2018	White Navy	ACUG 16-6 Rogue	Hensall District Co-operative Inc., Canada

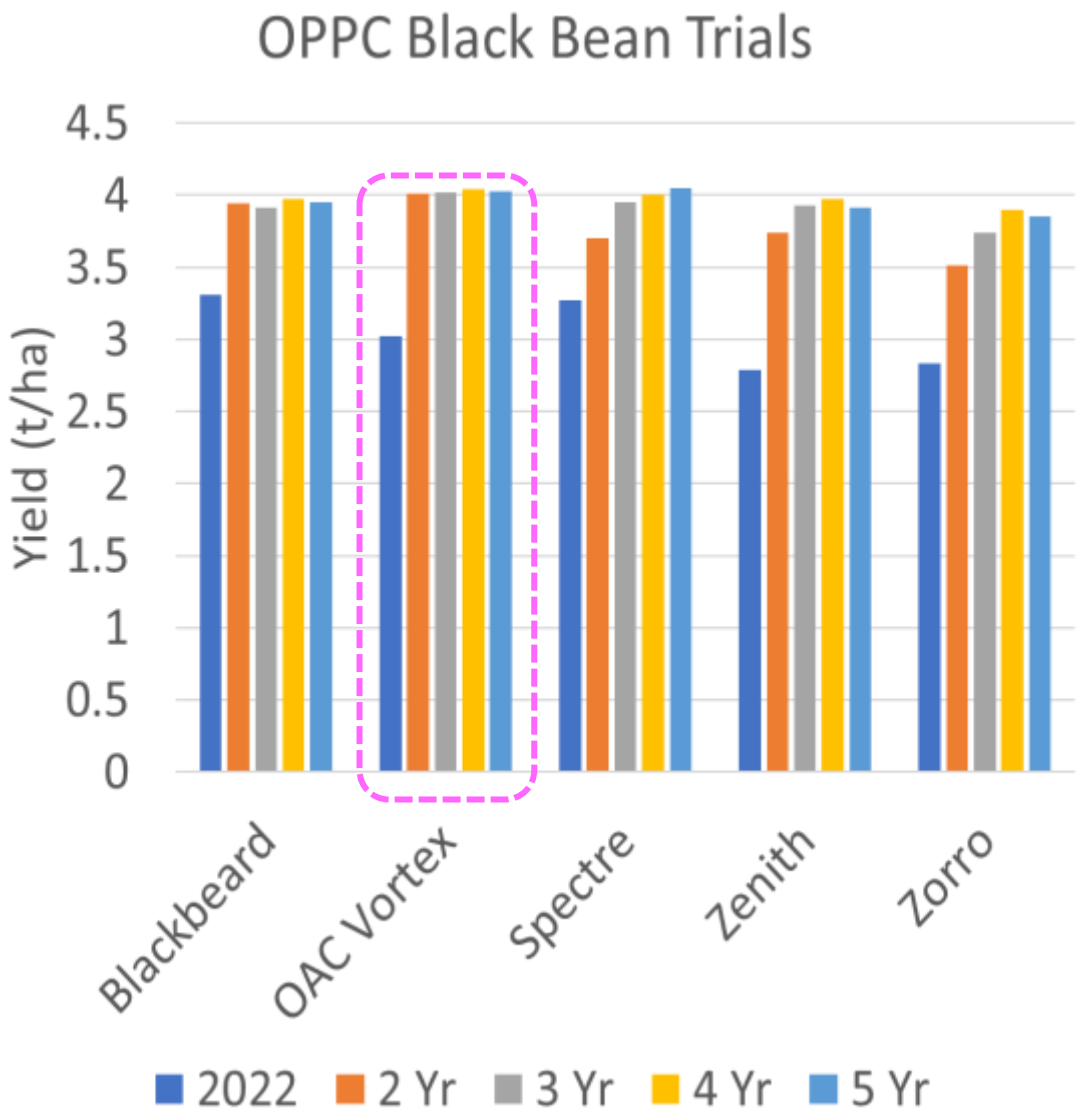
Seal, Vortex, Candycane and Firestripe Demonstration Plots

- **Anthracnose resistant**
- **CBB resistant**

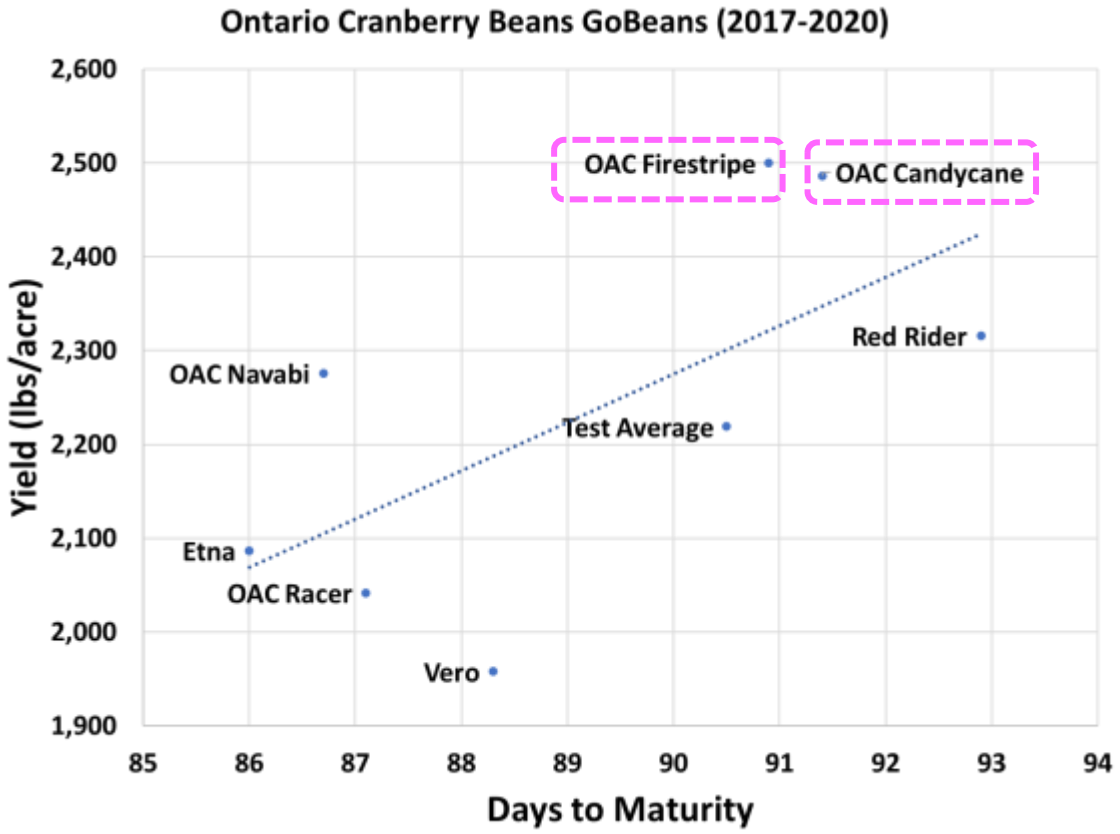


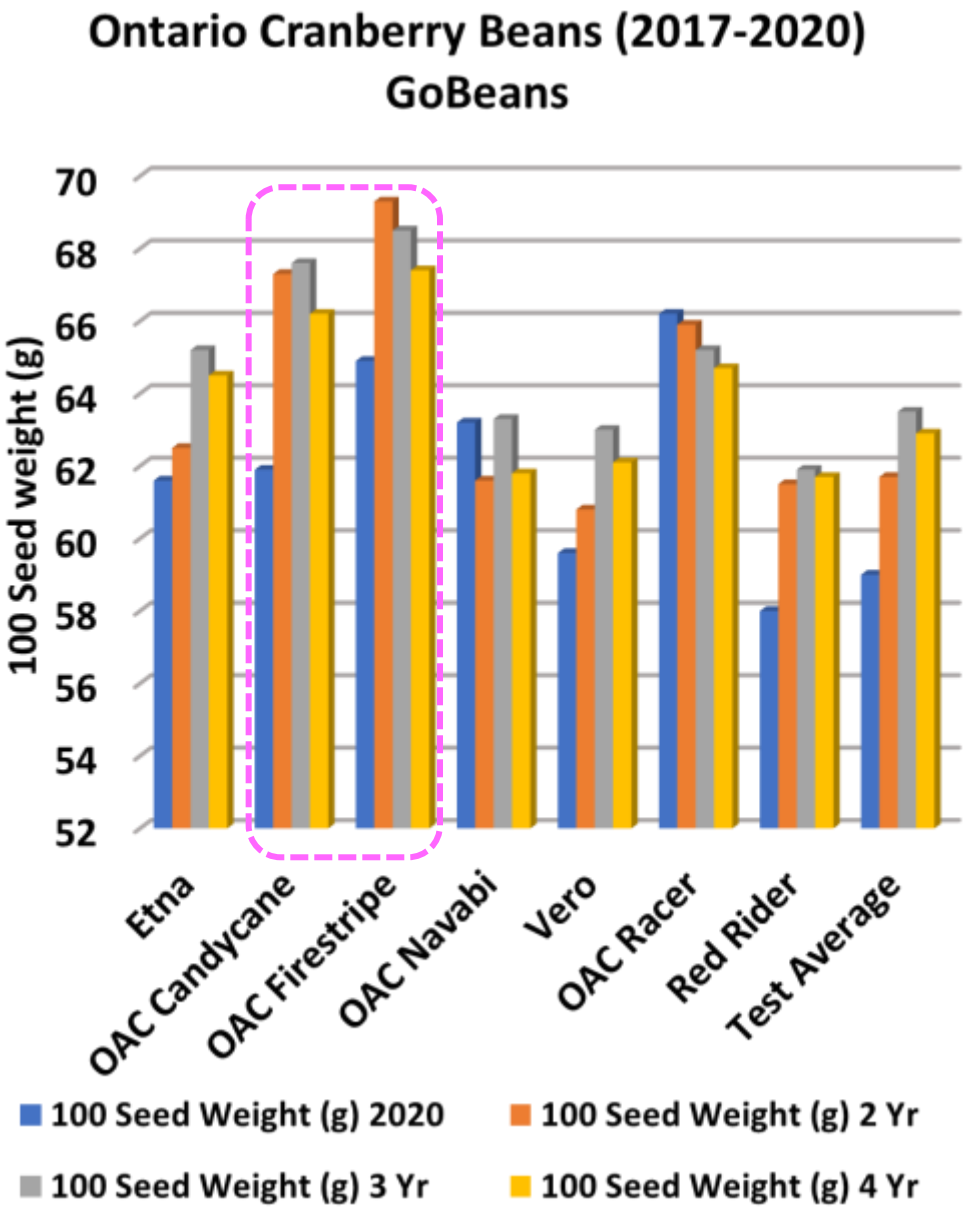

Vortex


OPPC Black Bean Trial 5 Year Ave
4.10
4.05
4.00
3.95
3.90
3.85
3.80
Yieeld (t/ha)
OAC Vortex, 97.5, 4.03
Spectre, 100, 4.05
Blackbeard, 96.3, 3.95
Zenith, 96.2, 3.91
Test Average, 96.7, 3.91
Zorro, 96.7, 3.85
96
97
97
98
98
99
99
100
100
Days to Maturity

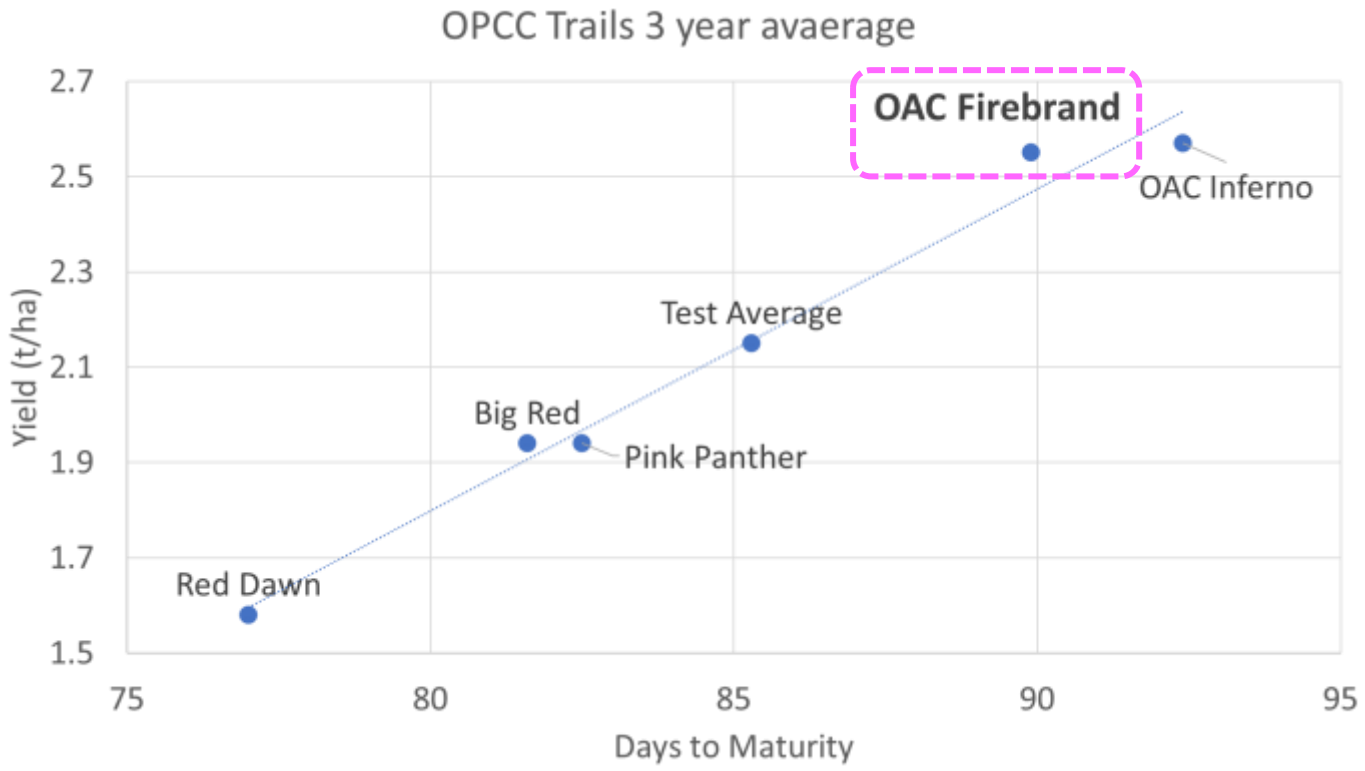

OPPC Black Bean Trials
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Yield (t/ha)
Blackbeard
OAC Vortex
Spectre
Zenith
Zorro
2022
2 Yr
3 Yr
4 Yr
5 Yr

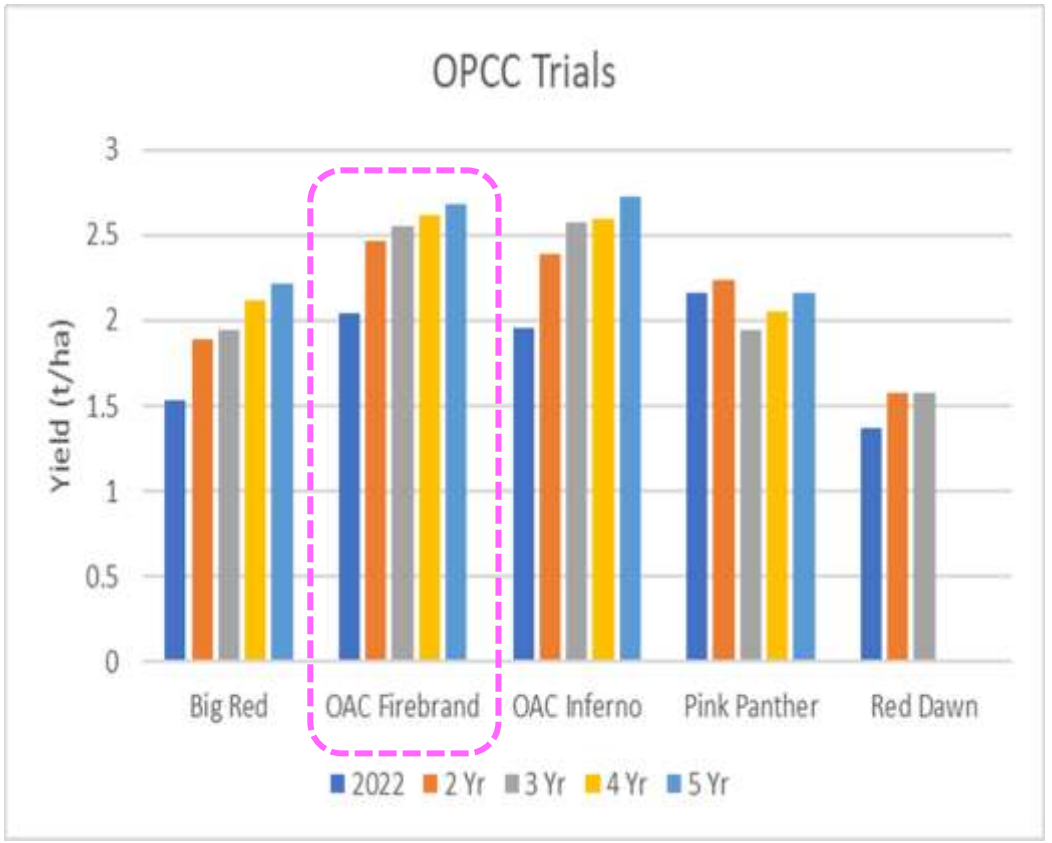

Candycane,
Firestripe


Ontario Cranberry Beans GoBeans (2017-2020)
Yield (lbs/acre)
2,600
2,500
2,400
2,300
2,200
2,100
2,000
1,900
85
86
87
88
89
90
91
92
93
94
Days to Maturity
OAC Firestripe
OAC Candycane
Red Rider
OAC Navabi
Test Average
Etna
OAC Racer
Vero

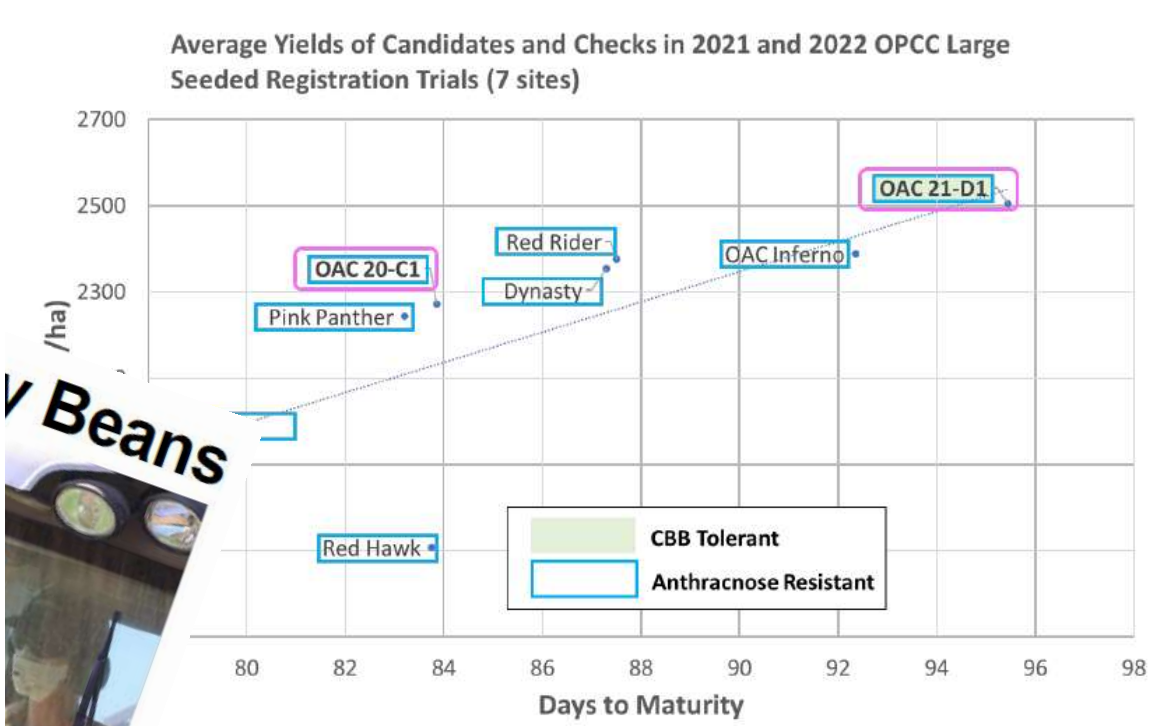

Ontario Cranberry Beans (2017-2020)
GoBeans
100 Seed weight (g)
70
68
66
64
62
60
58
56
54
52
Etna
OAC Candycane
OAC Firestripe
OAC Navabi
Vero
OAC Racer
Red Rider
Test Average
100 Seed Weight (g) 2020
100 Seed Weight (g) 2 Yr
100 Seed Weight (g) 3 Yr
100 Seed Weight (g) 4 Yr

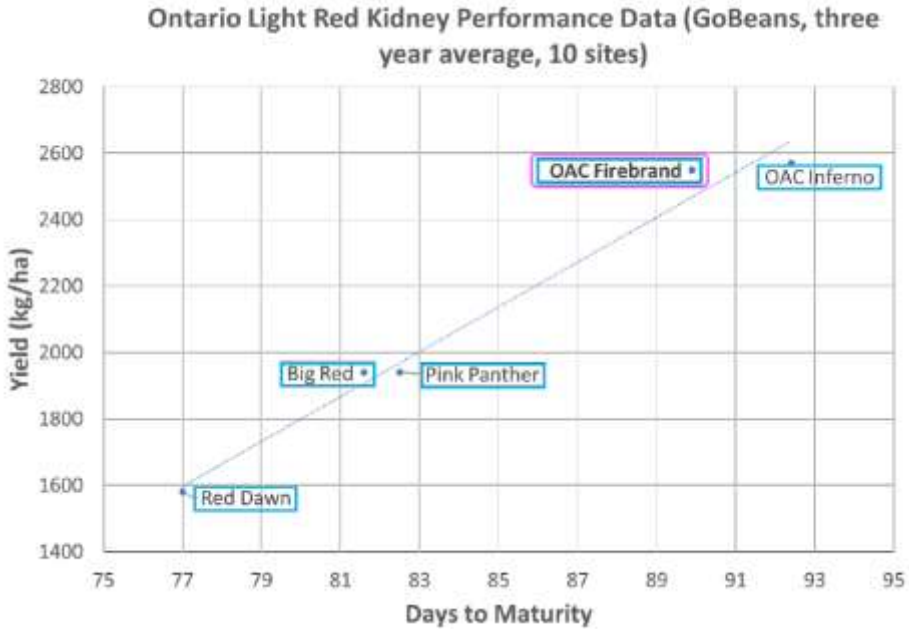

OAC
Firebrand


OPCC Trails 3 year avaerage
Yield (t/ha)
2.7
2.5
2.3
2.1
1.9
1.7
1.5
75
80
85
90
95
Days to Maturity
OAC Firebrand
OAC Inferno
Test Average
Big Red
Pink Panther
Red Dawn


OPCC Trials
Yield (t/ha)
3
2.5
2
1.5
1
0.5
0
Big Red
OAC Firebrand
OAC Inferno
Pink Panther
Red Dawn
2022
2 Yr
3 Yr
4 Yr
5 Yr


Average Yields of Candidates and Checks in 2021 and 2022 OPCC Navy Bean Registration Trials (7 sites)
Yield (kg/ha)
Days to Maturity
OAC 21-3
OAC 21-4
Rogue
T9905
Lighthouse
AAC Shock
Rexeter
OAC Thunder
Bolt
CBB Resistant
Anthracnose Resistant


Average Yields of Candidates and Checks in 2021 and 2022 OPCC Large Seeded Registration Trials (7 sites)
/ha)
Days to Maturity
OAC 21-D1
Red Rider
OAC Inferno
OAC 20-C1
Dynasty
Pink Panther
Red Hawk
CBB Tolerant
Anthracnose Resistant


Ontario Light Red Kidney Performance Data (GoBeans, three year average, 10 sites)
Yield (kg/ha)
Days to Maturity
OAC Firebrand
OAC Inferno
Big Red
Pink Panther
Red Dawn

Breeding for Sustainable and Profitable Bean Production in Ontario

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2) **Educate highly qualified personnel for the pulse industry in Canada**

3) **Create new knowledge about the genetic control of beneficial traits in beans**

2) Educate Highly Qualified Personnel (HQP)

- **High School, Undergraduate and Postgraduate Student Technical Help**
  - Shania Van Herk
  - Alec Schaefer
  - Natalie Miners
  - Natalie Arsenault
  - Rawan Eleraki

Lyndsay Schram

2) Educate Highly Qualified Personnel (HQP)

Current Graduate Students and Research Associate:

- **MSc**
  - **Holly Gallo – seed protein**
- **PhD**
  - **Sajida Noor – nondarkening seed**
  - **Maryam Vasin – yield selection**
  - **Mylene Corzo – CBB resistance**
  - **Edomo Omoregie – adzuki disease resistance**
- **Postdoctoral Research Associate**
  - **Yarmilla Reinprecht – N fix and diversity**

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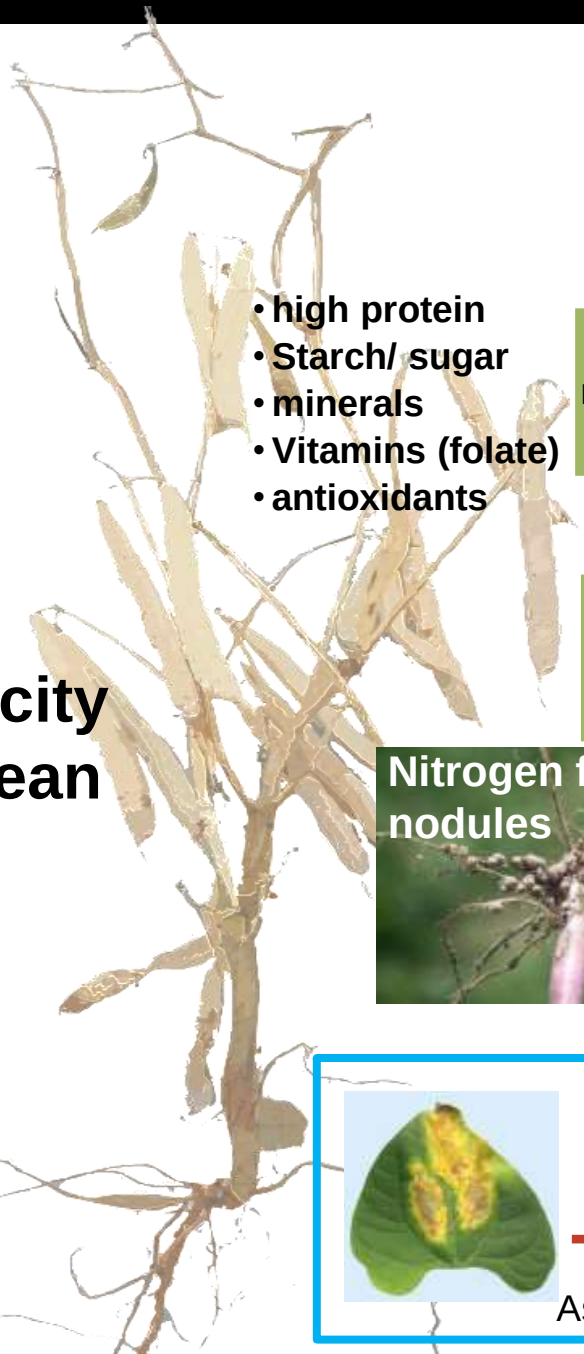
3) Create New Knowledge

About:

- bean breeding methodology
- germplasm diversity
- genes for yield
- genes for disease resistance
- genes for N_2 fix capacity
- genes determining bean quality:
  - ➢ nutritional value,
  - ➢ health promoting properties
  - ➢ visual appeal
  - ➢ fast cooking



• high protein
• Starch/ sugar
• minerals
• Vitamins (folate)
• antioxidants

Agronomics

Nutritional & nutraceutical value

Bean Breeding Germplasm Cycle

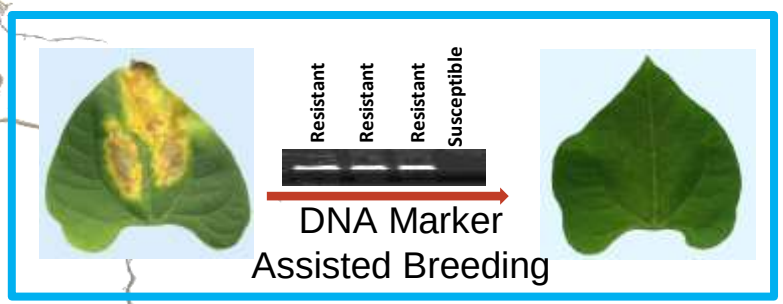
Ecosystem Services

Nitrogen fixation

Consumer appeal

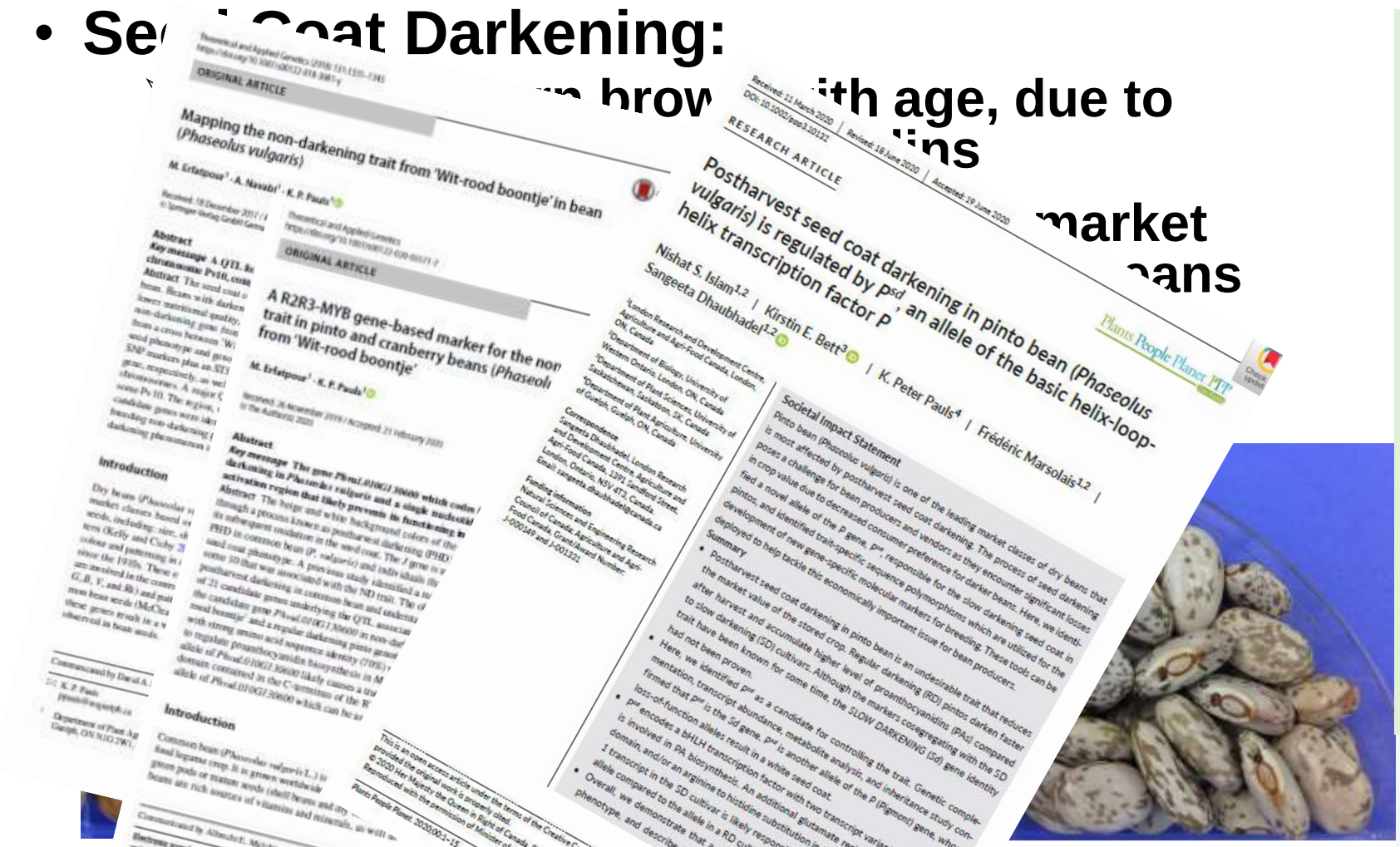
Nitrogen fixing root nodules

Disease resistance



Genetic Characterization and Utilization of the Non-darkening Trait in Cranberry and Pinto Beans

- Se[illegible]Coat Darkening:
  - [illegible]n brow[illegible]ith age, due to
  - [illegible]ins
  - [illegible]market
  - [illegible]eans



Non-darkening

jjSdSd

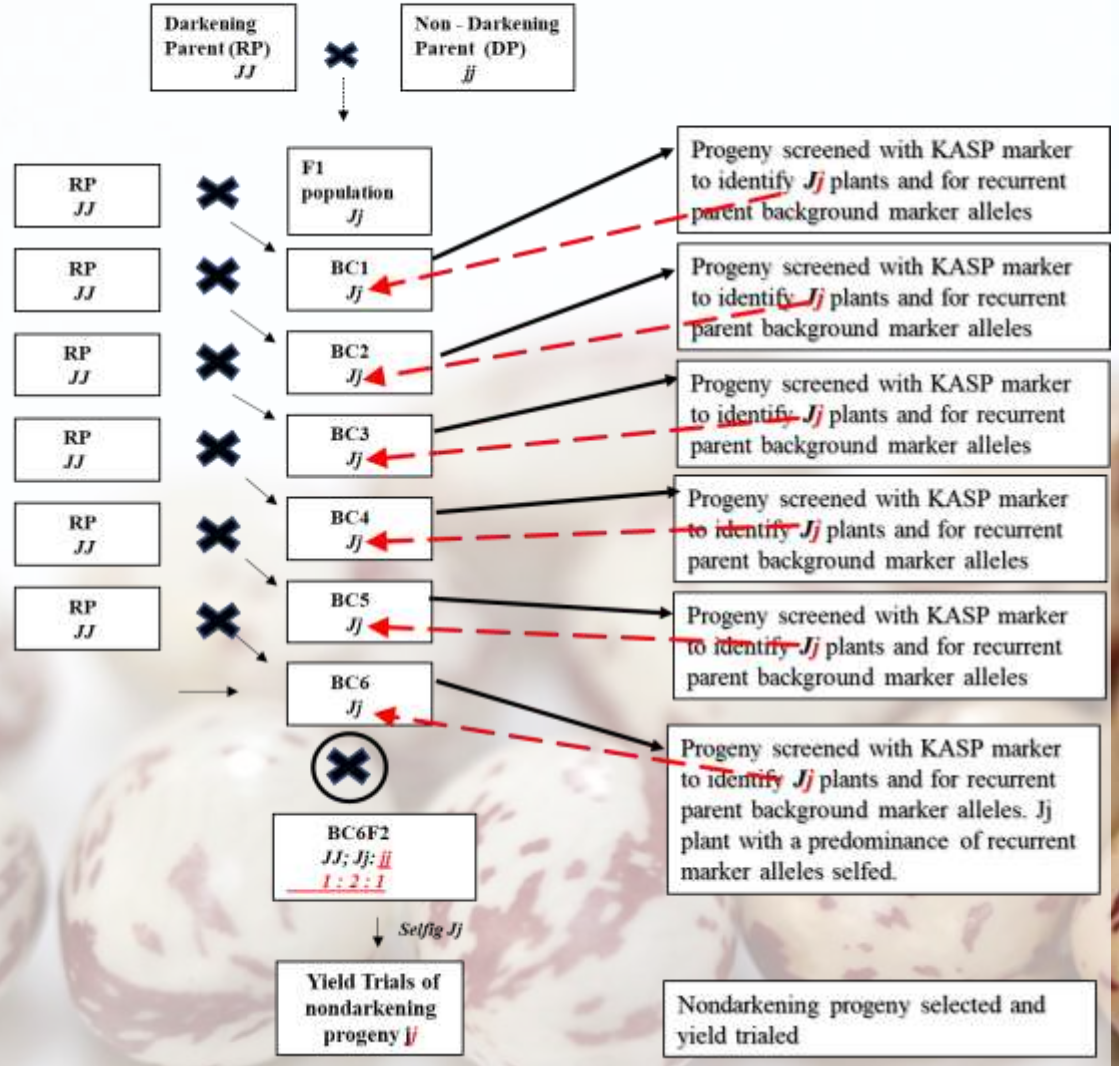
- The nondarkening trait:
  - protects value of stored beans
  - results in faster cooking beans
  - may result in higher iron availability in human diets

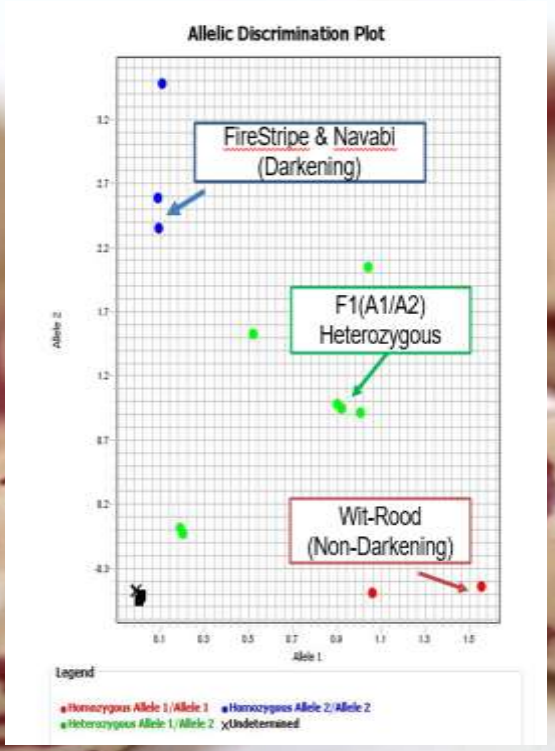
Selecting Nondarkening Beans

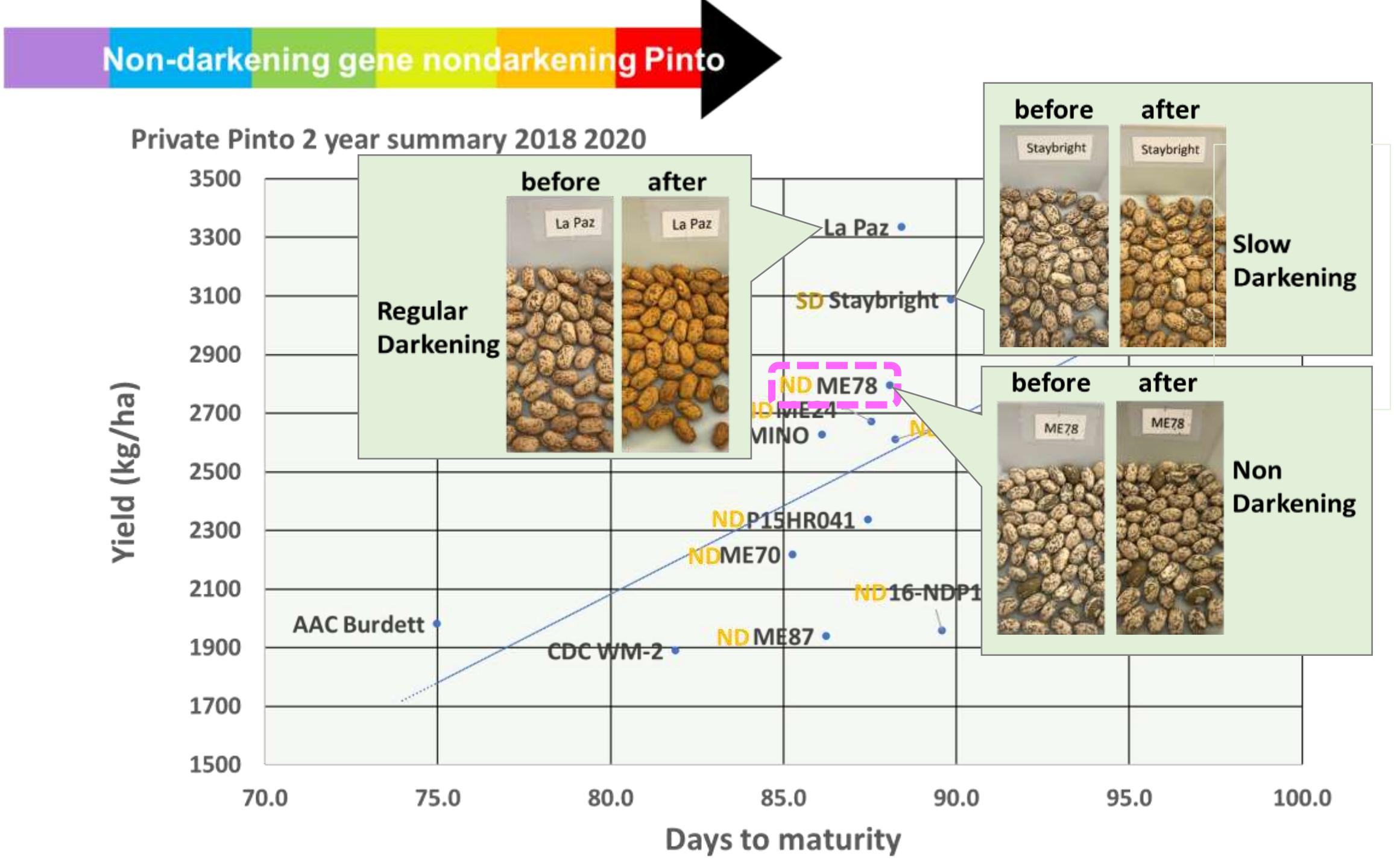
Sajida Noor

Recovery of Recurrent Parent Genotype in Conventional Backcrossing	
F_1	50%
BC_1	75%
BC_2	87.6%
BC_3	93.8%
BC_4	96.9%
BC_5	98%
BC_6	99%

Scheme of Marker-Assisted Backcrossing






Non-darkening gene nondarkening Pinto
Private Pinto 2 year summary 2018 2020
Yield (kg/ha)
3500
3300
3100
2900
2700
2500
2300
2100
1900
1700
1500
70.0
75.0
80.0
85.0
90.0
95.0
100.0
Days to maturity
Regular Darkening
before
after
La Paz
La Paz
La Paz
SD Staybright
ND ME78
MINO
ND P15HR041
ND ME70
ND 16-NDP1
ND ME87
AAC Burdett
CDC WM-2
before
after
Staybright
Staybright
Slow Darkening
before
after
ME78
ME78
Non Darkening

Non-darkening gene nondarkening Pinto

Newly Licensed Pinto Beans with Non-Darkening Trait

University of Guelph Research Innovation

XPT One

Columbia Seed Co. Ltd

Vauxhall, Alberta

Variety	Yield kg/ha [a]	Maturity DAP [b]	Suitability for Direct Harvest [c]	Hundred Seed Weight (g)
XPT One	**2796**	**88**	**2.1**	**40.2**
La Paz	3337	88	2.2	39.5
Staybright	3089	89	2.5	39.4
Palomino	2627	86	2.7	41.4

Eternal

Hensall District Coop

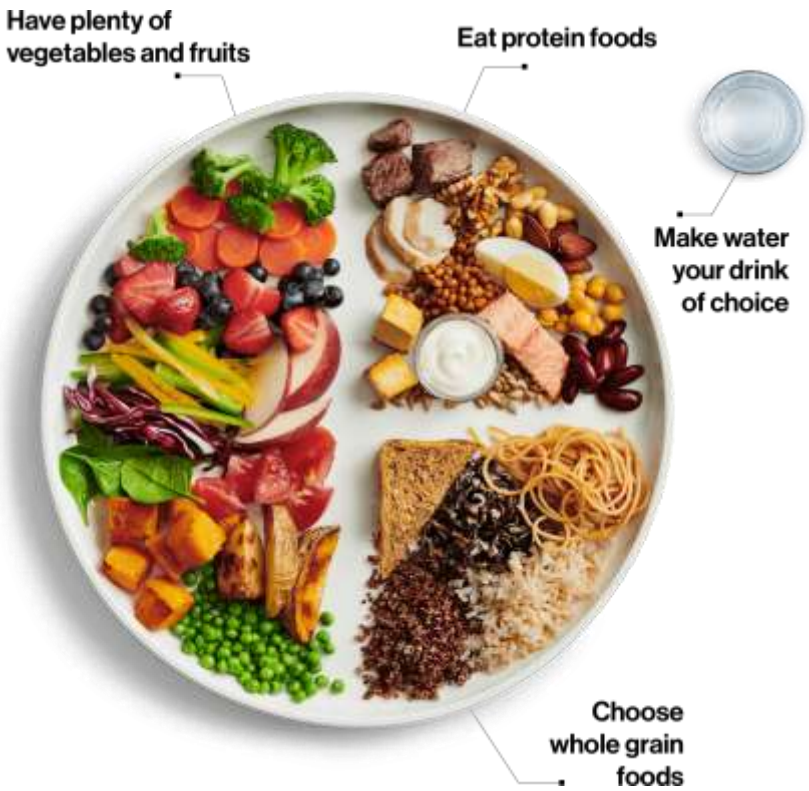
Hensall, Ontario

Variety	Yield kg/ha [a]	Maturity DAP [b]	Suitability for Direct Harvest [c]	Hundred Seed Weight (g)
Eternal	**2224**	**90**	**3.1**	**36.4**
La Paz	2418	83	2.4	38.6
Staybright	2254	83	2.7	36.5
Palomino	1904	82	2.7	36.1

Protein Content in Beans

Holly Gallo

- Current emphasis on plant-based protein represents an opportunity for bean breeding



Objective:

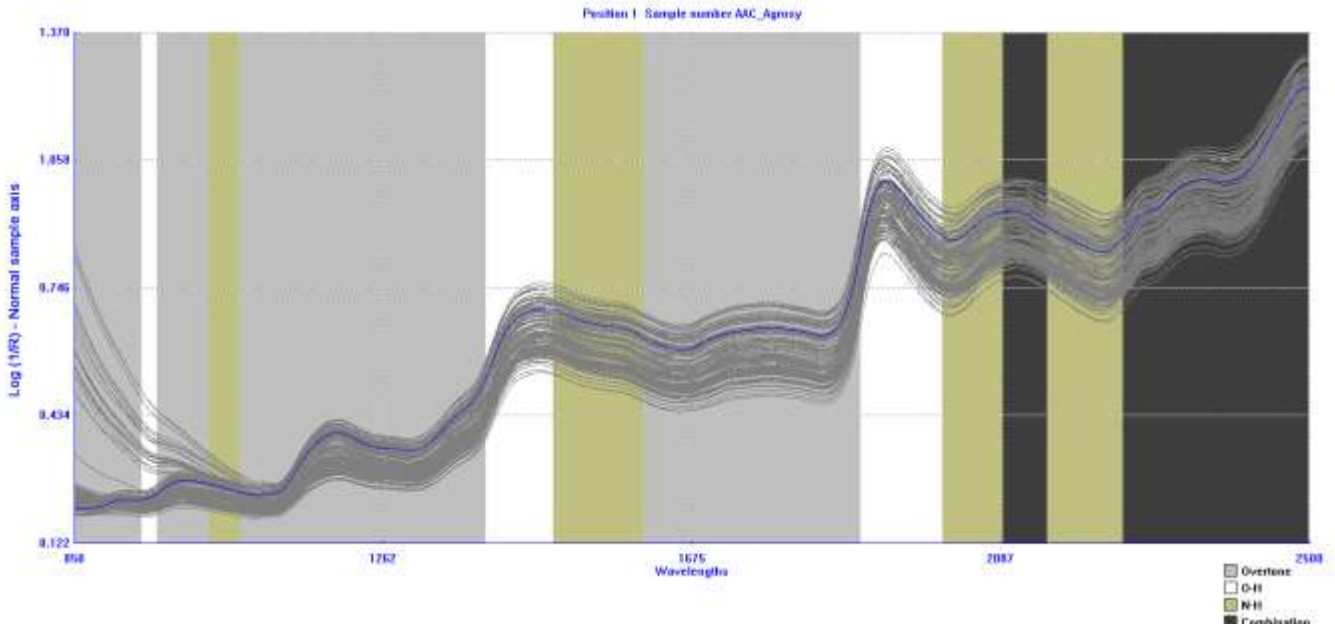
- Identify molecular markers related to seed protein content in bean genome

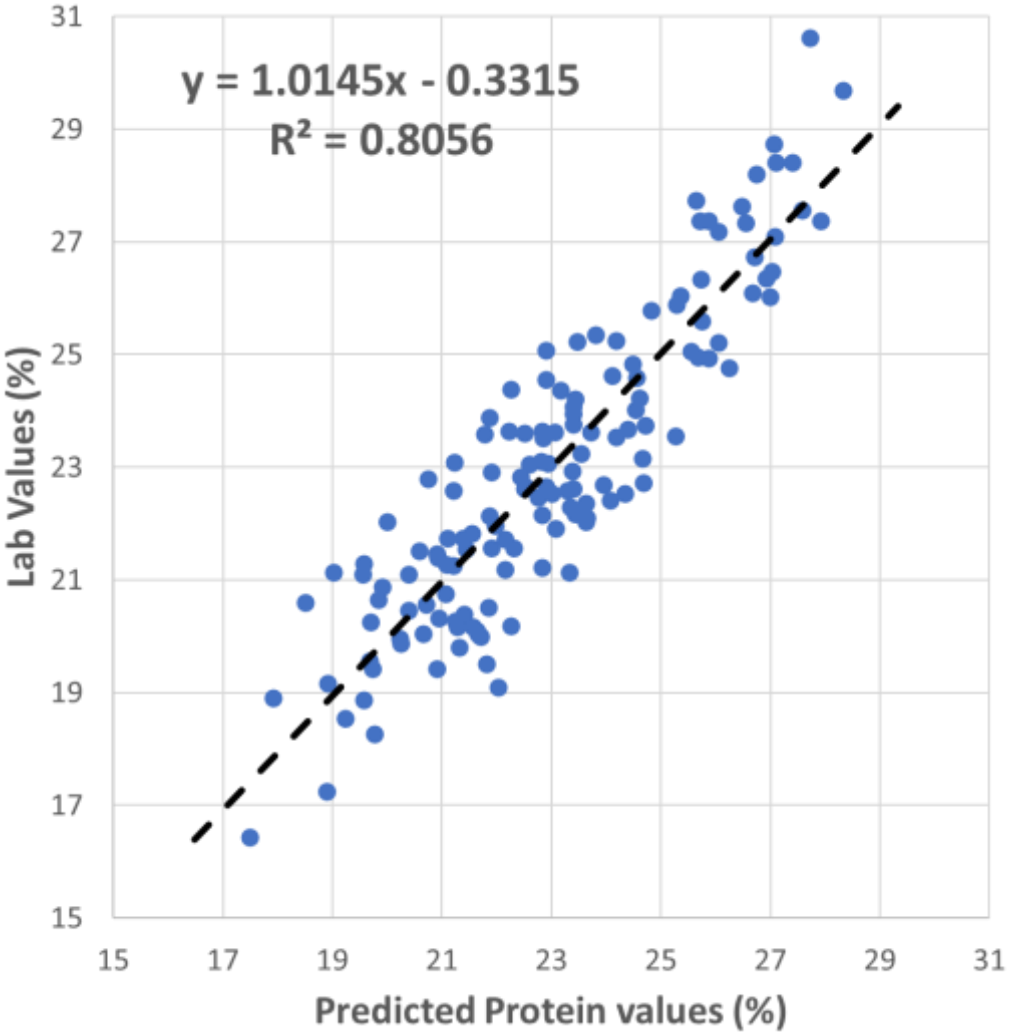
Methods:

- measure protein levels in a collection of 213 dry beans (from different market classes) – by combustion and NIR
- assay lines/ varieties for molecular marker differences – DNA fingerprinting
- correlate specific molecular markers with protein content in beans

Protein Content in Beans – building a NIR correlation

- Chemical analyses of 144 varieties
- NIR scans of whole seeds
- used to build a standard curve that can be used to determine protein content of intact seeds in the breeding program

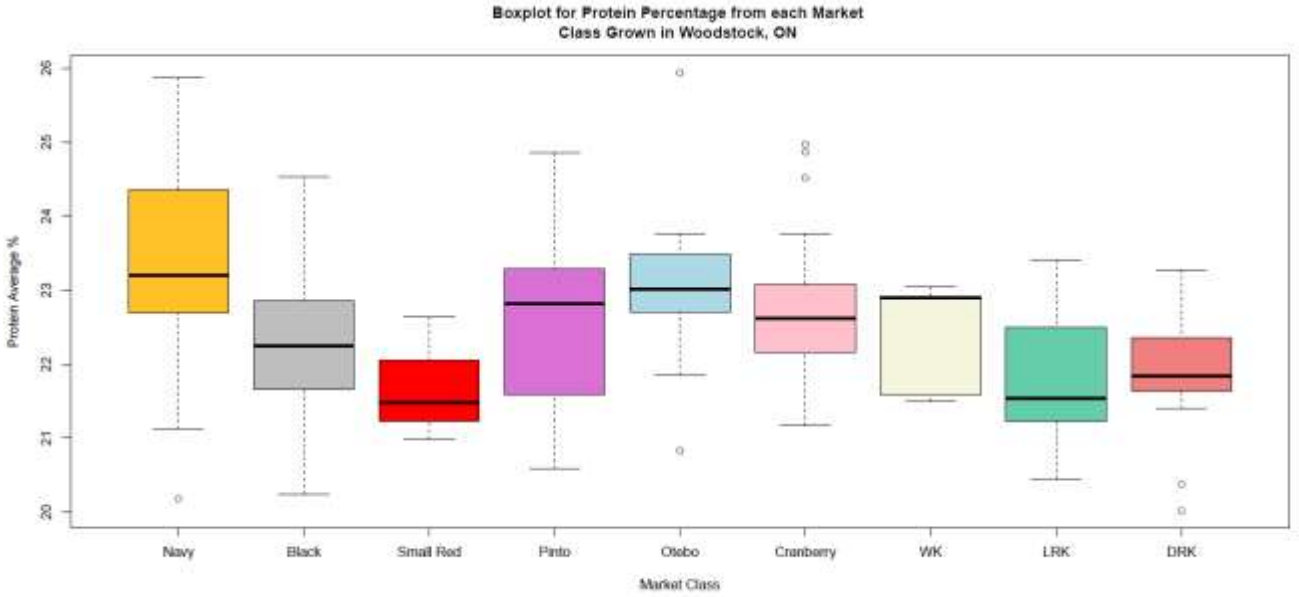


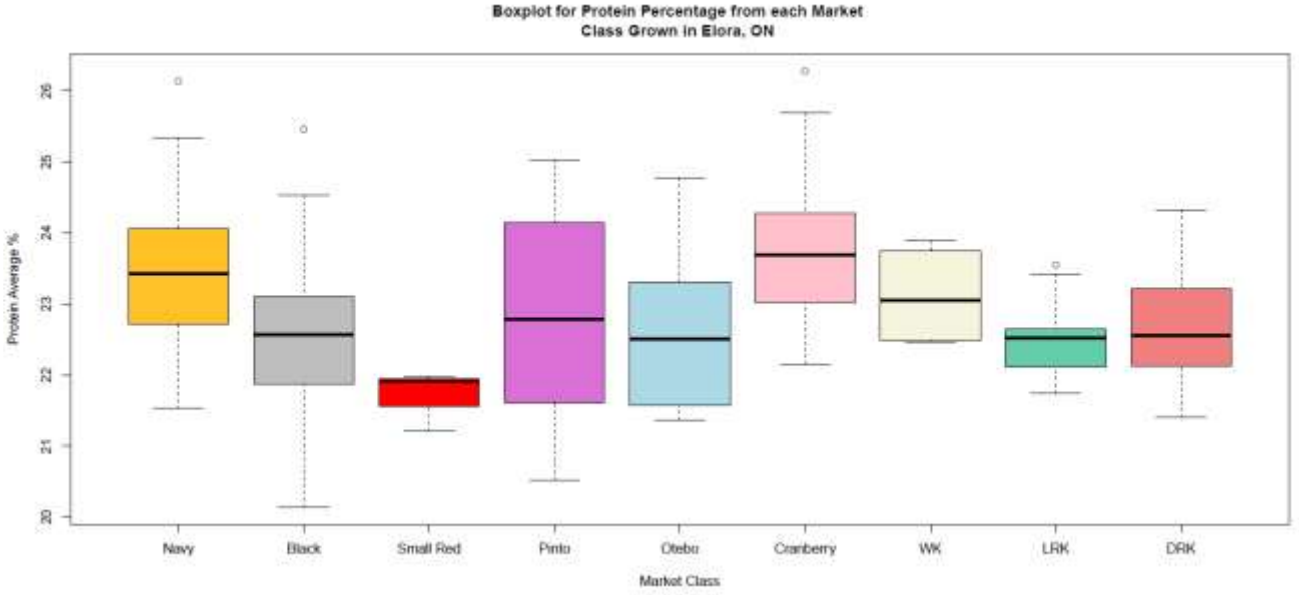


Protein Content in Beans –NIR analysis

Holly Gallo

- varieties showed differences among average protein contents for different market classes
  - (23%) navy beans, cranberry beans, white kidney > pinto, black, small red, dark red kidney, light red kidney (21%)
- differences between locations
  - Elora > Woodstock

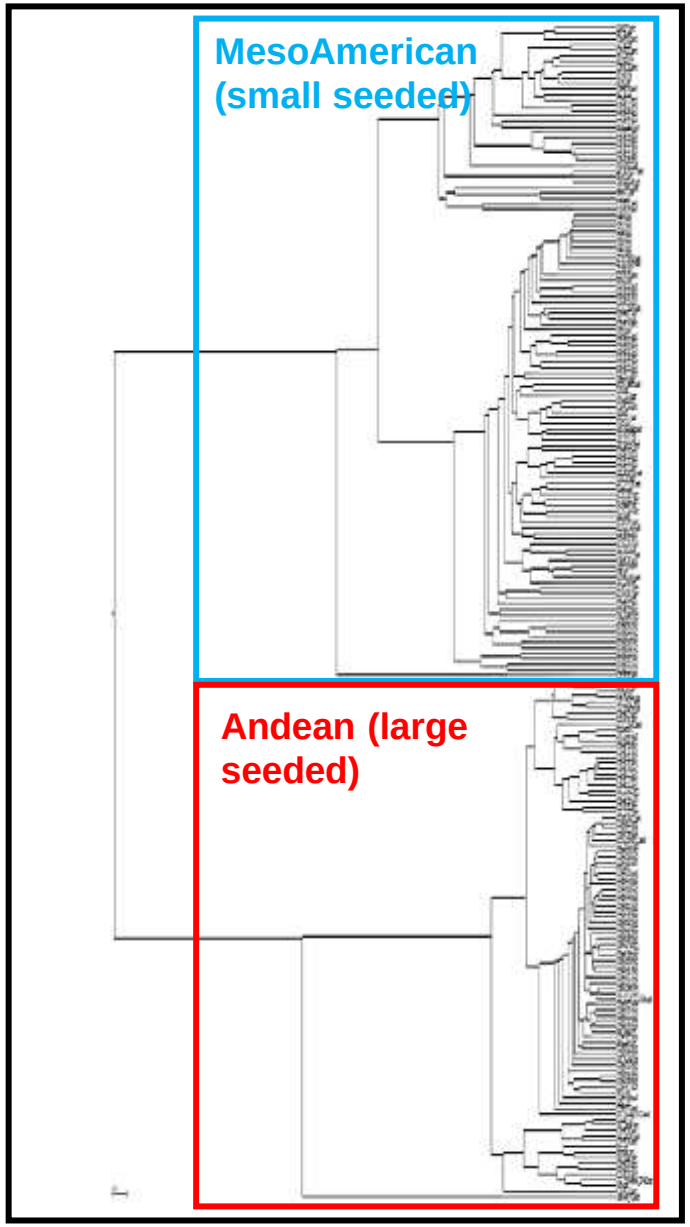




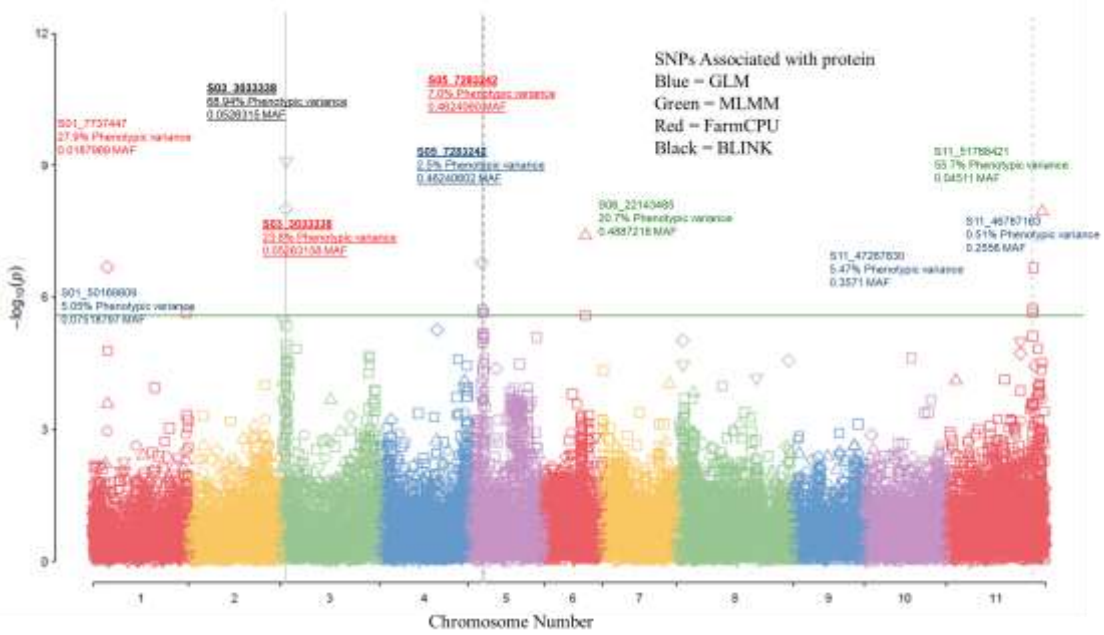
Protein Content in Beans

Holly Gallo

- Molecular markers (SNPs) identified by selective sequencing of the 213 lines/ varieties
  - 103,038 in total
  - 5,148 across the genome
    - (by selecting one SNP every 100,000bp)
- The markers can be used to build a family tree



- Molecular markers associated with protein content were identified on several chromosomes



- In the future the correlations may allow molecular marker selection of beans with high protein content

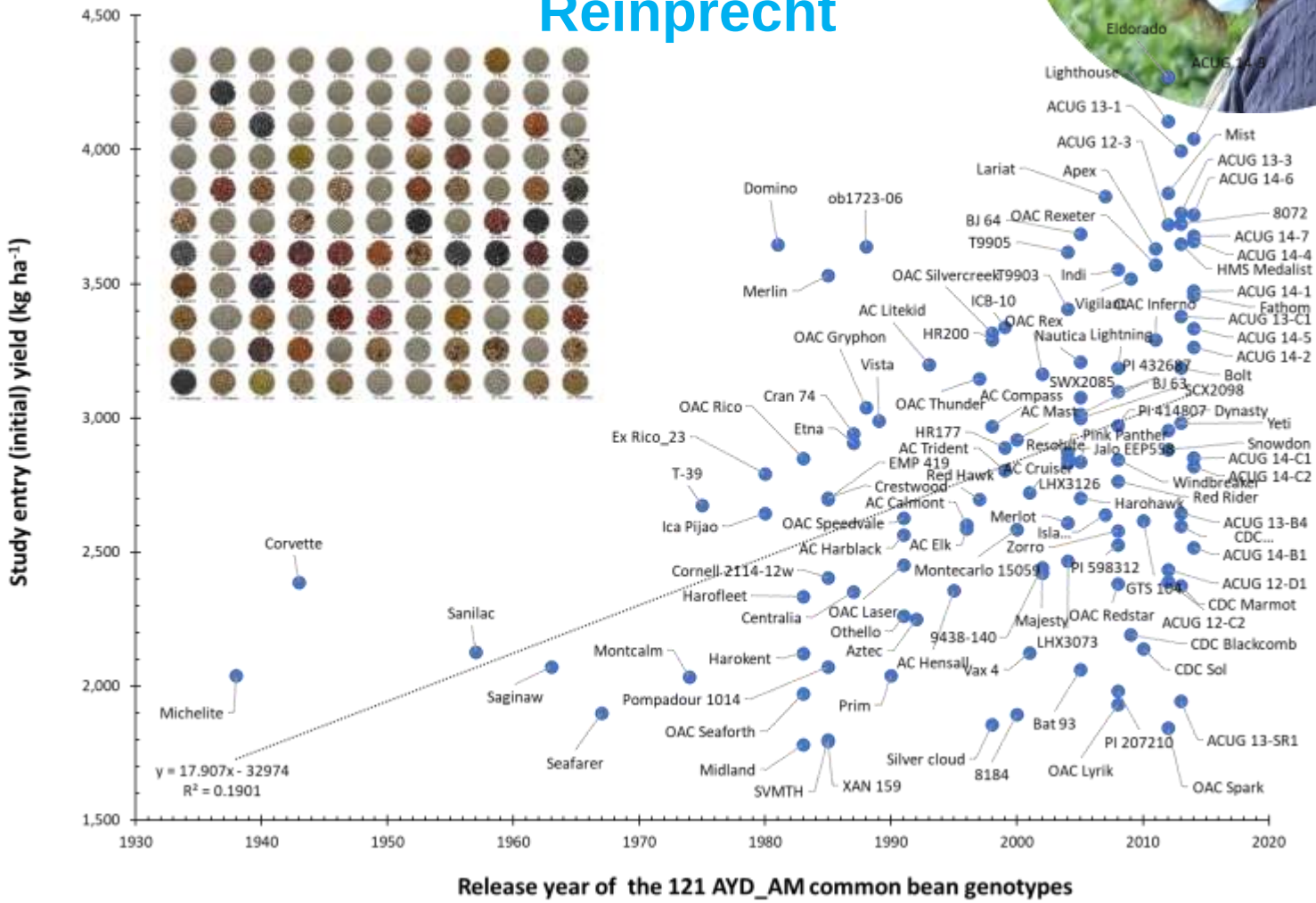
Mapping yield and yield-related traits with a collection of common bean genotypes

Yarmilla Reinprecht

Objective:

- to identify regions in the bean genome associated with yield and a number of yield-related traits using a collection of 121 bean genotypes with different yield potentials

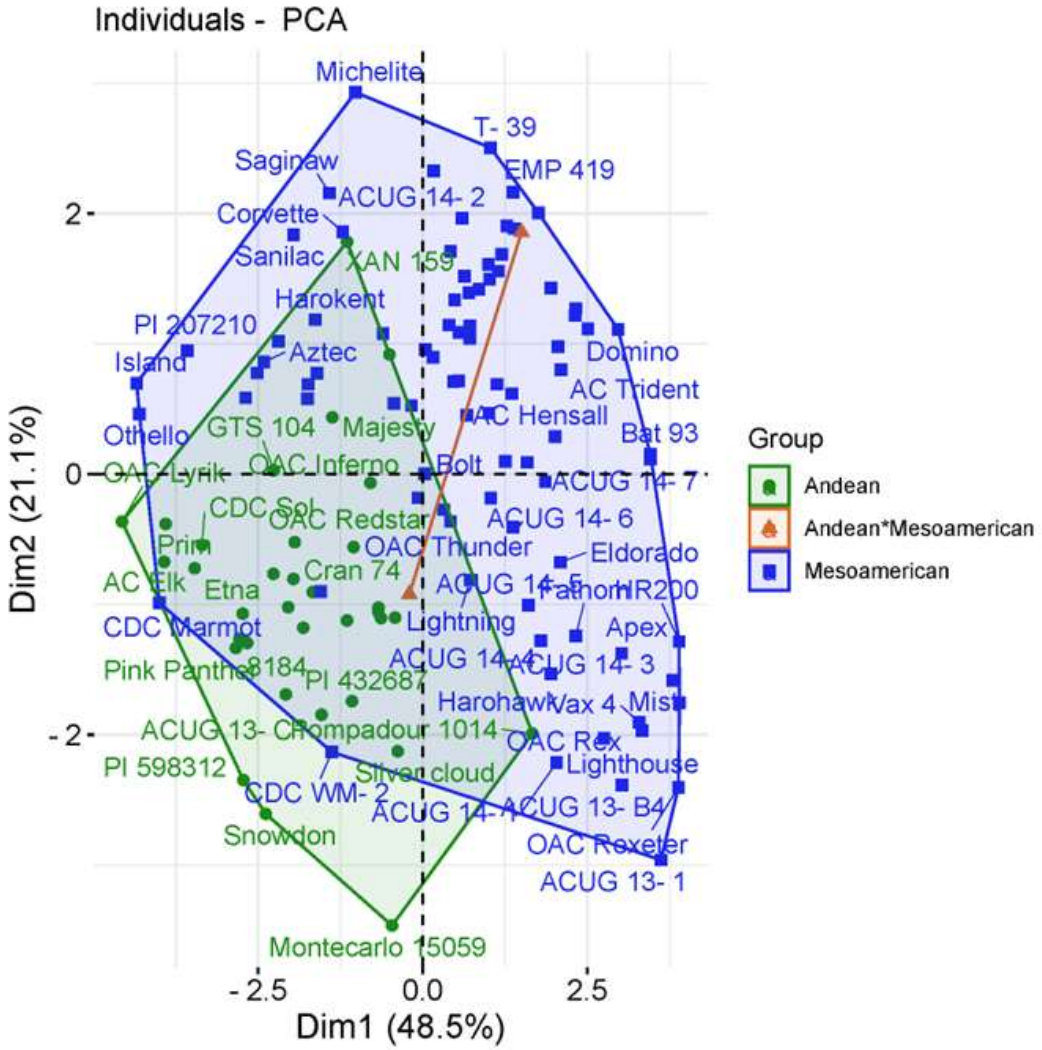
Yield vs year of release for selected genotypes (121)



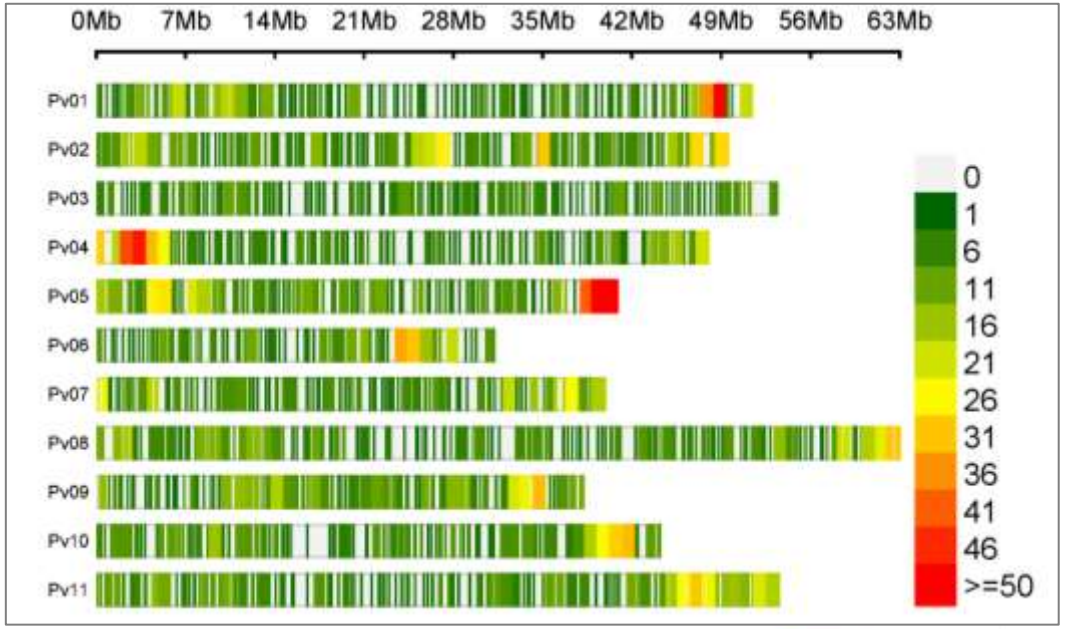
Mapping yield and yield-related traits with a collection of common bean genotypes

Yarmilla Reinprecht

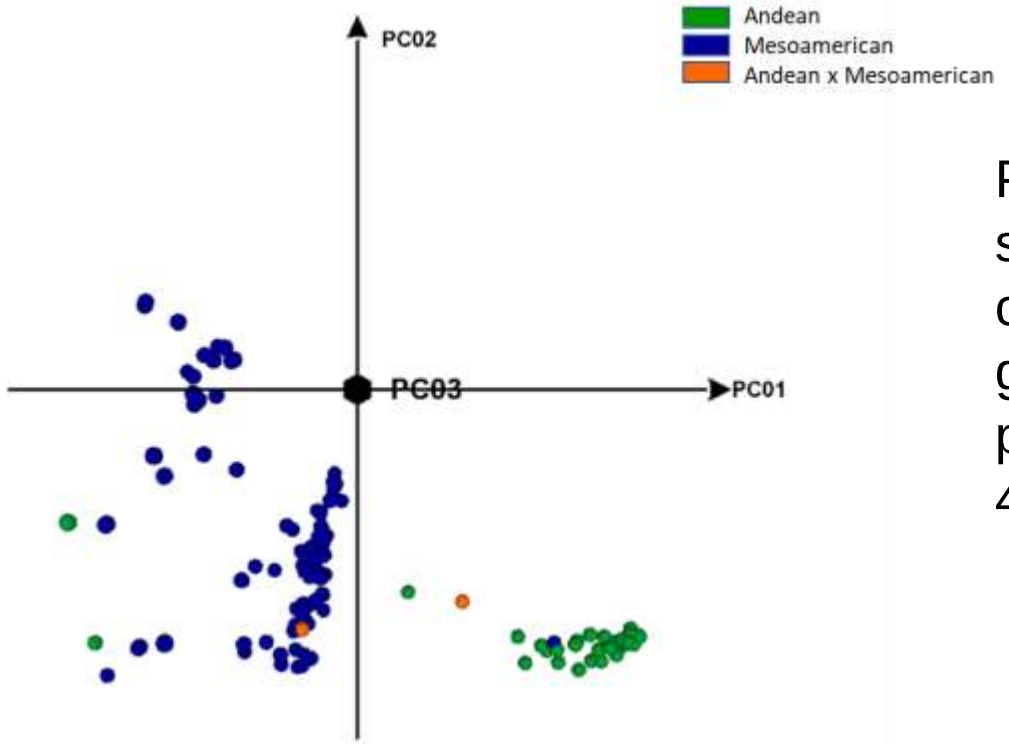
- Phenotyping
  - ➢ Lines evaluated for yield and yield-related traits in replicated trials
    - at Elora and Woodstock
    - over two years
  - ➢ Resistance to common bacterial blight (CBB)
    - by AAFC Harrow RDC
  - ➢ Significant variation among genotypes was identified for all traits



- Genotyped with:
  - BARCBean6K_3 chip
    - (5,398 SNPs),
  - two yield/ antiyield gene-based markers
    - AYD1m and AYD2, and
  - seven markers for CBB
    - including a Niemann-Pick gene-based (NPP) codominant marker
  - 4,485 SNPs used
  - genome-wide average marker density = 1 SNP every 114.5 kb (or 8.7 SNPs per Mb)



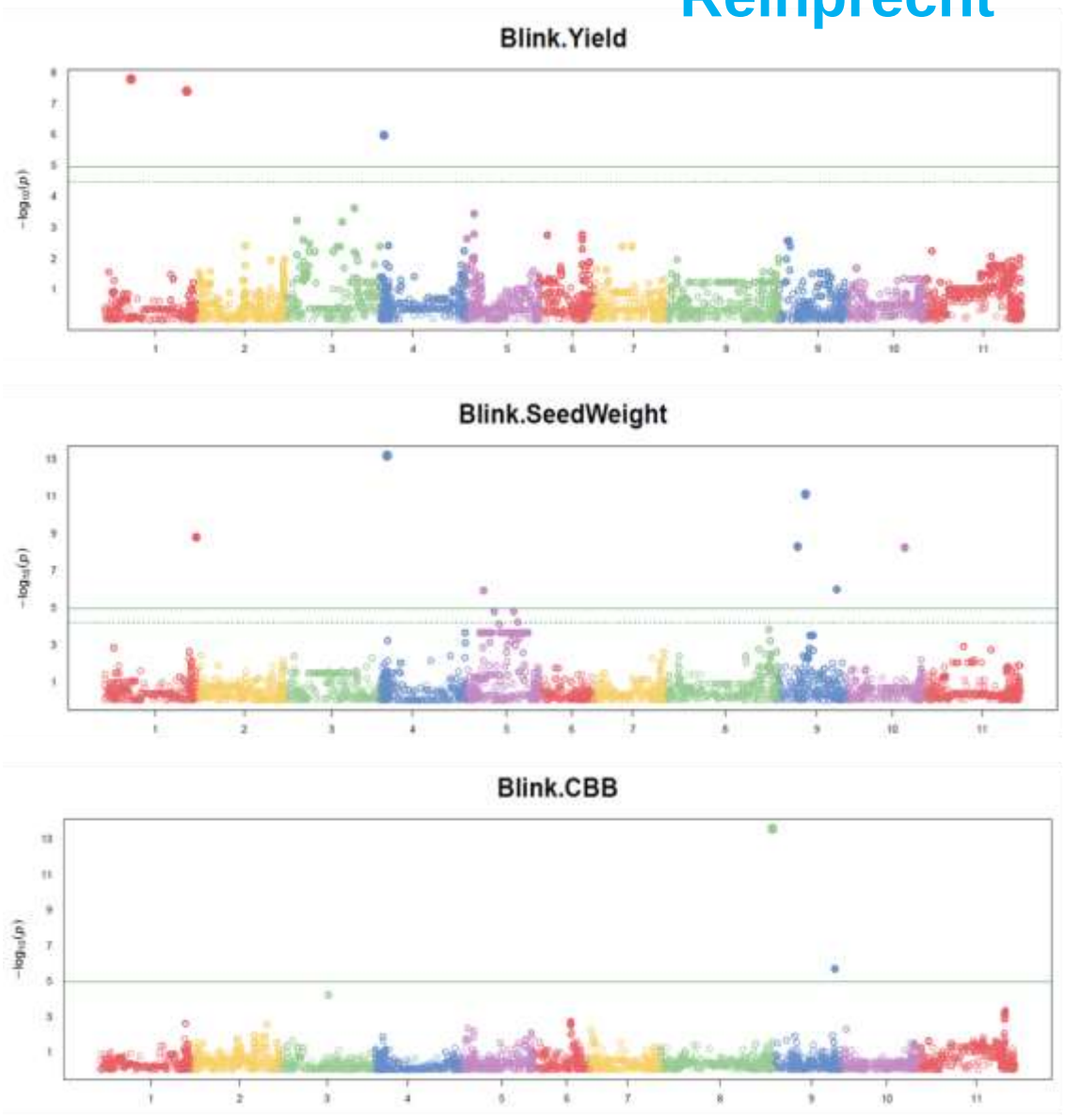
SNP distribution



Population structure of 121 common bean genotypes performed with 4,485 SNPs

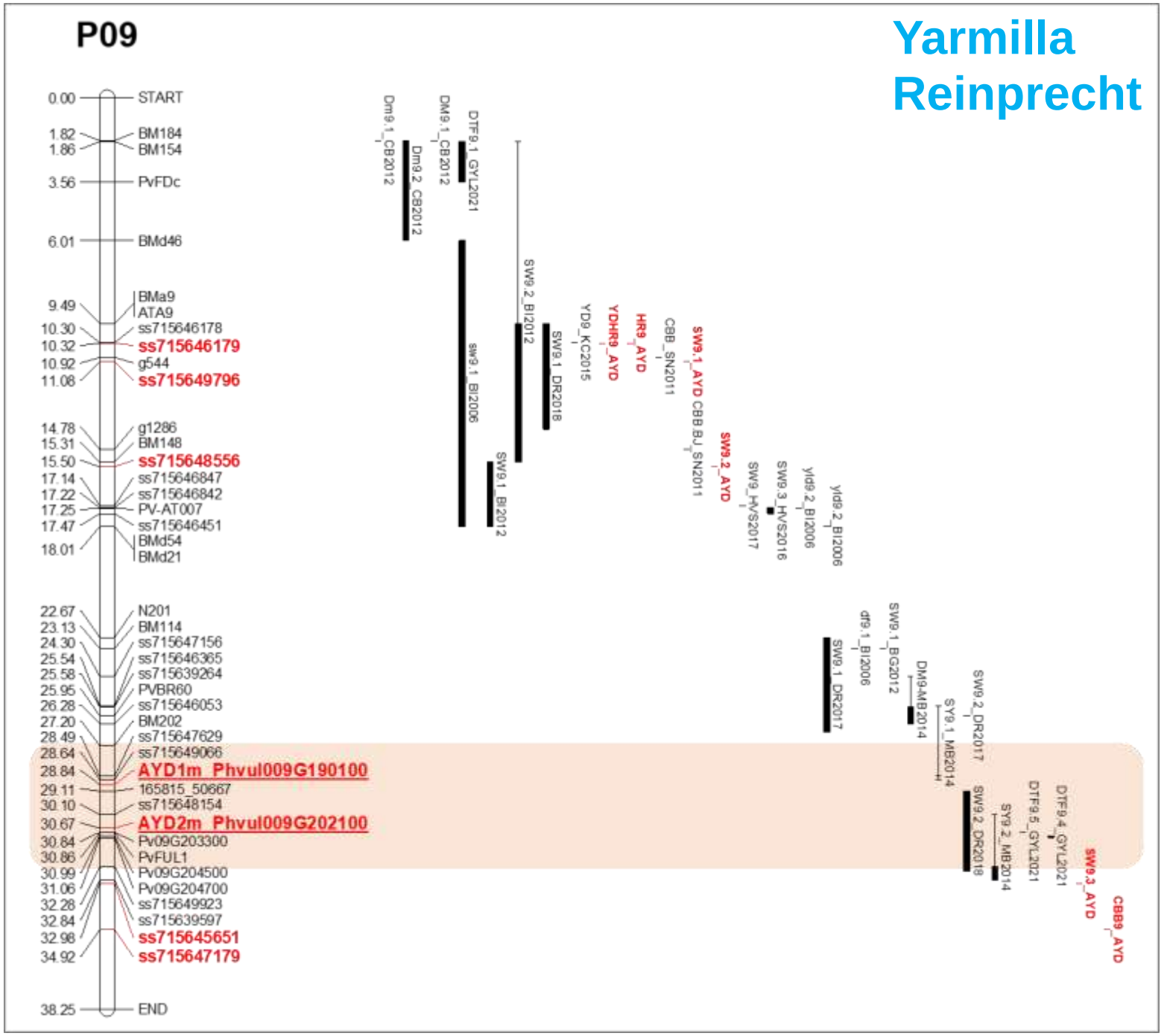
- Twenty-eight marker-trait associations (MTAs) were identified
  - the CBB marker (NPP) was significantly associated with both CBB ratings as well as Area Under the Disease Progress Curve (AUDPC)
  - the GWAS analysis did not identify association of two yield/antiyield gene-based markers (AYD1m and AYD2m) with any of the analyzed traits

Yarmilla Reinprecht



QTL and marker validation

- results of a single marker analysis validated usefulness of the yield/ antiyield (AYD1m and AYD2m) markers in screening beans for yield-related traits
- The results support previous QTL analyses of yield in bean



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