Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

Developing ‘Quality’ Wheat Varieties:

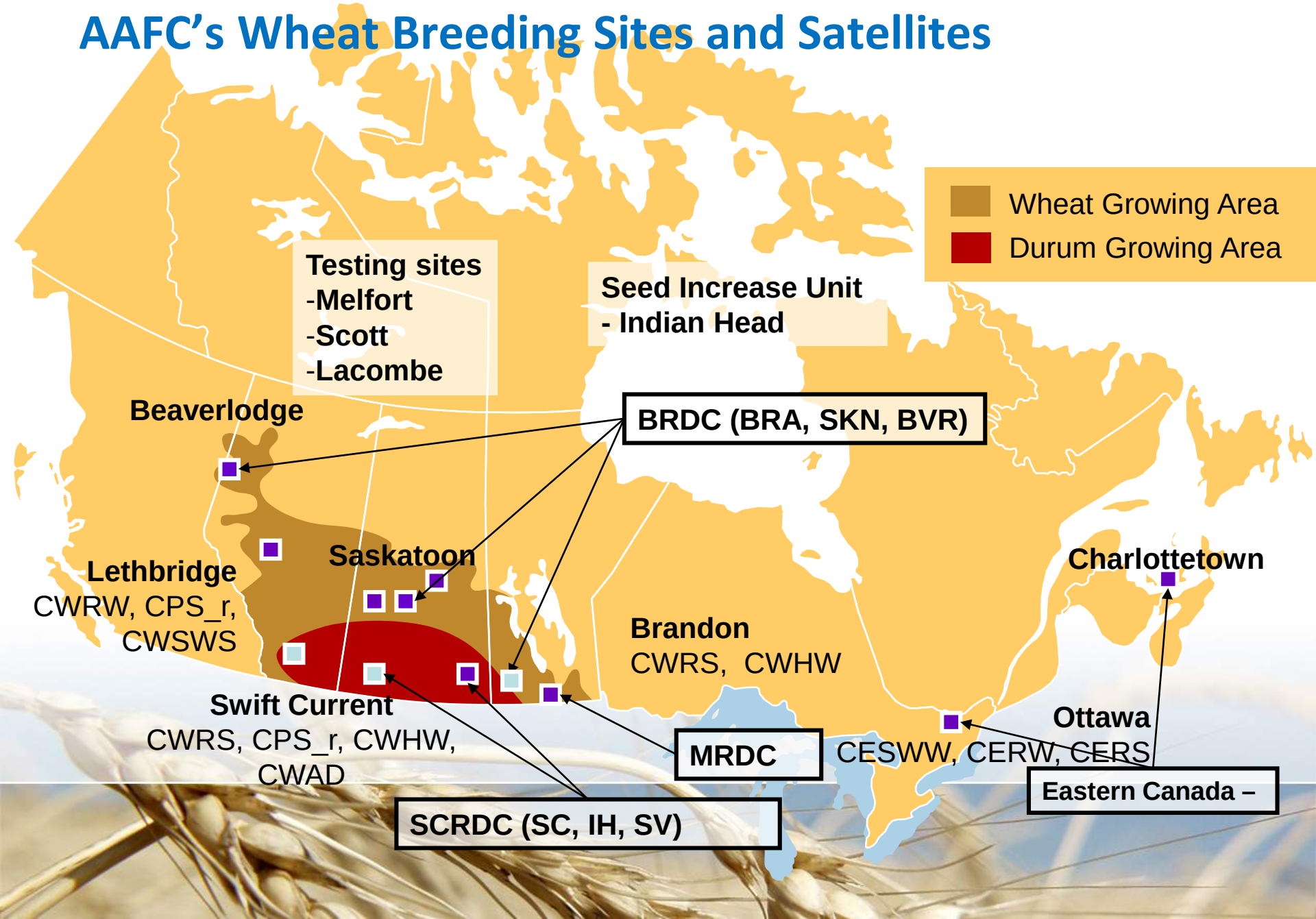
Advances in wheat breeding and research

Sask Wheat DEVELOPMENT COMMISSION

Canada

AAFC – Swift Current Research & Development Centre

AAFC's Wheat Breeding Sites and Satellites



Swift Current Wheat Breeding

SCRDC Wheat Scientists	
Dr. Samia Berraies	Term Scientist – Wheat/Durum FHB Resistance
Dr. Vijai Bhadauria	Quantitative Genetics
Dr. Firdissa Bokore	Term Biologist – Wheat Pathology / Doubled Haploidy
Dr. Richard Cuthbert	CWRS, CPS and Hard White Wheat Breeding
Dr. Myriam Fernandez	Pathology: Root, Leaf and Kernel Diseases
Dr. Ron Knox	Wheat Pathology & Biotechnology
Dr. Lin Li	Term Scientist – Durum Genetics
Dr. Yuefeng Ruan	Durum Wheat Breeding
Dr. Raja Ragupathy	Geneticist
Dr. Jatinder Sangha	Crop Physiology (Grain Quality)

Swift Current Wheat Breeding Collaborations

Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada

NRC·CNRC

Plant & Food RESEARCH
RANGAHAU AHUMARA KAI

University of Saskatchewan

University of Manitoba

University of Alberta

University of Guelph

syngenta

ICARDA
Science for Better Livelihoods in Dry Areas

CIMMYT
International Maize and Wheat Improvement Center

Cigi

Canadian Grain Commission
Commission canadienne des grains

Limagrain Cereals Research Canada

BIOTRIGO GENÉTICA

Embrapa

OR SEMENTES

KWS

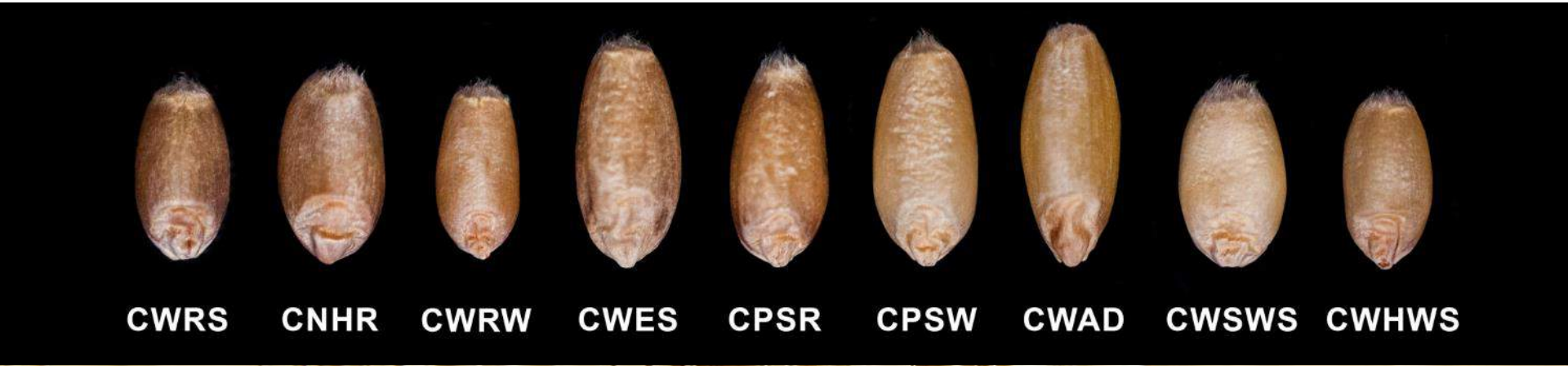
Market Classes – SCRDC Varieties

Bread (Hexaploid) Spring Wheats:

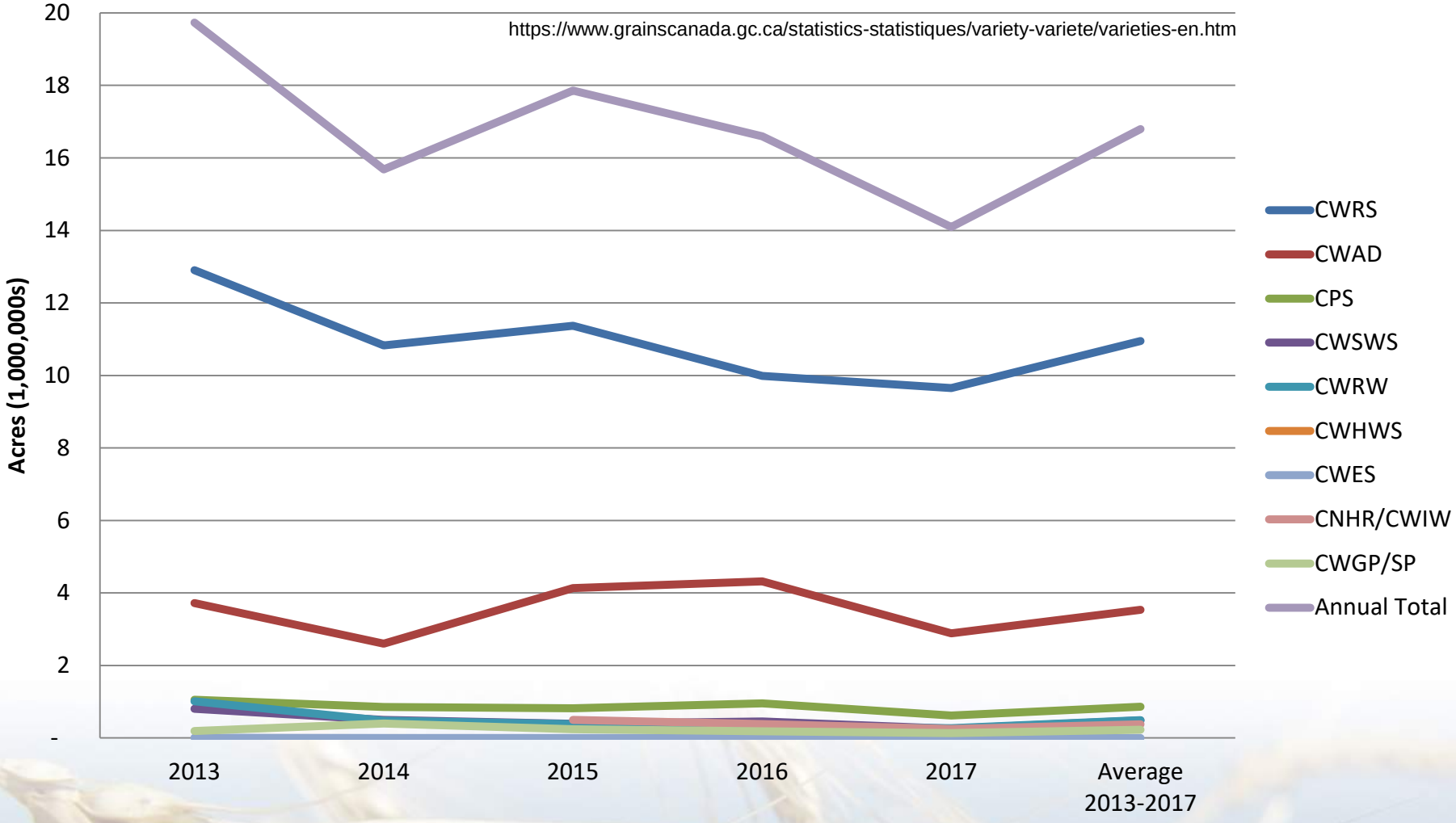
- CWRS - Canada Western Red Spring
- CPS_r - Canada Prairie Spring Red
- CNHRS - Canada Northern Hard Red Spring
- CWHWS - Canada Western Hard White Spring
- CWSP - Canada Western Special Purpose

Durum (Tetraploid) Wheat:

- CWAD - Canada Western Amber Durum



Insured Wheat Class Acreages (2013 to 2017)



SCRDC CWRS Varieties – Currently Available

AAC Brandon	AAC Elie	AAC Connery	AAC W1876
CWRS High yield strong strawed semi-dwarf *FHB: MR*	CWRS High yield strong strawed semi-dwarf *FHB: Intermediate*	CWRS High protein, strong strawed semi-dwarf. Awnless *FHB: MR* *Doubled Haploid* Excellent stripe rust resistance	CWRS Similar to Carberry in yield and plant type. *FHB: Intermediate* Selected for end-use quality by Warburtons
SeCan	ALLIANCE SEED	CANTERRA SEEDS	Warburtons CANTERRA SEEDS

SCRDC CWRS Varieties - New

AAC Viewfield	AAC Redberry	AAC Tisdale	AAC Alida VB
CWRS	CWRS	CWRS	CWRS
High yield/protein semi-dwarf very short/strong straw	High yield/protein semi-dwarf; early heading & maturity	High protein and early maturity	Midge Tolerant high yield/protein semi-dwarf with very strong straw
FHB: Intermediate	*FHB: Intermediate*	*FHB: MR*	*FHB MR*
Doubled Haploid	*Doubled Haploid*		*Doubled Haploid*
Excellent yield in water limited environments		Lower FHB symptoms	Excellent disease package, lower FHB symptoms and lower DON accumulation
FPGenetics	ALLIANCE SEED	SeCan	SeCan MIDGE TOLERANT WHEAT Plant·Protect·Preserve

SCRDC CWRS Varieties – Just supported

BW5011	BW5013
CWRS	CWRS
Midge Tolerant ~14% higher yield semi-dwarf short/strong straw	Midge Tolerant ~12% higher yield semi-dwarf short, very strong straw
FHB: MR	*FHB: Intermediate*
Excellent disease package, lower FHB symptoms and lower DON accumulation	Excellent disease package, FHB resistance similar to Carberry
SeCan MIDGE TOLERANT WHEAT Plant·Protect·Preserve	SeCan MIDGE TOLERANT WHEAT Plant·Protect·Preserve

SCRDC CPS_r/CNHR/HW Varieties

AAC Penhold	AAC Goodwin	AAC Concord	AAC Cirrus
CPS_r Very short/strong strawed semi-dwarf *FHB: MR* Stripe rust resistance (MR)	CPS_r Very stable high yield, high protein and strong straw *FHB: Intermediate* *Doubled Haploid*	CNHR Very solid stem, high yield with improved FHB resistance. *FHB: Intermediate* Solid stem would likely confer very good resistance to the Wheat Stem Sawfly	CWHWS Short/strong strawed hard white with improved disease resistance. *FHB: Intermediate*
SeCan	SeCan	CANTERRA SEEDS	FPGenetics

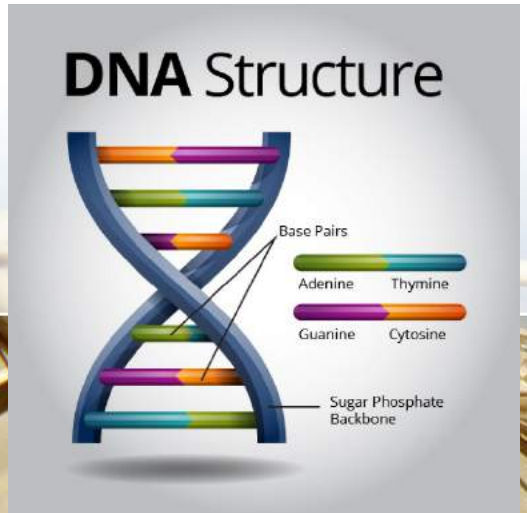
Bread Wheat

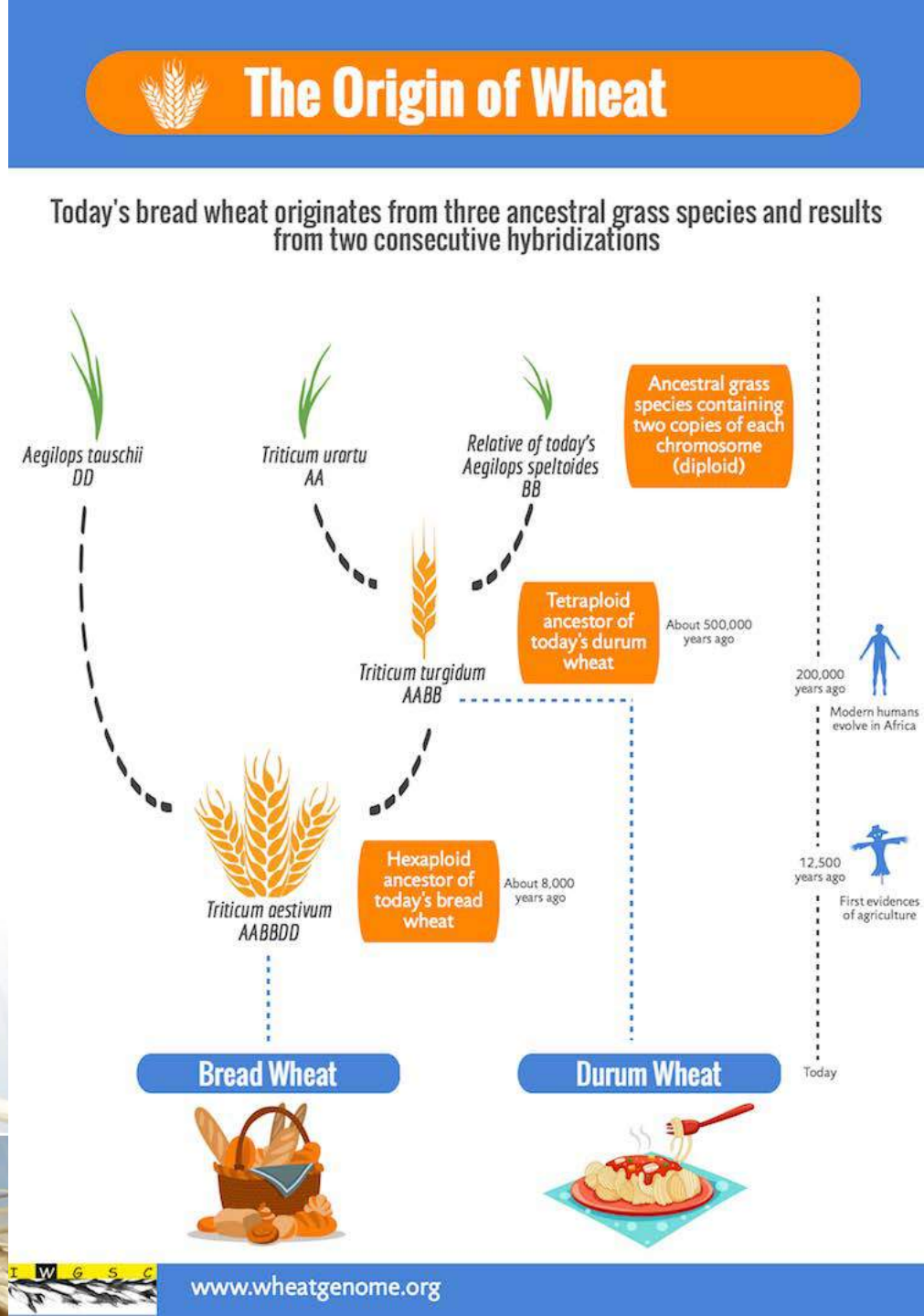
Wheat provides 1/5 of all calories & protein consumed globally.

Canada produces ~30 MT annually. (~740 MT produced globally).

Large genome – CHALLENGE!

- 17 billion base pairs
- 5X larger than human genome
- 105,000 genes





Improving Bread Wheat Varieties – Better, not more.

Agronomics

Disease/Pest Resistance

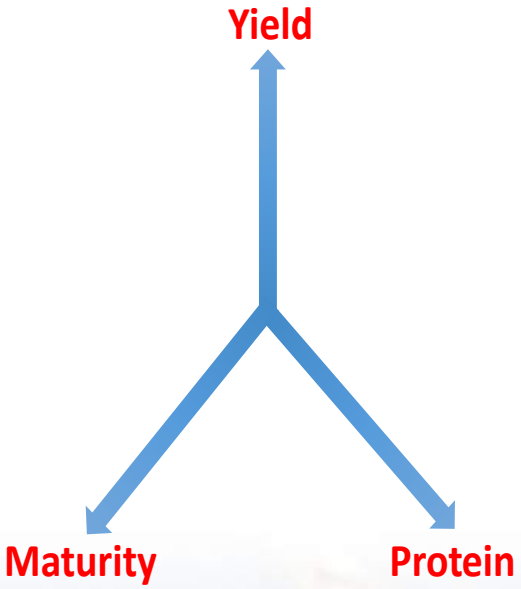
End-Use Quality

Red Fife

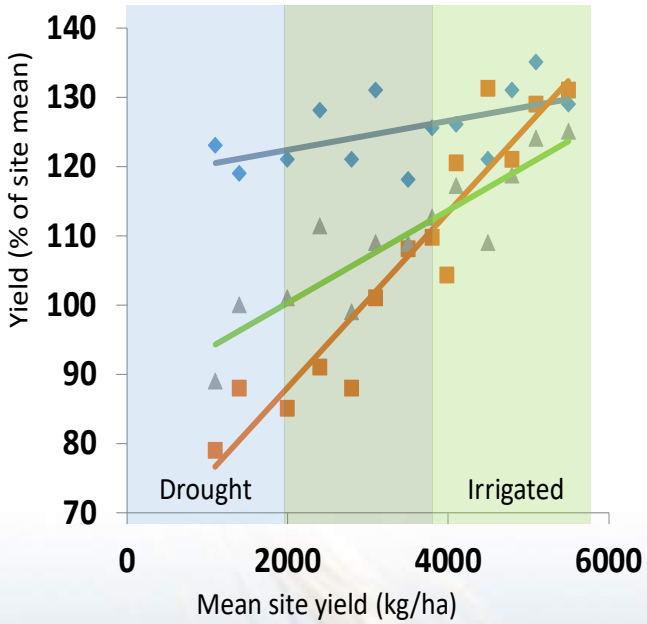
AAC Alida VB

Challenges in wheat breeding

Inter-trait



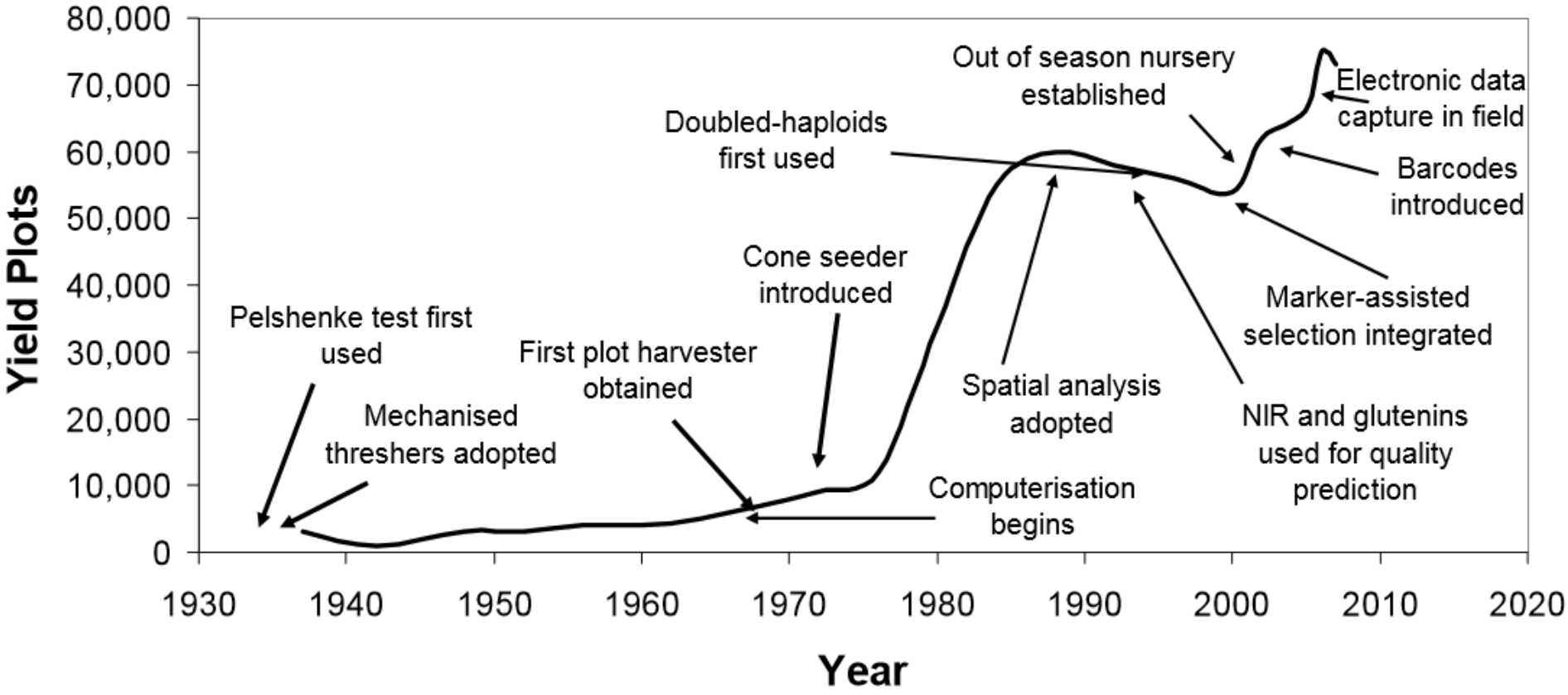
G X E Interactions



Evolving

C. Pozniak, U of S

Chronology of technologies in breeding



C. Pozniak, U of S

Agronomics

Producers need cultivars which **yield** well and are resilient

Grain Yield

Grain Protein

Maturity

Height (Semi-Dwarf)

Strong Straw Strength

Threshability (shattering)

Test Weight

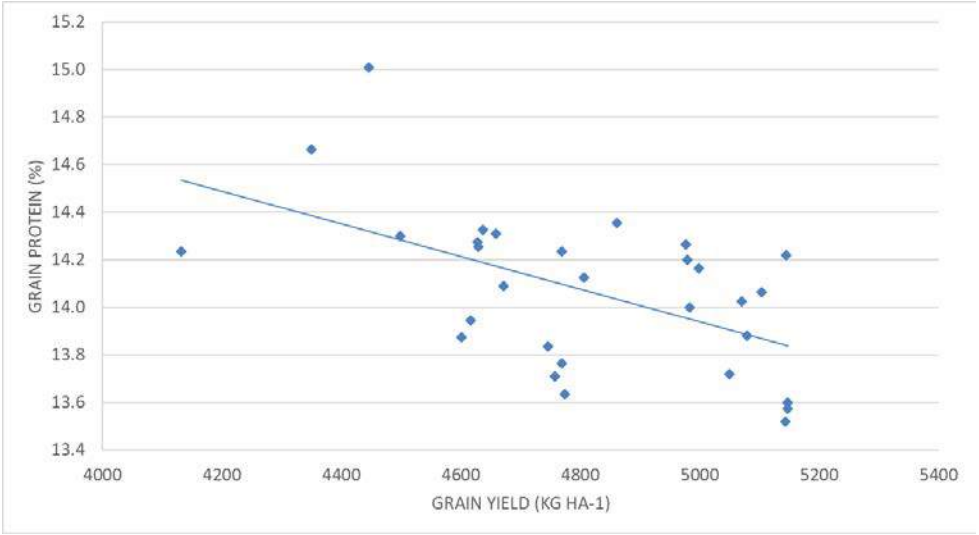
Kernel Weight

Water Use Efficiency (drought tolerance)

Nitrogen Use Efficiency

Cold tolerance - Early spring seeding

Grade Protection



Disease/Pest Resistance (Biotic Stresses)

Fusarium Head Blight/Mycotoxins

Leaf rust, Stem Rust, **Stripe Rust**

Common Bunt

Loose Smut

Leaf spot complex

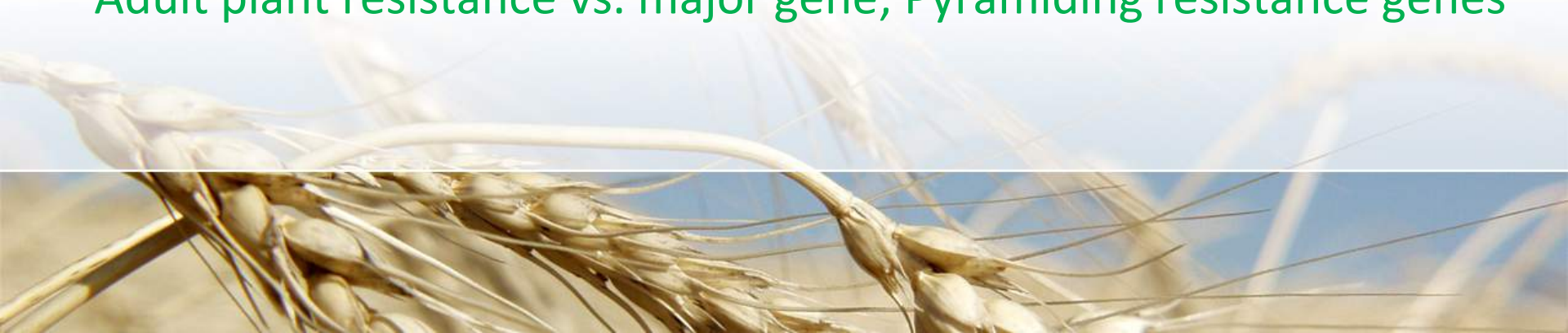
Ergot

Wheat Stem Sawfly

Orange Wheat Blossom Midge

Durable genetic resistance

Adult plant resistance vs. major gene; Pyramiding resistance genes



Disease Resistance

Fusarium Head Blight

Fusarium damaged kernels

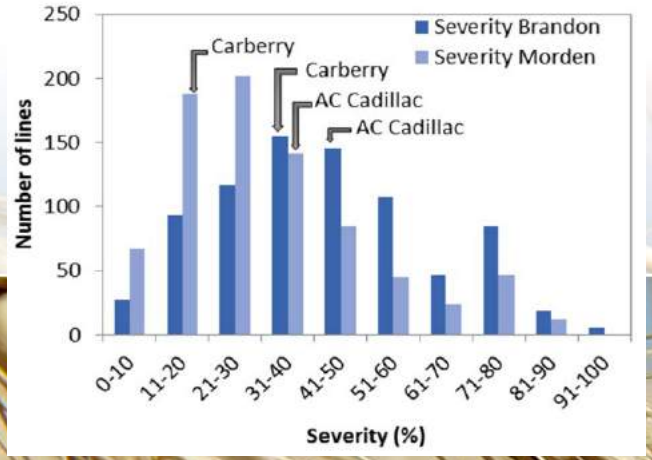
Mycotoxins – Deoxynivalenol (DON)

Resistance is quantitatively inherited

- Some major loci (Fhb1)
- **No loci have been officially cloned!**

Originally diverse sources of resistance

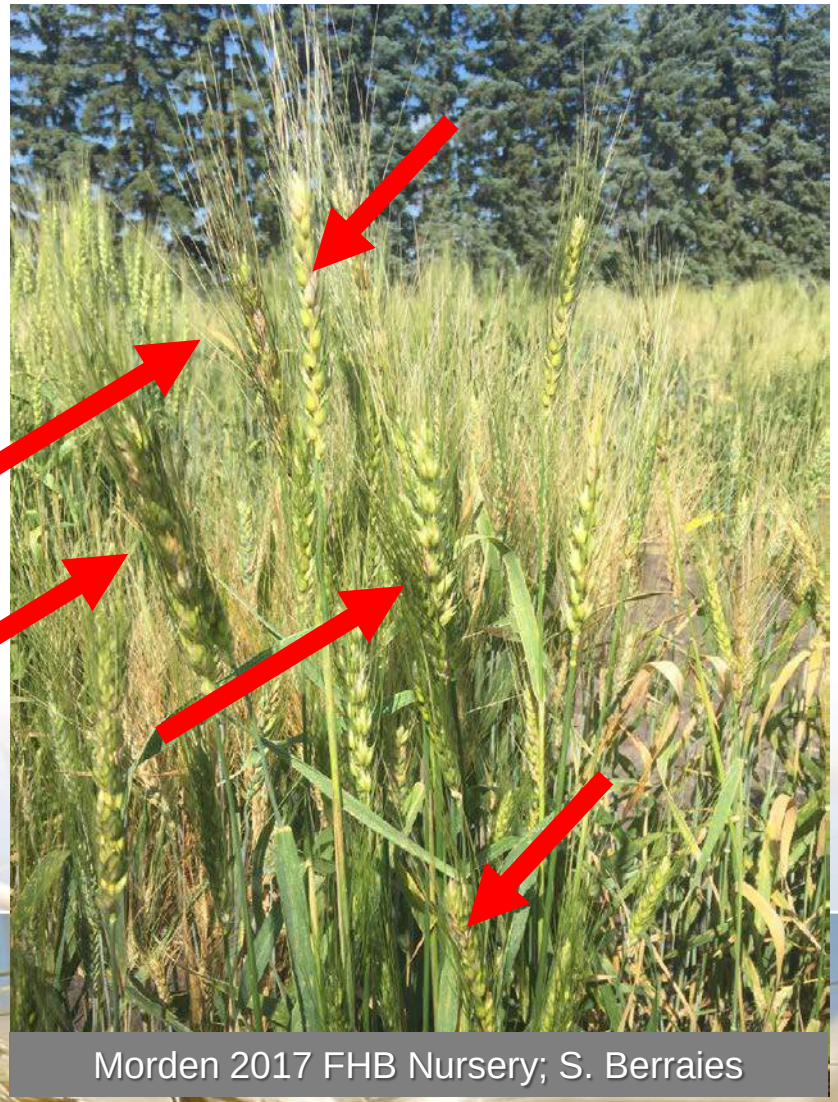
- Sumai3, Wuhan, Maringa, Wangshubai, etc…



Fusarium Head Blight Ratings

‘R’ rating does not imply symptom-free

AAC Tenacious: (R) →



Morden 2017 FHB Nursery; S. Berraies

Fusarium Head Blight Ratings

ISD = (20% incidence + 20% severity + 60% DON)

Checks:

AAC Tenacious = R

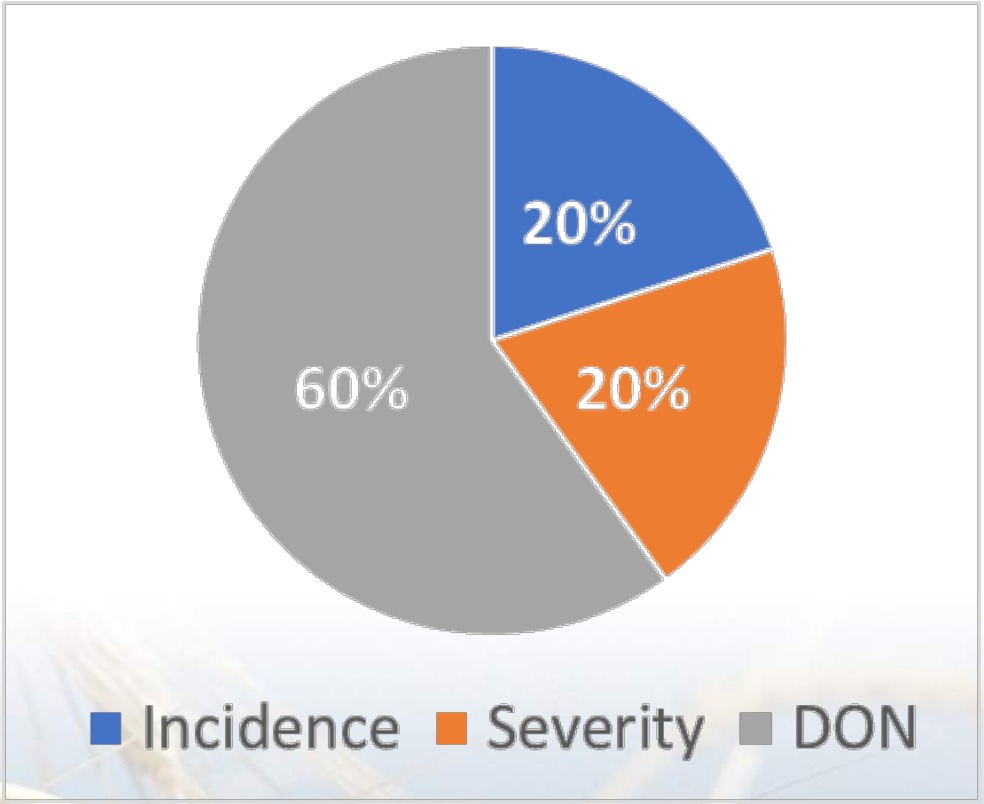
AAC Alida VB = MR

Carberry = MR/I

AC Barrie = Intermediate

Stettler = MS

Lillian = S



Fusarium Head Blight Ratings

ISD = (20% incidence + 20% severity + 60% DON)

Disease Resistance

Rusts

Yellow

Stem (Ug99)

Leaf

Ergot

Common Bunt

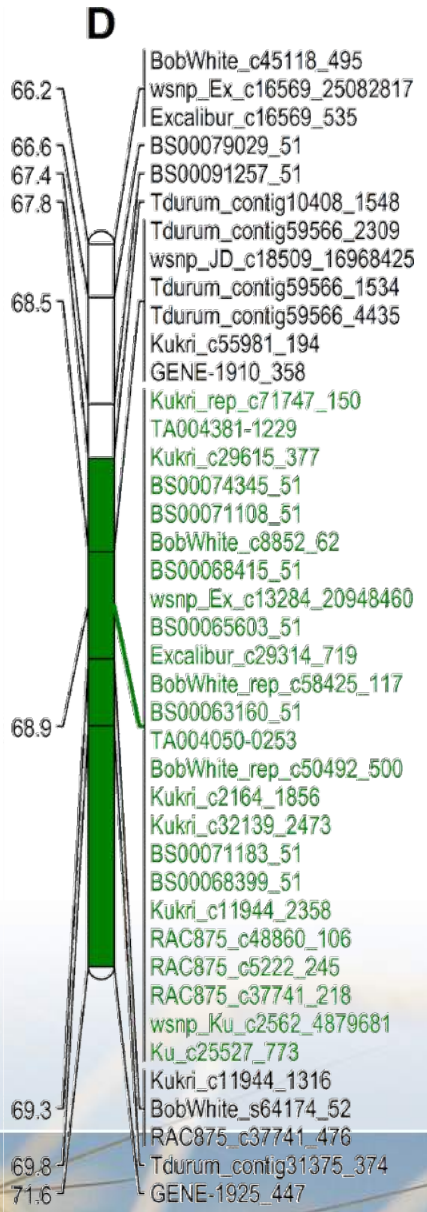
Loose Smut

Leaf Spot Complex

Pest Resistance

Wheat Stem Sawfly

- Solid stem cultivars (Lillian, AAC Concord)
- SSt1 solidness gene (Nilsen et al. 2017)



Pest Resistance

Orange Wheat Blossom Midge

- *Sm1* gene (Goodeve, AAC Alida)

MIDGE TOLERANT WHEAT
Plant · Protect · Preserve

Canada Western Red Spring

Most restrictive class for end-use quality in Canada

used for production of high volume pan bread

used alone or in blends with other wheat for hearth bread, steamed bread, noodles, flat bread, common wheat pasta

Canada Western Red Spring

Pre-Harvest Sprouting (Falling Number)

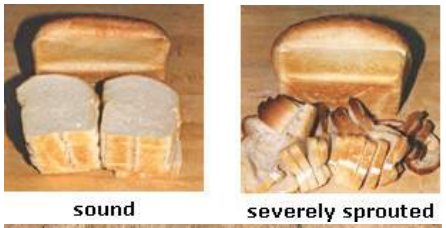
Protein **(grain, flour)**

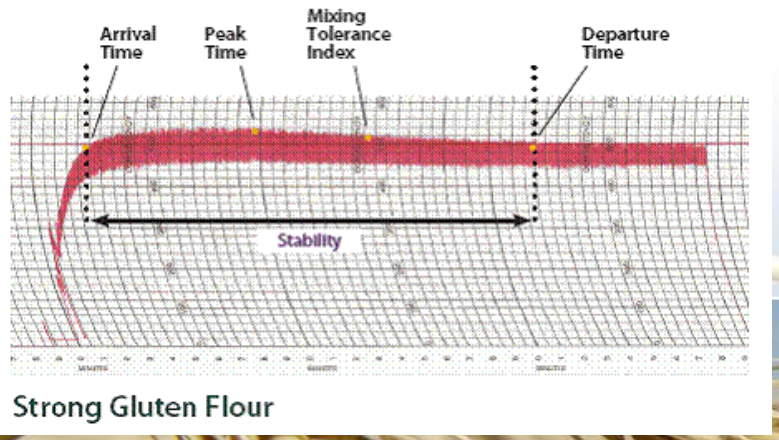
Milling (flour yield, flour ash, kernel texture)

Gluten Strength/Extensibility (mixo-, farino-, extenso-graph)

Baking (water absorption, crumb structure, loaf volume)

(Noodle Parameters)



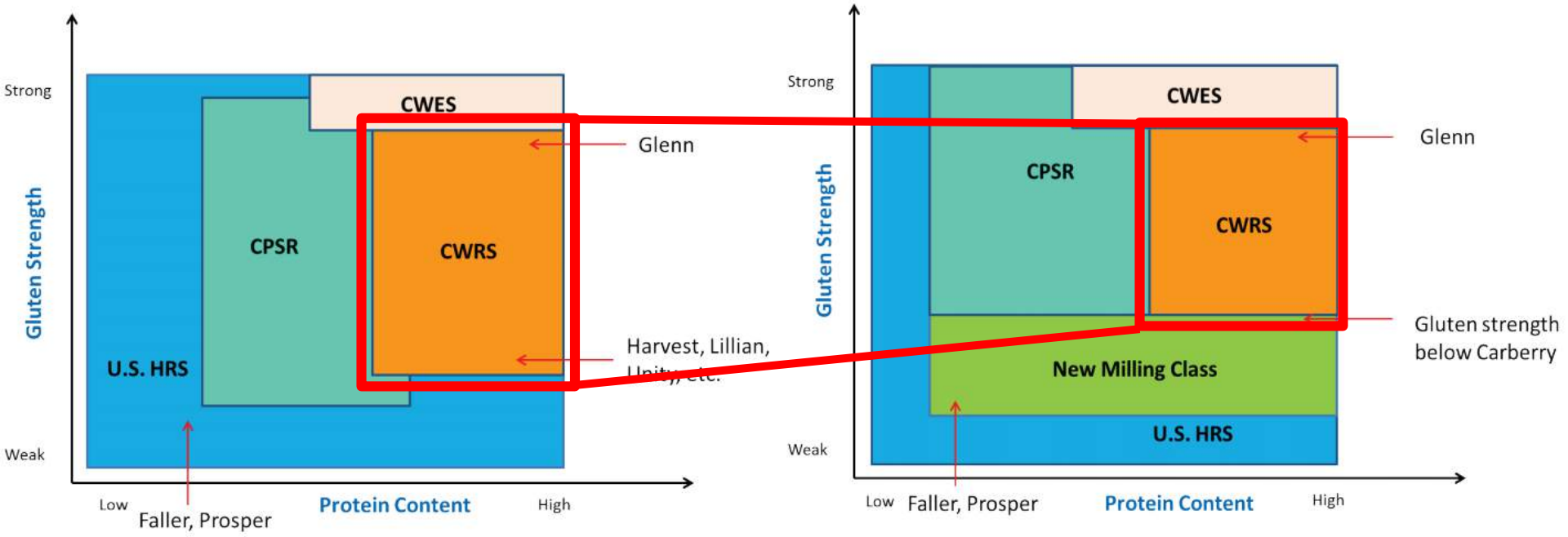


Strong Gluten Flour

Wheat Class Modernization

Previous Targets

Current Targets



http://www.grainscanada.gc.ca/consultations/2015/classes-pdgc-2015-en.pdf

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GENEALOGY

Canada Western Red Spring

Marquis

Neepawa

AC Barrie

bx: Backcross; number of backcrosses. If the number is above the off-spring line, the recurrent parent is the upper parent; if the number is below the off-spring line, the recurrent parent is the lower parent.

* Backcross

† Prior to 1923

Date: Year of registration

Bold: Cultivar grown in Canada

Parent "A"

Parent "B"

Progeny from parents to the left

Sib's from parents A and B

Sib's from parents A and B

Progenitor overhops other parental originator

Wheat relatives in CWRS genealogy

Triticum turgidum ssp. *diccocoides*
T. turgidum ssp. *durum*
T. speltoides

Doubled haploid cultivars:

McKenzie, CDC Abound, Carberry, Lillian, Waskada, Muchmore, Superb, Stettler, Alvena, Shaw

Cultivars developed using molecular marker assisted selection:

Lillian, Vesper, Somerset, Goodeve

Swift Current Breeding Strategy

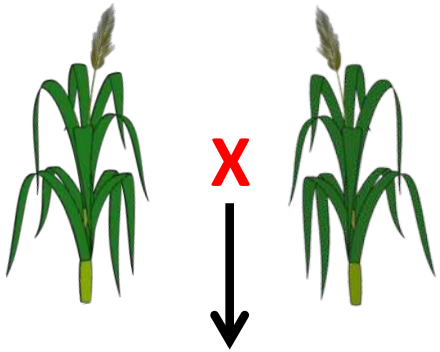
- Low diversity in parents
  - to maintain quality profile
  - diversity → linkage drag on economically important traits

- Low cross numbers
  - ~24 3-way, 12 Doubled Haploid populations

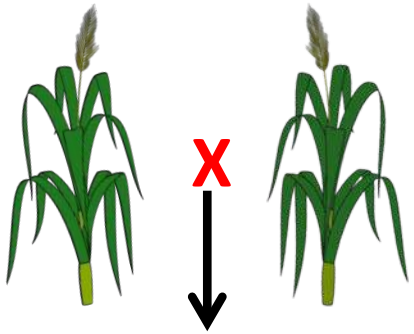
- Larger populations (mine recombination)

- Simultaneous Qualitative and Quantitative trait selection
  - Heat/Drought Stress

Swift Current CWRS Breeding Pipeline



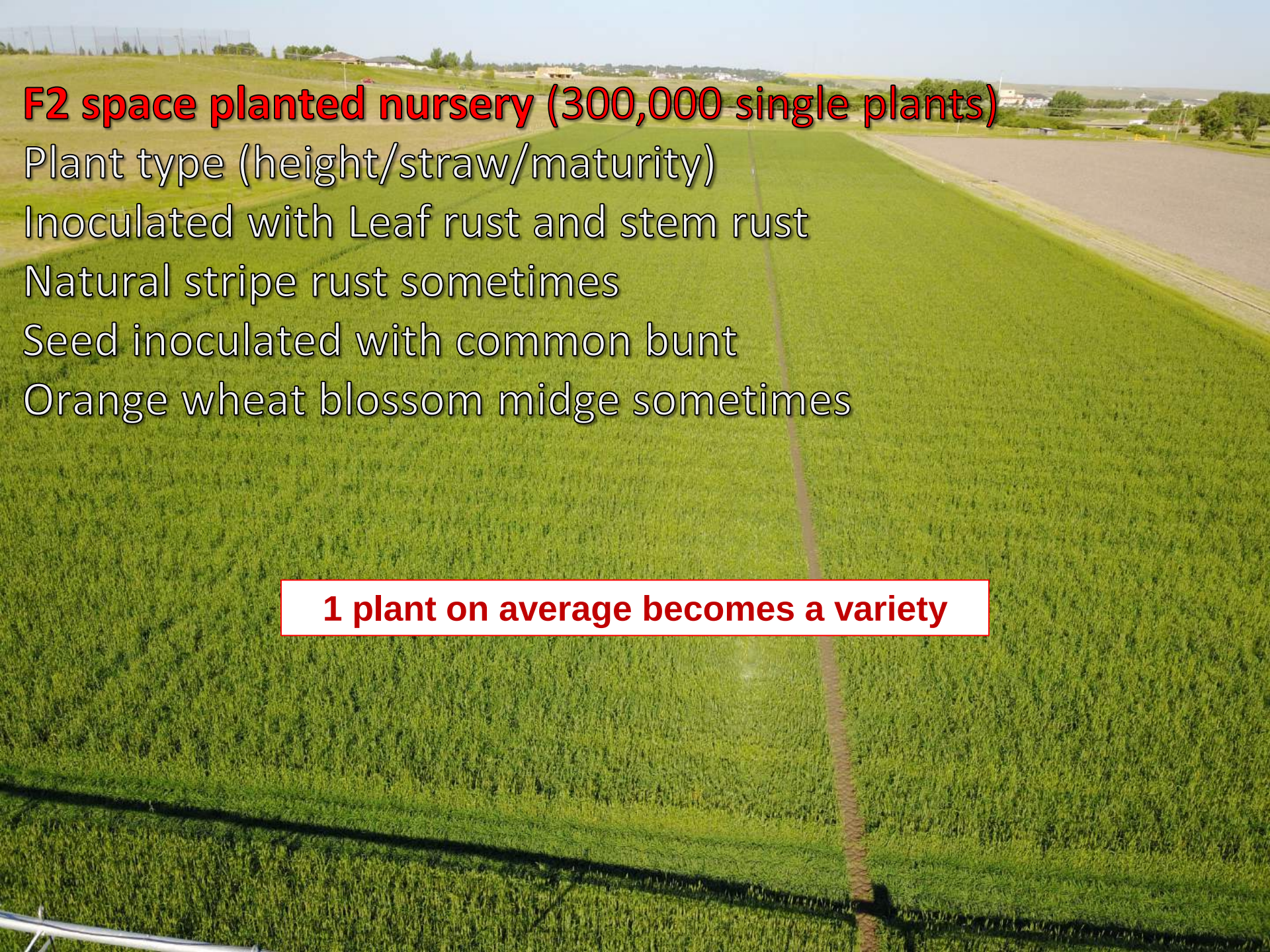
24 3-way populations per year



Top Cross F_1
Wider crosses

Bulk increase [and **Marker Assisted Selection (up to 4)]**

Space planted F_2 disease nursery


F2 space planted nursery (300,000 single plants)
Plant type (height/straw/maturity)
Inoculated with Leaf rust and stem rust
Natural stripe rust sometimes
Seed inoculated with common bunt
Orange wheat blossom midge sometimes
1 plant on average becomes a variety

Contra-Season Nursery – Real World Speed Breeding

1 F_2 plant → 1 F_3 row
Assess materials for agronomics/diseases

Sufficient seed for yield/disease/quality evaluation in next growing season

F4/F6/F8/DH yield trials

Plant height, lodging, maturity

Grain yield

Grain protein

Test weight

Thousand kernel weight

Quality (Kernel hardness, Flour yield, Gluten strength)

FHB nurseries (F4/F6/F8/DH)

[Morden, Brandon, Carman] MB

[Indian Head] SK

Incidence & Severity = Visual Index ($)

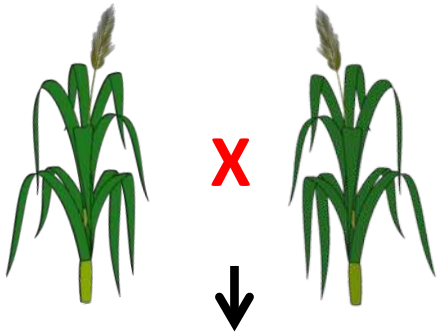
Deoxynivalenol (DON) strategically ($$$$)

FHB Resistance Breeding

We are making progress!

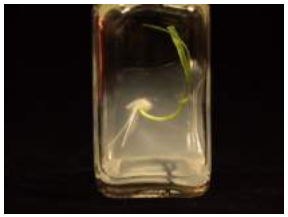
Swift Current Double Haploid Program

12 DH populations per year

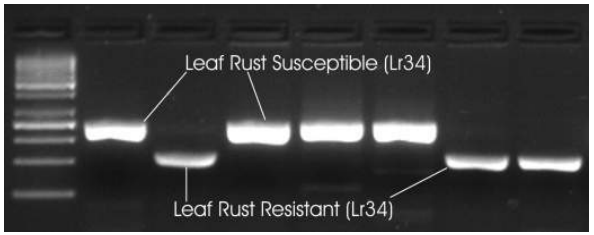


Double Haploid Program

High Value Crosses



Marker Assisted Selection



Pure breeding progeny (within 1 year)

Lillian, Carberry, Muchmore, Stettler, AAC Connery, AAC Viewfield, AAC Redberry, AAC Alida VB

Wheat Breeding Efficiency

Success in breeding is ultimately efficient use of resources:

-**Tools -** Yield plots, disease nurseries, quality testing, double haploids, etc…

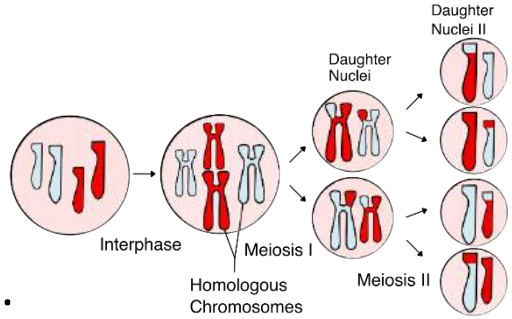
-300,000 F2 plants – ~1 plant is a variety.

-8,000 DH lines - ~1 plant is a variety.

We are bound by recombination (meiosis)

-Population size is important (increased gametes).

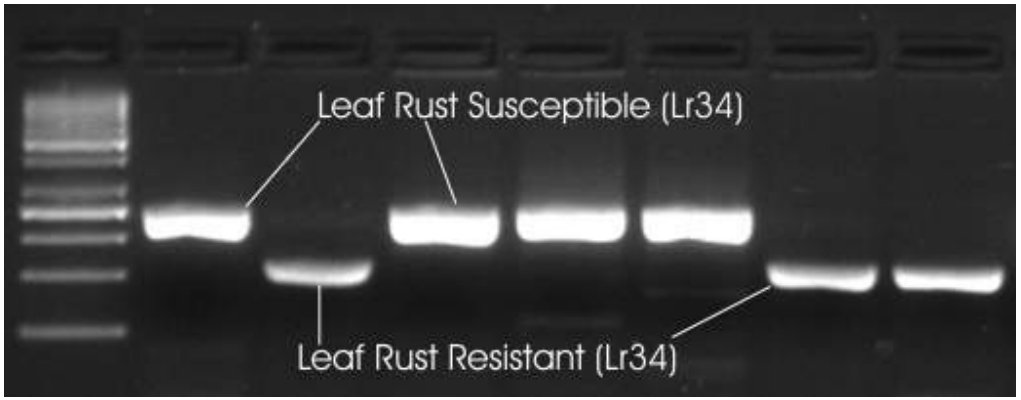
-Assessing progeny with precision/accuracy is imperative.



Discard the worst as quickly as possible.

Marker Assisted Breeding

We can improve our odds of finding desirable genotypes by using markers. This has been done for over 20 years.



Parent ‘A’ has an important gene. Parent ‘B’ does not have the gene. A DNA marker is tightly linked to this gene which we can screen on progeny and discard lines without the gene.

1600 advanced lines * $50 a plot @ 3 locations = $240,000

If we did not discard lines lacking the gene, ~800 lines would not likely be useful.

If we ACTIVELY discard the non-carriers at an early generation, the 1600 advanced lines can all be used to further screen for improved yield, FHB resistance, quality, etc… → better variety

Cost to screen with the marker - $2 per line = $3200

Marker Assisted Breeding

What if we could look at the genotype (genes) of all lines/plants in early generations of the breeding program?

“Wheat Breeding Chip” → Cost effective genotyping

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Crop Development Centre
COLLEGE OF AGRICULTURE AND BIORESOURCES
AGBIO.USASK.CA

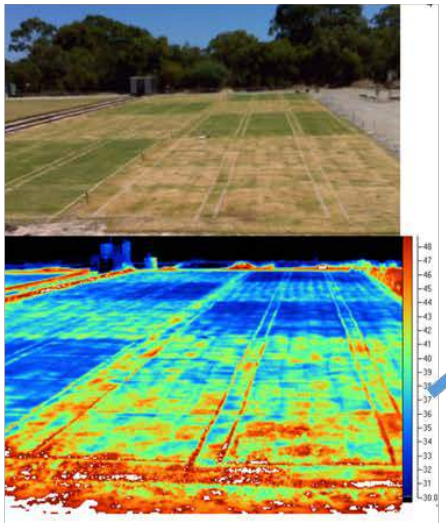
CTAG2 Canadian Triticum Applied Genomics

Predictive Breeding – A Biometric approach

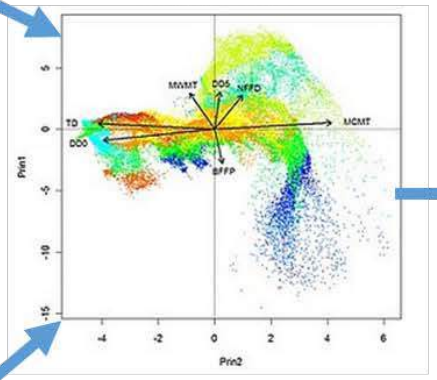
'Genomic Selection'

Genotyping

Phenotypic Data

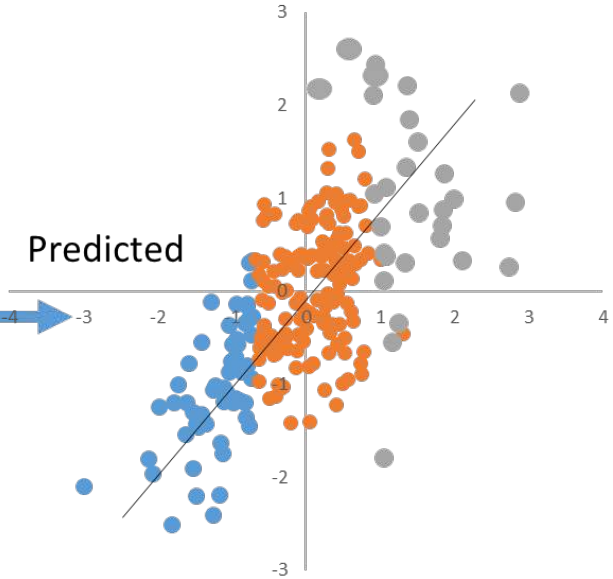


Multivariate Statistics



Predictive Models

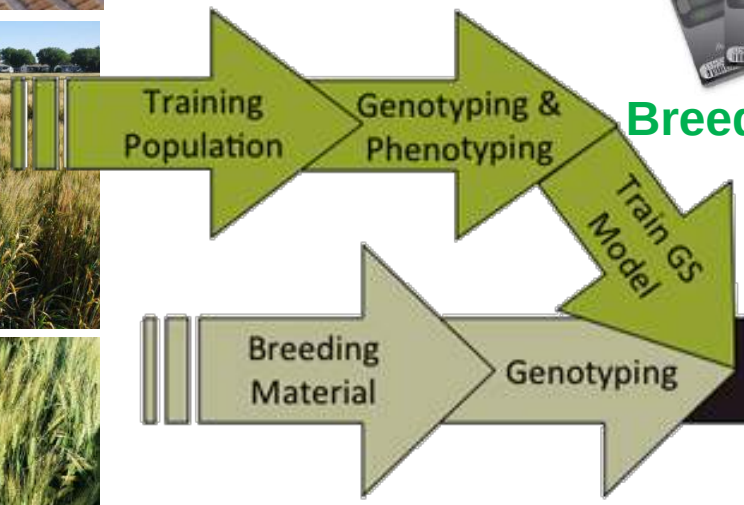
Grain Yield (kg/ha)



GenomeCanada
GenomePrairie
Western Grains Research Foundation
Government of Saskatchewan
Alberta Wheat Commission
GROWTH. INNOVATION. RESULTS.
SaskWheat Development Commission
GIFS Global Institute for Food Security
Growing science for life
PotashCorp - a Founding Partner

Genomic Selection

Breeder Chip



CTAG² Canadian Triticum Applied Genomics

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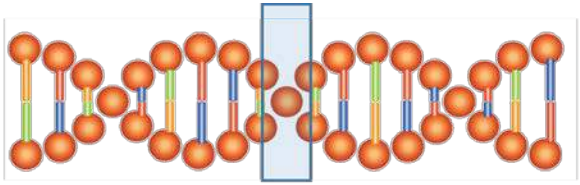
When we know the genes…

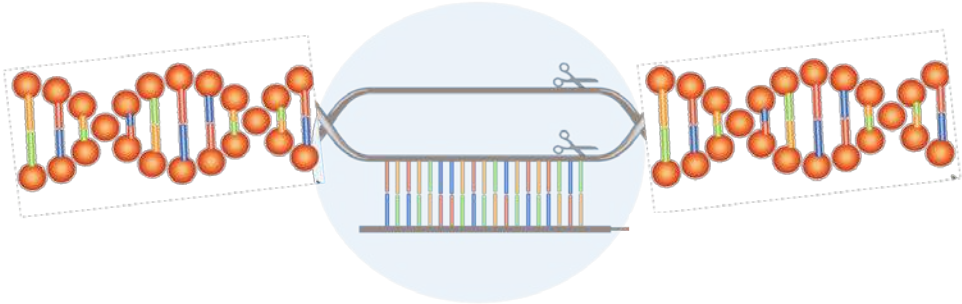
CRISPR-CAS: A “targeted” plant breeding technology

Native Gene

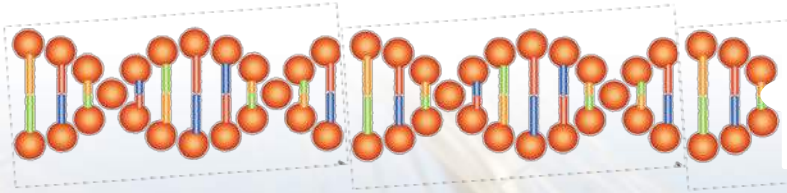


Targeted Break

Targeted Repair

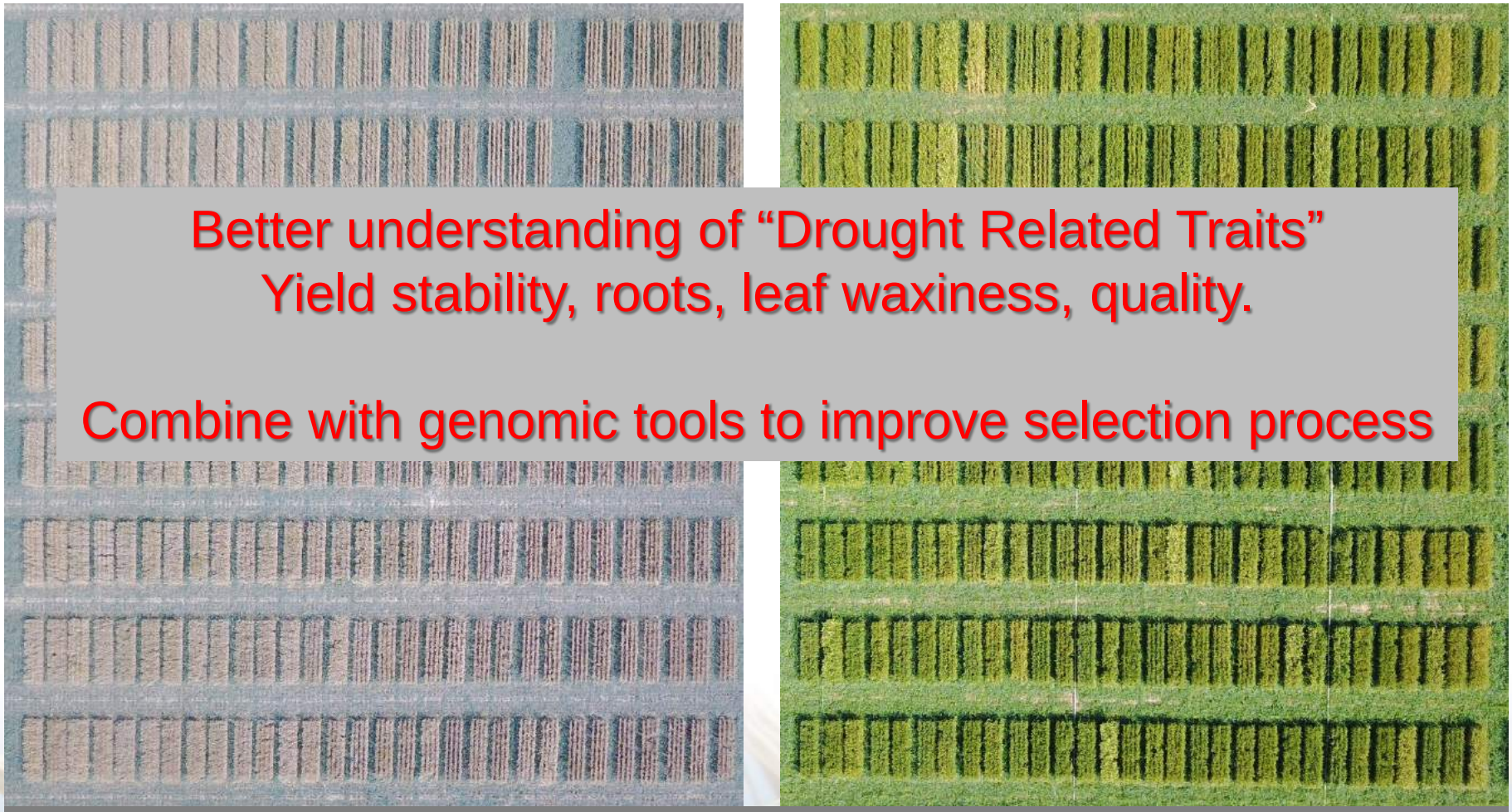


“Repaired” Gene



C. Pozniak, U of S

Abiotic (Drought/Heat) Stress 2017



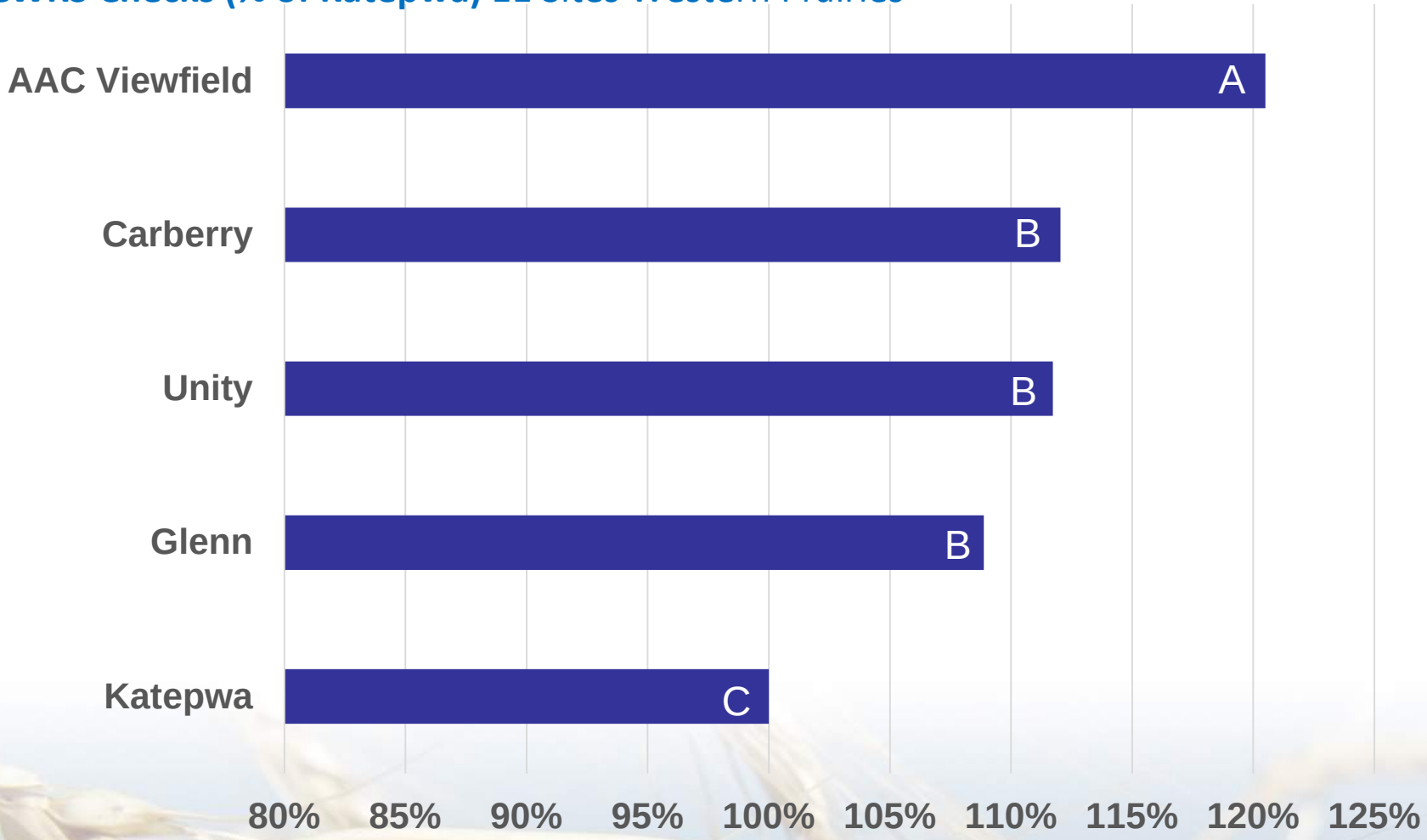
Better understanding of “Drought Related Traits”
Yield stability, roots, leaf waxiness, quality.

Combine with genomic tools to improve selection process

B0767& = Carberry/AC Cadillac
Same block of land – Same day – rainfed vs irrigated

Drought performance 2017

CWRS Checks (% of Katepwa) 11 Sites Western Prairies



The future of wheat breeding?

We have come a long way, but much more to do…

Access to tools increases efficiencies → better varieties.

Genomic selection will likely allow the “bad” to be discarded faster than previously possible.

Gene editing is a promising technology. We need to understand the genes involved.

Phenotyping remains king!

Thank you!

Western Grains Research Foundation

Sask Wheat Development Commission

Alberta Wheat Commission

Manitoba Wheat and Barley Growers Association

Government of Saskatchewan

Canada

CTAG2 Canadian Triticum Applied Genomics

SeCan

Agriculture and Agri-Food Canada

Agriculture et Agroalimentaire Canada

Test Name	Target Class
BW1041	CWRS
BW1045	CWRS
BW1048	CWRS
BW1049	CWRS
BW5011	CWRS
BW5013	CWRS
BW5022	CWRS
PT485	CWRS
PT596	CWRS
PT650	CWRS
PT782	CWRS
PT783	CWRS
PT784	CWRS
PT785	CWRS
DT878	CWAD
DT881	CWAD
DT591	CWAD
NH004	CNHR
GP190	CWSP spring
KWS Alderon	CWSP spring

PGDC-PRCWRT 2018

20 new wheat lines supported for registration