What the Dickens has Oat Genomics Done for You Lately ?

The Groats of Christmas
Past, Present, and Yet-to-Come

Nick Tinker
Ottawa Research and Development Centre

First, please appreciate the Oat Genome – in context:

12.7 Billion bp / 2 x 21 chromosomes
= 6 metres of DNA

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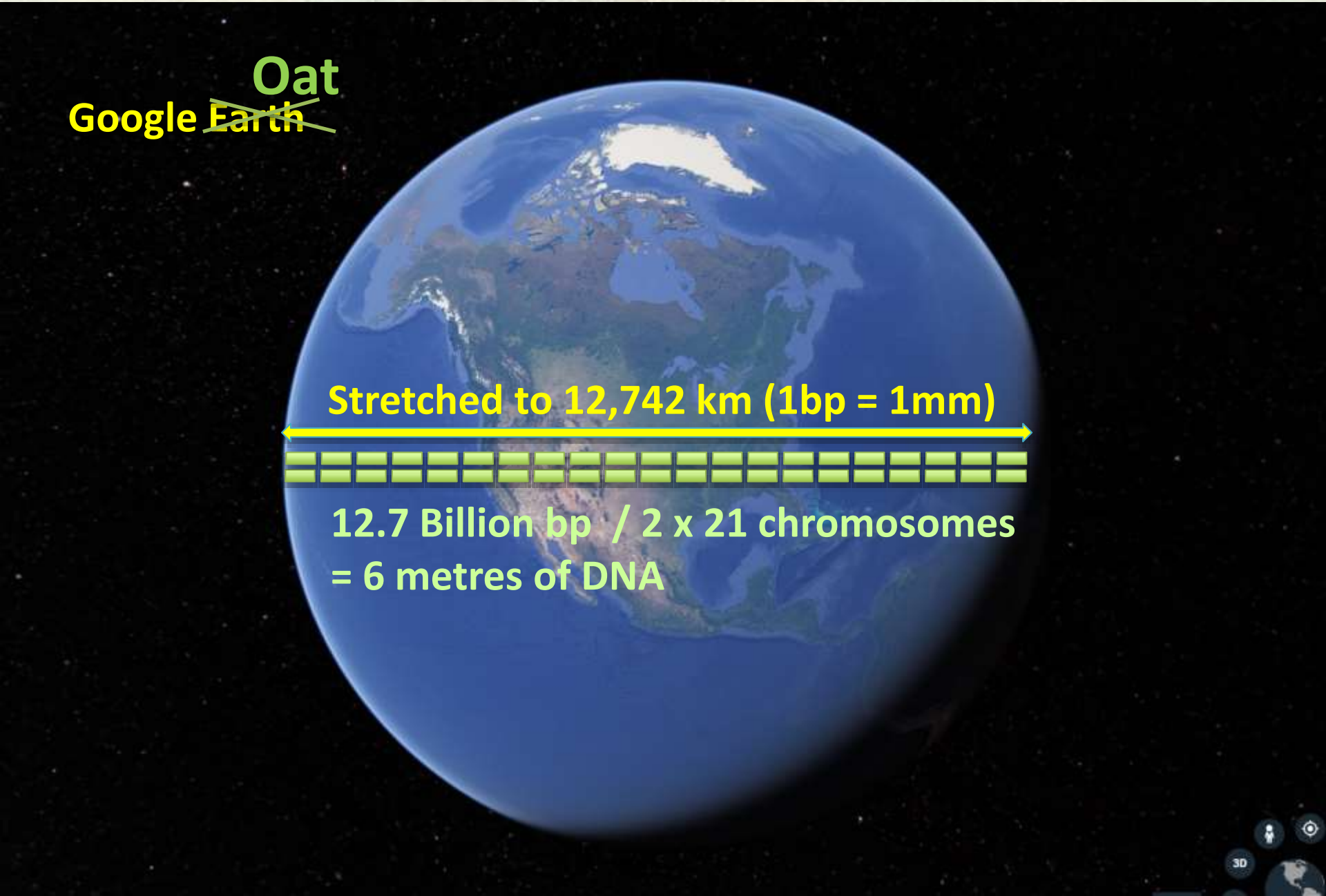
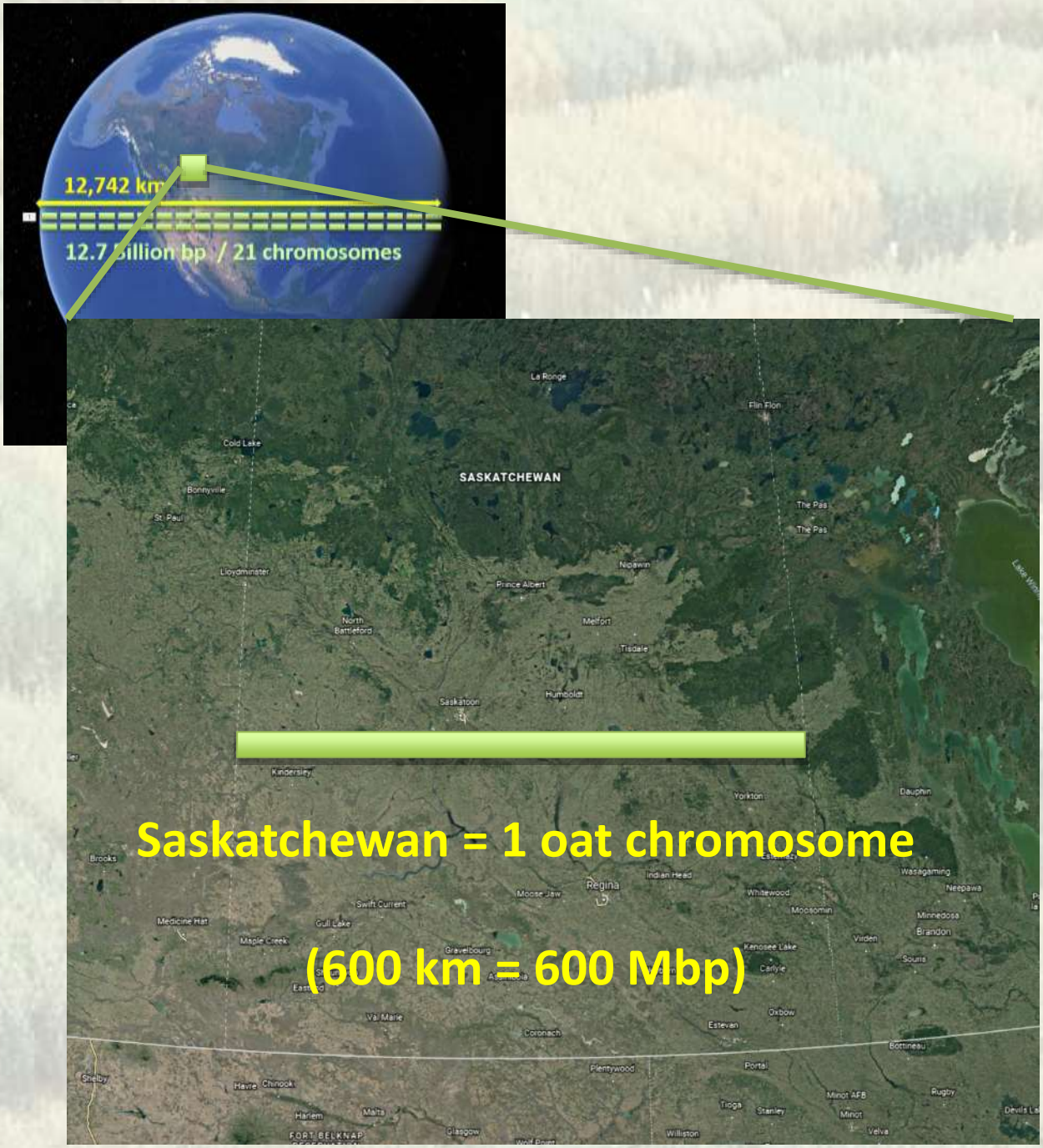
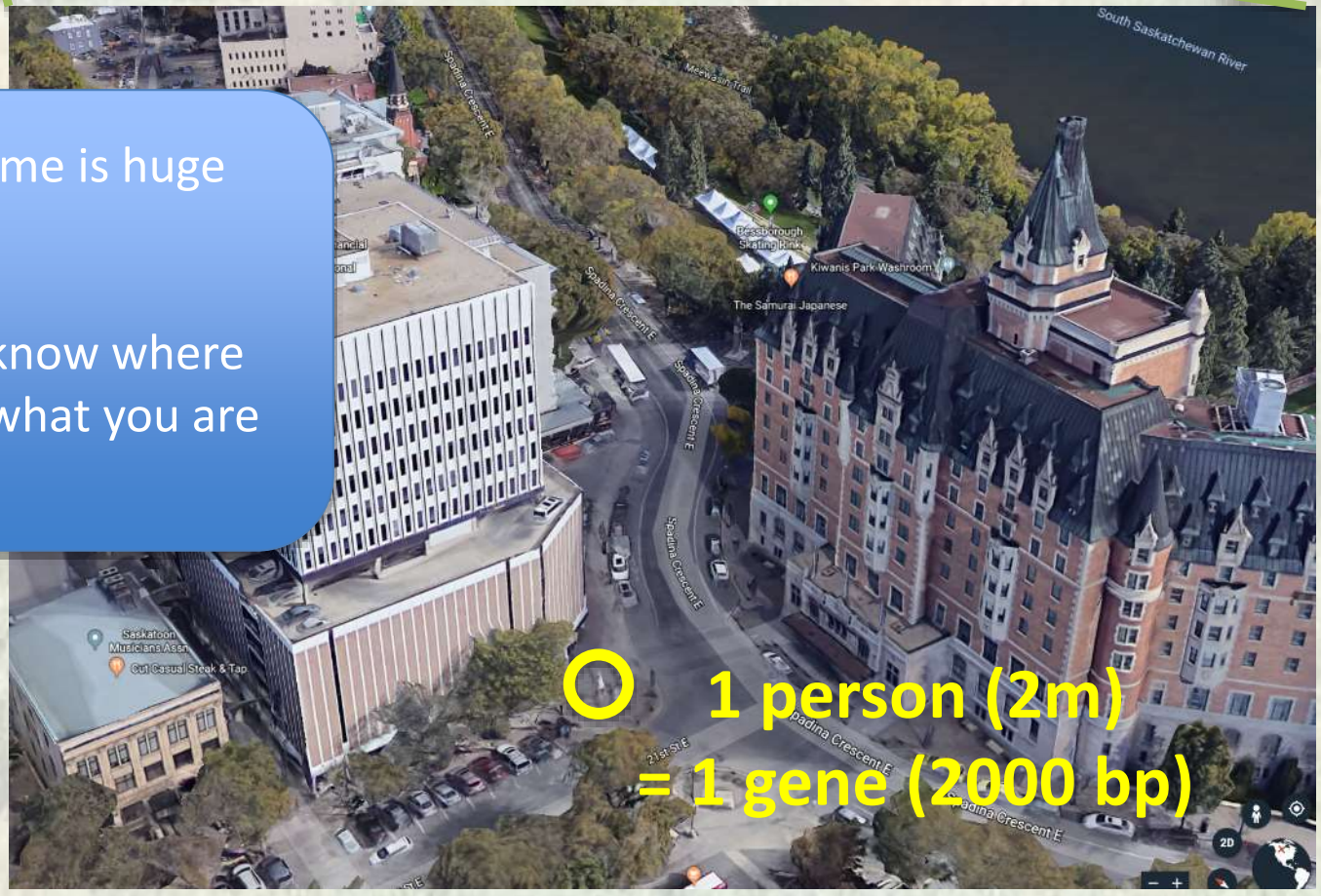



12,742 km
12.7 billion bp / 21 chromosomes
SASKATCHEWAN
Saskatchewan = 1 oat chromosome
(600 km = 600 Mbp)


Saskatchewan - 1 oat chromosome
(600 km = 600 Mbp)

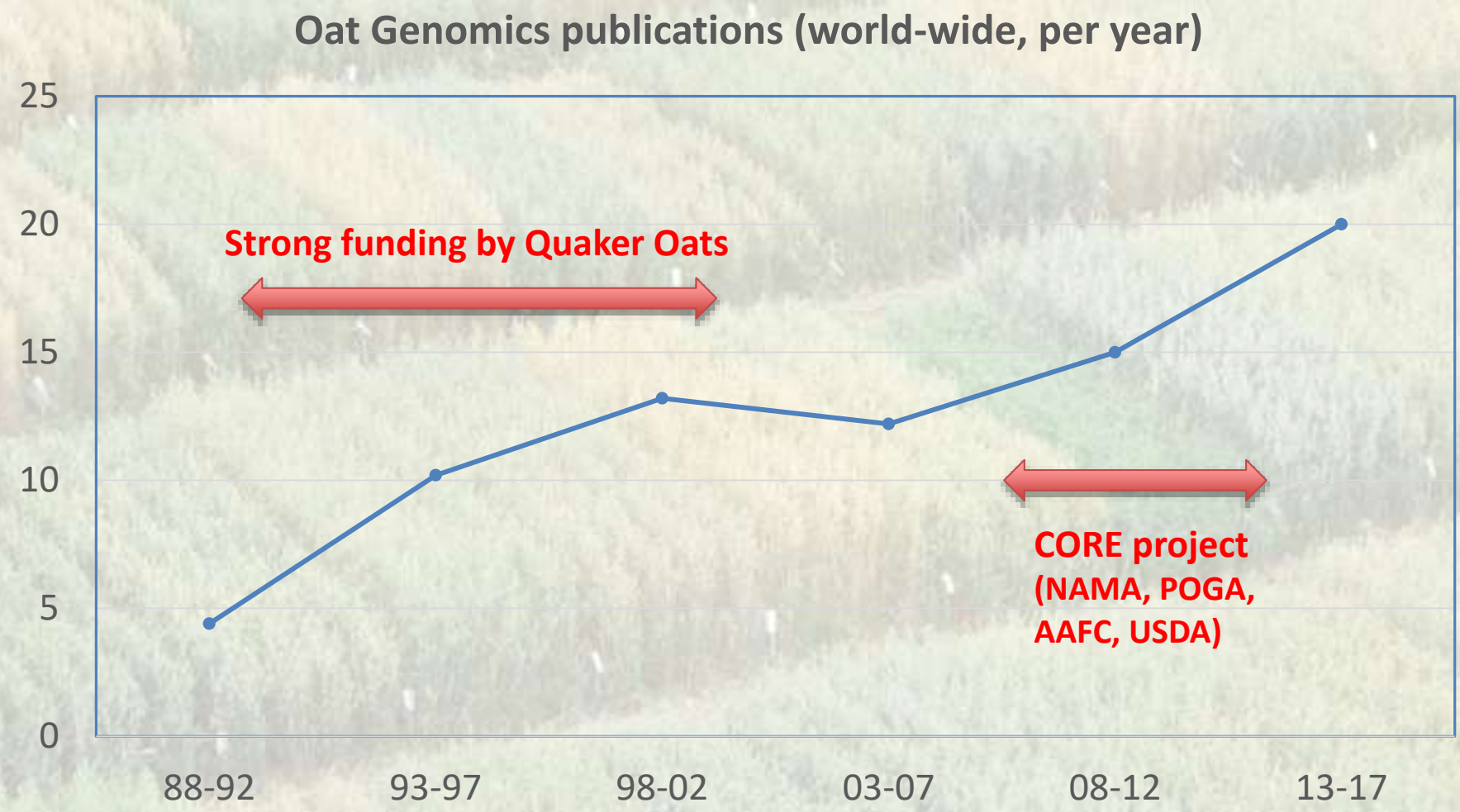

Saskatoon:
3 km (distance to university)
= 1 cM (on the oat genetic map)
WOODLAWN
MAYFAIR
NORTH PARK
CENTRAL INDUSTRIAL
CITY PARK
UNIVERSITY OF SASKATCHEWAN MANAGEMENT AREA
CASWELL HILL
ESTMONT
Saskatoon
CENTRAL BUSINESS DISTRICT
RIVERSDALE
ALBERT
NUTANA
KING GEORGE
GROSVENOR PARK
Google

1. The oat genome is huge and complex
2. You need to know where to look, and what you are looking for

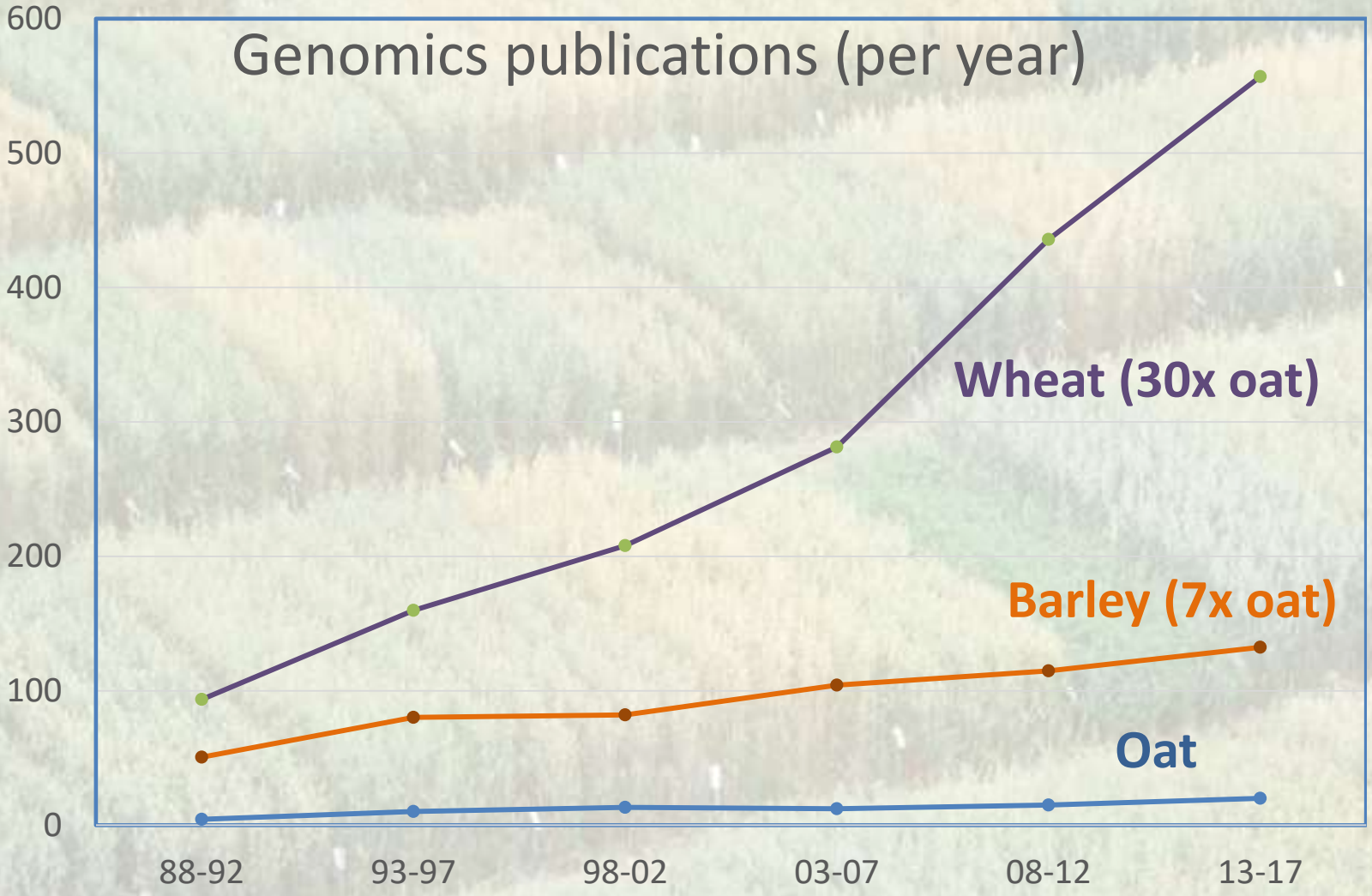


The “groats of Christmas Past”

30 years of oat genomics ….



Reality check…….



What have we accomplished ?

- Essential genomics Infrastructure
  - Integrated genetic map (despite complex genome)
  - Molecular markers (as good as other crops)
  - QTL studies (map locations of genes)
- Marker assisted selection for key rust genes
- Understanding and broadening of germplasm
- Complete genome sequences in progress
  - Wild relatives (smaller genomes)
  - Cultivated oat (US nearly complete + Swedish group…)

The ‘past’ should not be ‘passed’

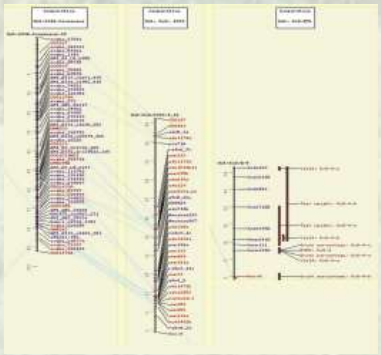
Charlene Wight, AAFC

Oat Newsletter (OatNews.Org)

Pedigrees of Oat
(Pool.aowc.ca)

T3 Oat
(triticeaetoolbox.org/oat)
Unpublished data sets

GrainGenes
(wheat.pw.usda.gov)
Published data



The Groats of Christmas Present

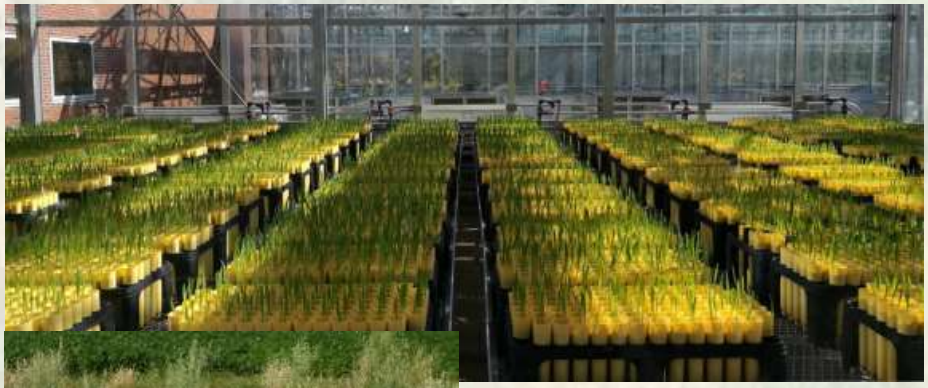
* Focus on genomic selection (largest impact)

Plant breeding takes 10 to 12 years

Year 1	• F0 (80 -90 crosses) • F1 (500 lines)
Year 2	• F2 -> F4
Year 3	• F5 hills **(10,000)**
Year 4	• F6 observation plots **(1,200)**
Year 5	• Home test **(300)** • 2 reps @3-4 sites
Year 6	• Preliminary trials • 60 lines @ 10 sites
Year 7-9	• Registration trials • 30 lines @ 10 sites
Year 10-12	• Seed increase

Weikai Yan – Oat Breeder, AAFC Ottawa

10,000 potential oat varieties……



Mostly visual selection

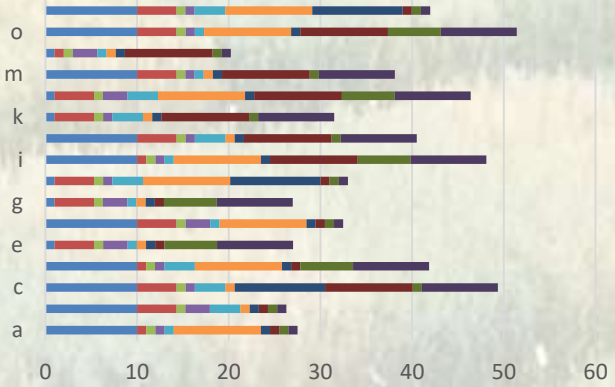
Multi-year
Multi-location
Large plots

- **Year 1**
  - F0 (80 -90 crosses)
  - F1 (500 lines)
- **Year 2**
  - F2 -> F4
- **Year 3**
  - F5 hills **(10,000)**
- **Year 4**
  - F6 observation plots **(1,200)**
- **Year 5**
  - Home test **(300)**
  - 2 reps @3-4 sites
- **Year 6**
  - Preliminary trials
  - **60 lines** @ 10 sites
- **Year 7-9**
  - Registration trials
  - **30 lines** @ 10 sites
- **Year 10-12**
  - Seed increase **(1 variety)**

Genomic Selection

Phenotypes + genotypes

```
TAGCACTRATGTCAGTANAAGR
          5         6
TAGCACTAATGTCAGTACAAGA
TAGCACTAATGTCAGTACAAGG
TAGCACTAATGTCAGTATAAGA
TAGCACTAATGTCAGTAGAAGA
TAGCACTGATGTCAGTATAAGA
```



Prediction model

Training population

Genotyping & Phenotyping

Train GS model

DNA

Breeding material

Genotyping

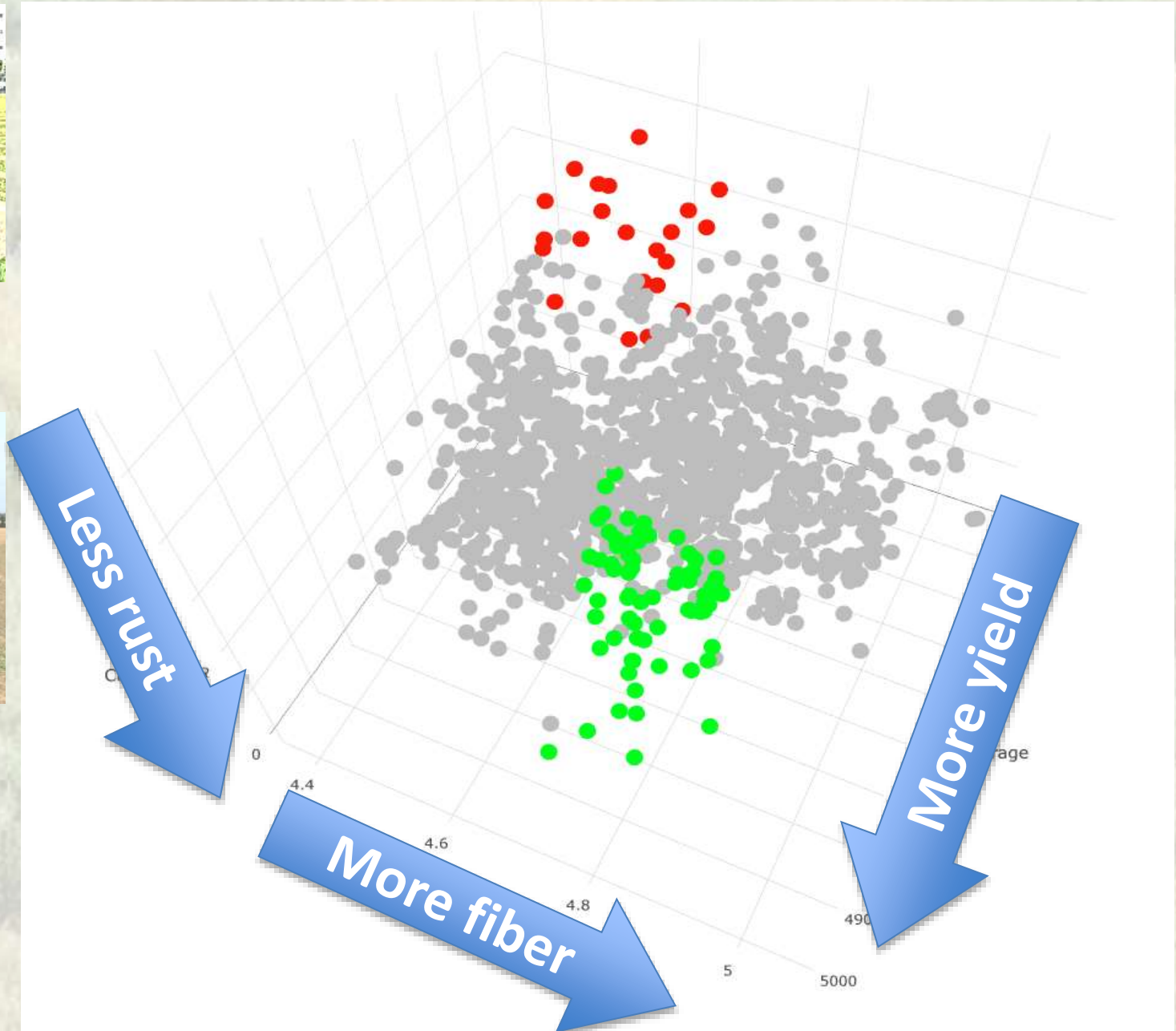
Make Selection

```
TAGCACTRATGTCAGTANAAGR
          5         6
TAGCACTAATGTCAGTACAAGA
TAGCACTAATGTCAGTACAAGG
TAGCACTAATGTCAGTATAAGA
TAGCACTAATGTCAGTAGAAGA
TAGCACTGATGTCAGTATAAGA
```

Genomic selection (2018 - 3 traits)

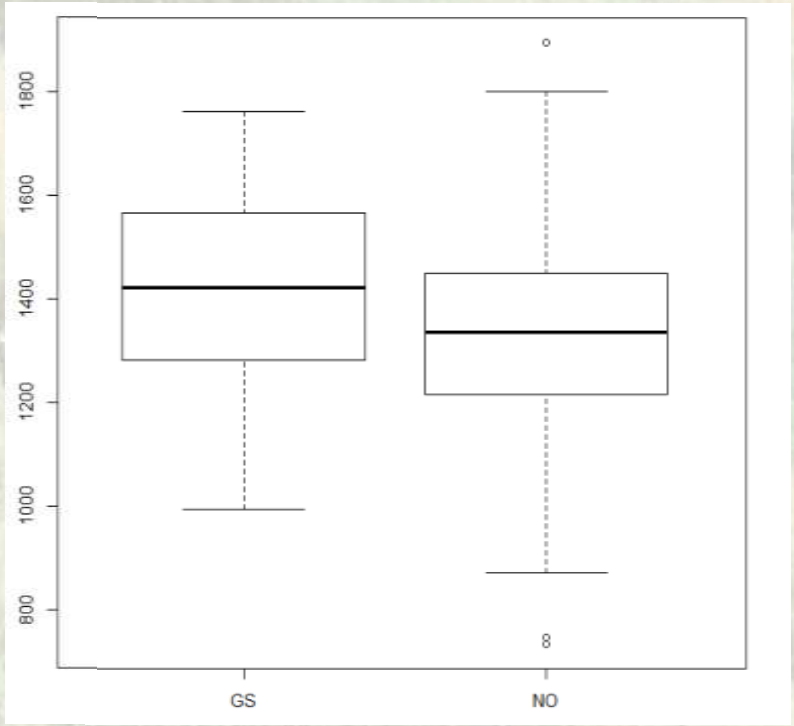
Asuka Itaya

Wubi Bekele



Genomic selection: Validations (2016 → 2018)

Lines selected based on DNA show
higher yield than those selected visually



Genomic selected

Visually selected

The Groats of Christmas
Yet to Come…

Goals

- Genomic selection:
  - Faster, cheaper, more automated
    - E.g. next-year's GS will cost < $15 per sample
  - Prediction is better through more training environments (and experience)
  - GS is cost-effective and indispensable

Goals (continued)

- Oat is fully sequenced (more than once)
- Historical info and model species link to oat genome sequence database
    - What do genes do ? Why are they important ?
- Gene diversity database
    - What versions of these genes exist in oat ?
- Gene editing (for gene validation)
- Genomic selection integrated with high-value target genes…
    - What do I mean by this??

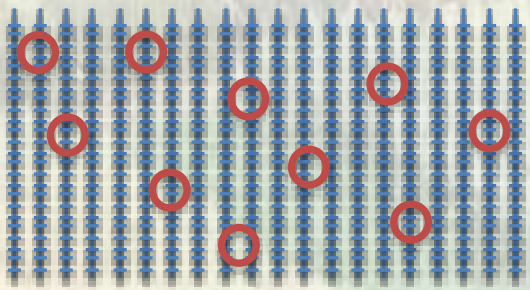
Genomic selection vs target genes

1990 - 2010:
- Map genes and select them one-by-one

2010 - 2015:
- This is not working very well!

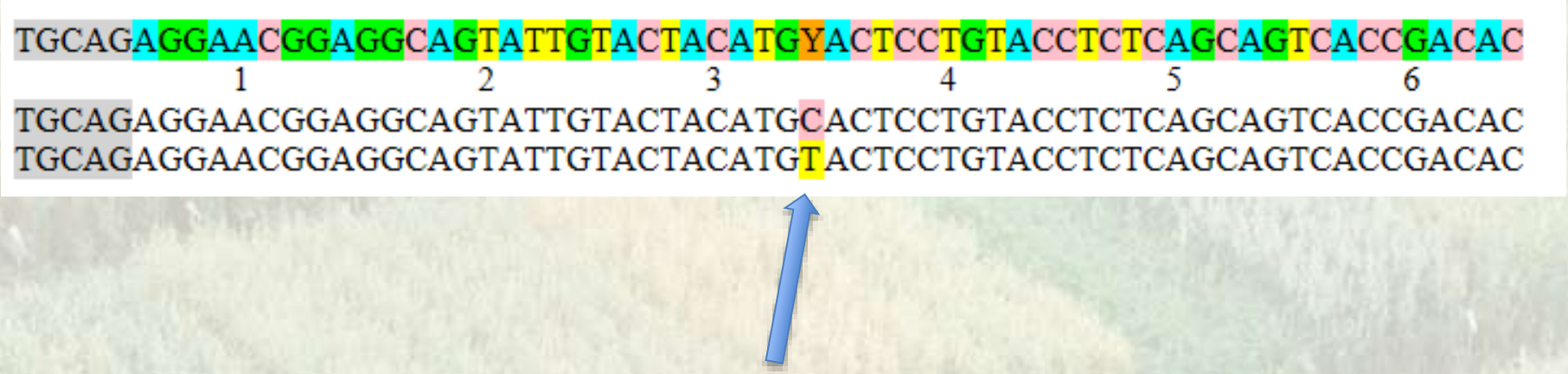
Quantitative Trait Locus (QTL)
- Small part of one trait
- limited accuracy

2015-2020:
- Genotype the whole genome
- Statistical models, weighted markers
- Integrates well with breeding



2020-2030 ?
- In depth biochemistry & physiology
- Identify gene versions with large effects
- Combine with knowledge from genomic selection
- = Integrative genomic breeding

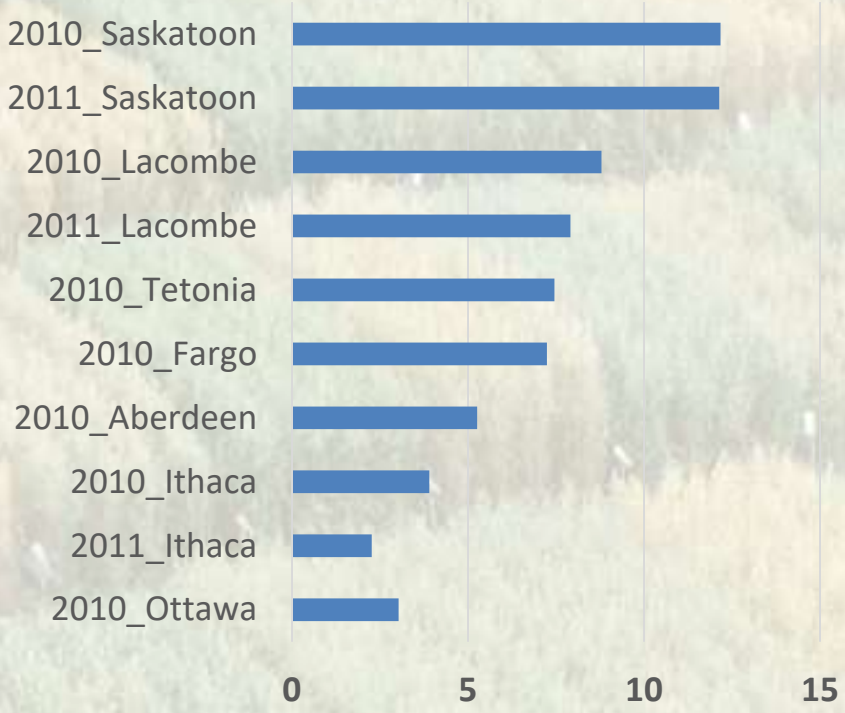
Example: marker “avgbs_201782”



Every oat we have tested has either the “C” or “T” version

Effect of “C” vs “T” (averaged over 400 spring oats)

“C” makes oats yield more

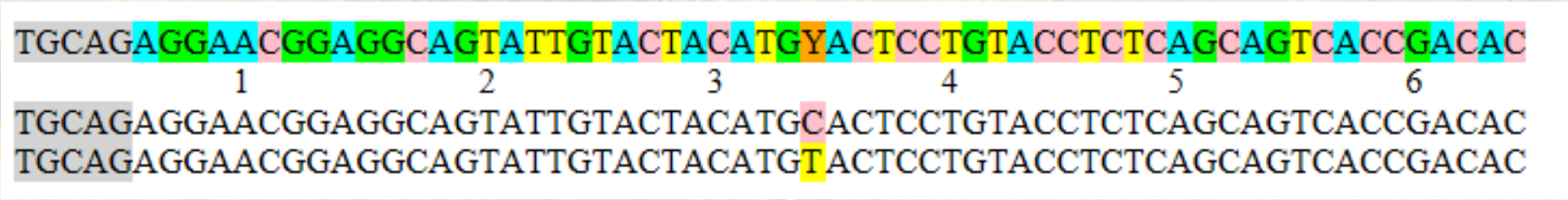


% yield increase (C vs T)

“C” makes oats head later

Days to heading (C vs T)

avgbs_201782



- Avgbs_201782 = linked to a gene that responds to long days.
- I hope our future work will prove this, and characterize the gene

- Then what. Who cares?
  - Often we cross with germplasm containing the “T” version
  - Then we need to re-select the “C” version
  - Genomic selection can accomplish this

  - But if we are deliberate in our selection of this gene, GS can be more efficient in dealing with other genes.

Traits where one gene can make a difference

- Rust (AAFC/USDA)
- Dwarfing (AAFC/UK)
- Flowering time (AAFC)
- B glucan and oil (AAFC/USDA/Cornell)
- Drought (AFFC/Spain)

Value of oat genomics in Canada ???

1% yield increase = $ 10 M

1% value increase = $ 10 M

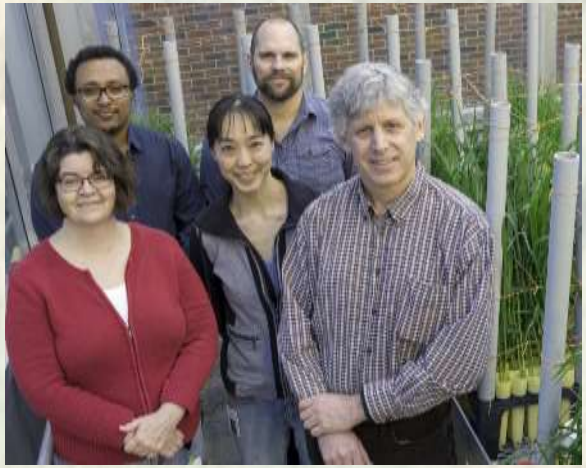
1% export increase = $ 5 M …. Etc…

Or… (if we don't keep up):

- Cost of losing oat as a commodity ?
- Cost of losing export share ?
- Cost of losing Canadian-owned varieties ?

What do you think… Let's talk!

Thank You



Prairie Oat Growers Association

PEPSICO

North American Millers' Association NAMA

SeCan Canada's Seed Partner

GENERAL MILLS

GRAIN MILLERS

RICHARDSON

GRAIN FARMERS OF ONTARIO

Atlantic Grains Council

PRODUCTEURS DE GRAINS DU QUÉBEC

Agriculture and Agri-Food Canada