# Nitrogen Use Efficiency in spring canola: Steps towards getting more from less

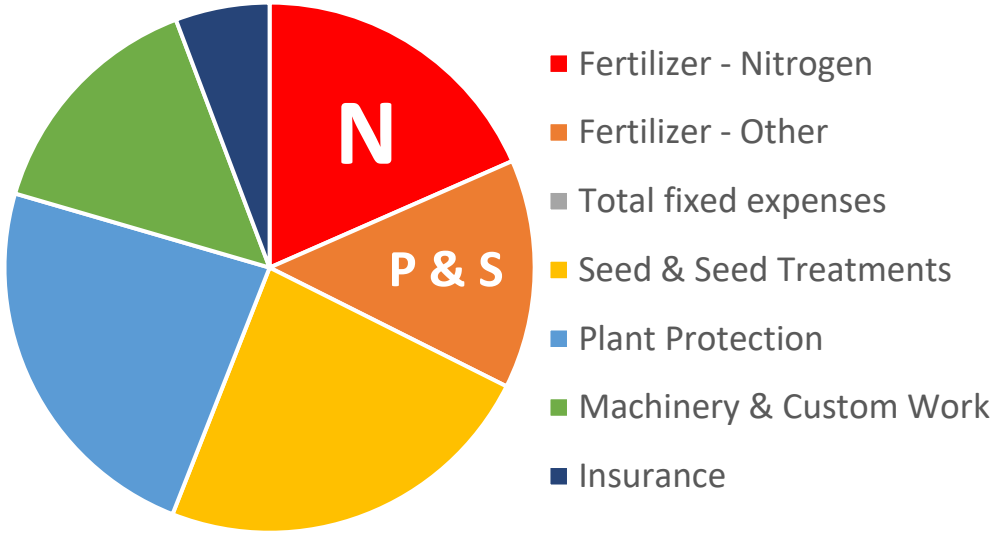
**Sally Vail**

**GCIRC Technical Meeting**
**Cambridge, UK**
**April 10th, 2025**

# Background

## Economic Considerations

Variable Expenses in the Dark Brown & Black Soil Zones




[Crop Planning Guide and Crop Planner | Saskatchewan Farm Business Management | Government of Saskatchewan]

## Environmental Considerations


Between 2005 and 2019, fertilizer use INCREASED BY 71% IN CANADA, while $N_2O$ emissions from FERTILIZER APPLICATION INCREASED BY 54%.

Maximize fertilizer efficiency

Reduce greenhouse gas emissions

target to reduce fertilizer emissions by **30% by 2030**

Maintain or increase yields

**Our goal is to reduce harmful emissions while supporting fertilizer efficiency and increasing yields.**

[Canada's fertilizer emissions reduction target - agriculture.canada.ca]

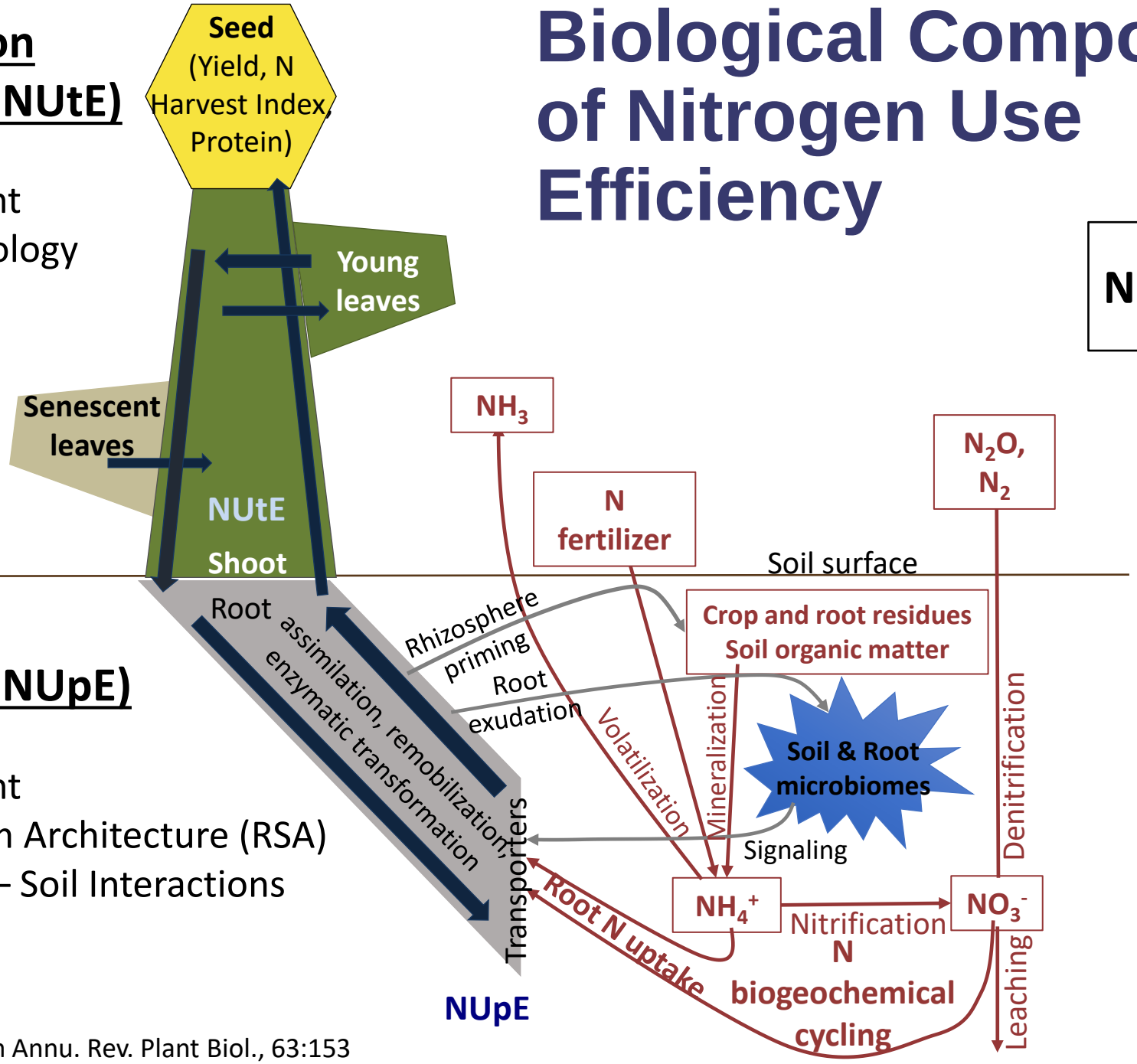
# Biological Components of Nitrogen Use Efficiency

**NUE** = NUpE + NUtE

**N Utilization Efficiency (NUtE)**
- Agronomy
- Environment
- Plant Physiology

**N Uptake Efficiency (NUpE)**
- Agronomy
- Environment
- Root System Architecture (RSA)
- Plant Root – Soil Interactions

NUE




Other NUE Indices:
- $NUE_{yield}$
  - Yield-based NUE
- $NUE_{crop}$
  - Crop-based NUE
- NHI
  - Nitrogen harvest Index
- NNI
  - Nitrogen nutrition index
- PFP
  - Partial-factor Productivity
- Many others

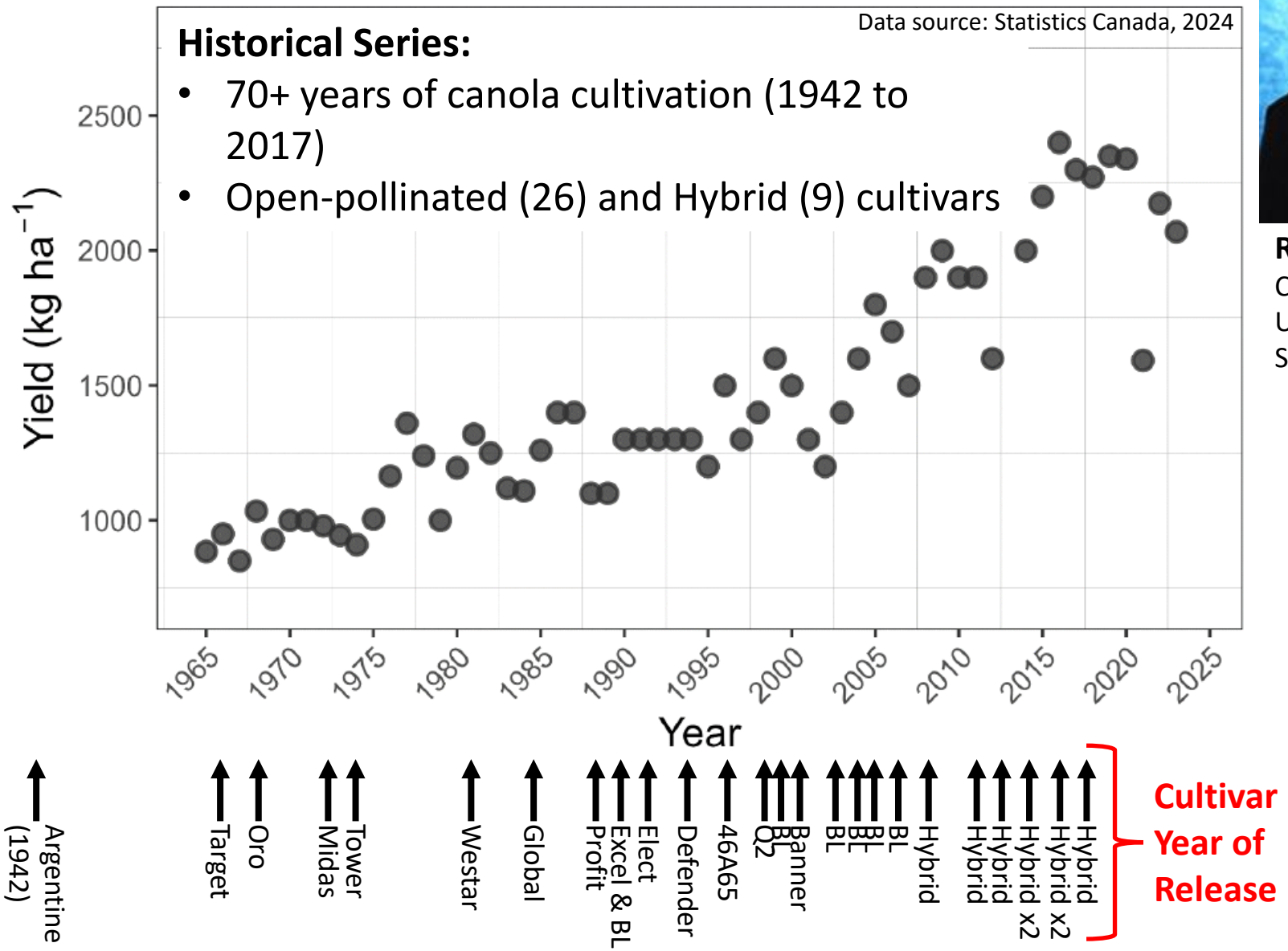
Adapted from Annu. Rev. Plant Biol., 63:153

# Overview

- **Canadian Rapeseed to Canola: Changes in NUE over the past 75 years**
- **Prospects for improved NUE: Diversity for NUE-related traits in spring *Brassica napus***
- **Overcoming the technical challenges: Tools and protocols for field assessment of NUE**

- **Previous Knowledge Gaps:**
  1. Focused on yield-based NUE rather than whole-plant NUE metrics
  2. Limited studies in spring *Brassica napus* for cultivar/ genotype variation in NUE metrics

# Canadian Rapeseed to Canola




**Rosalind Bueckert**
Crop Physiology
University of Saskatchewan

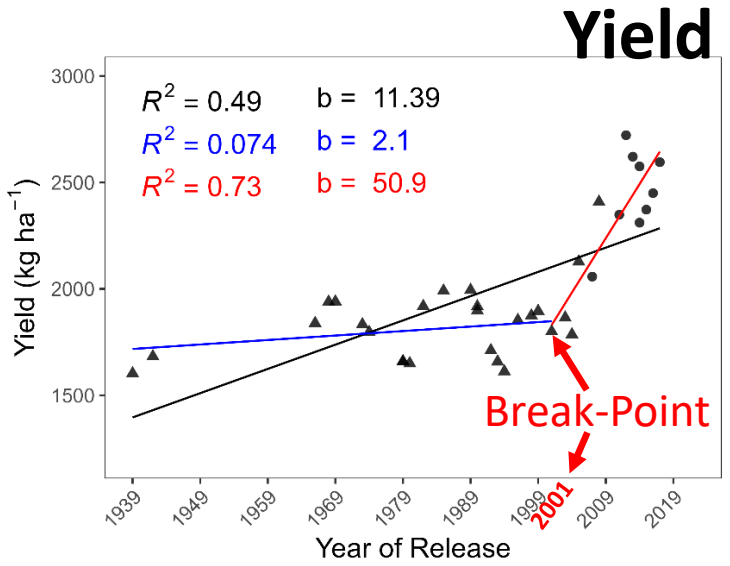
**Raju Soolanayakanahally**
Plant Physiology
AAFC

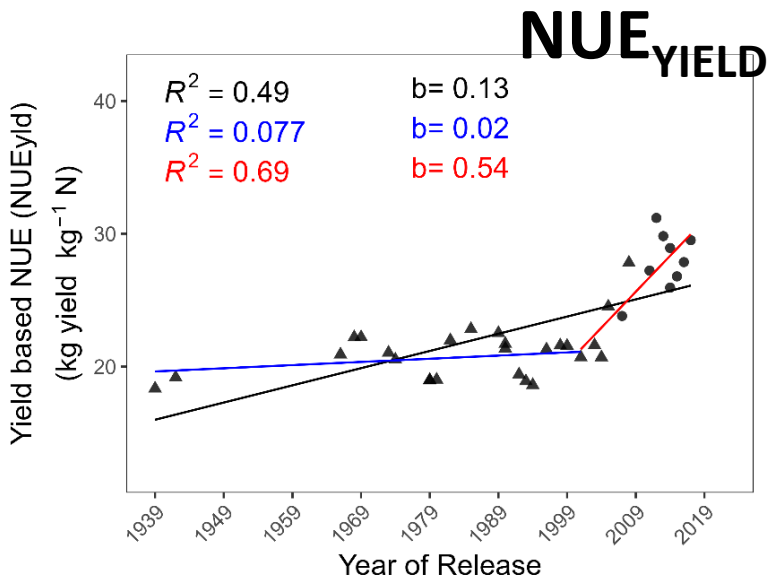
**Initial conception of the historical series**

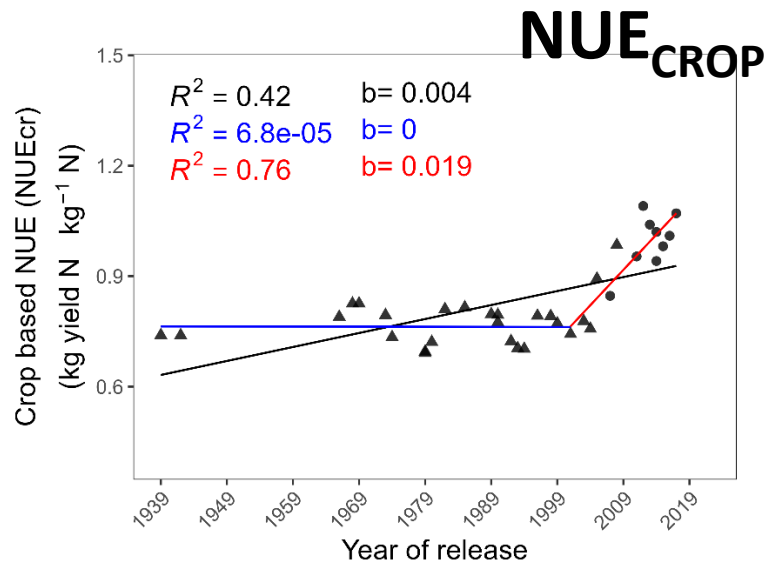
# Canadian Rapeseed to Canola

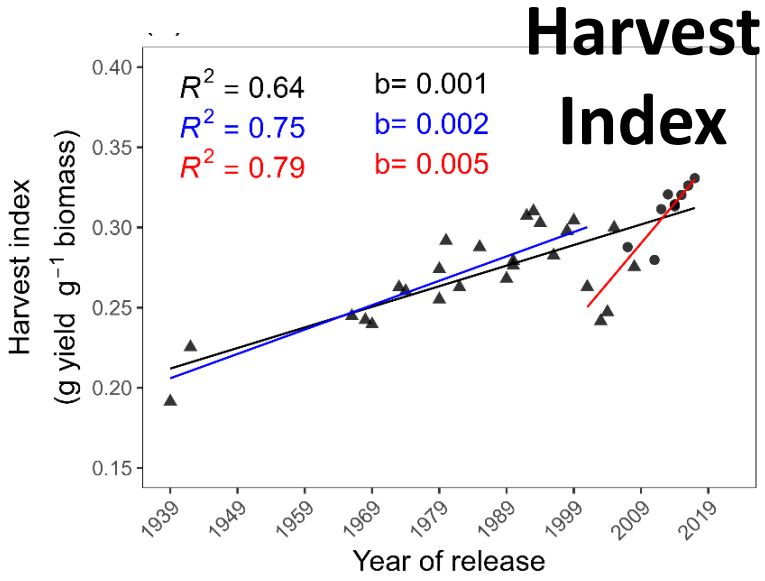
- **Historical Series Grown:**
  - 2019 & 2020
  - Saskatoon & Melfort, SK
  - Fertilization rates:
    - Low (60Kg/ha)
    - High (120 Kg/ha)
  - Measured for:
    - Yield and seed quality
    - Standard agronomic traits
    - N-Uptake, in-plant distribution and N partitioning, throughout lifecycle
    - NUE Indices:
      - $NUE_{YIELD}$, $NUE_{CROP}$, NUtE, NUpE, NHI

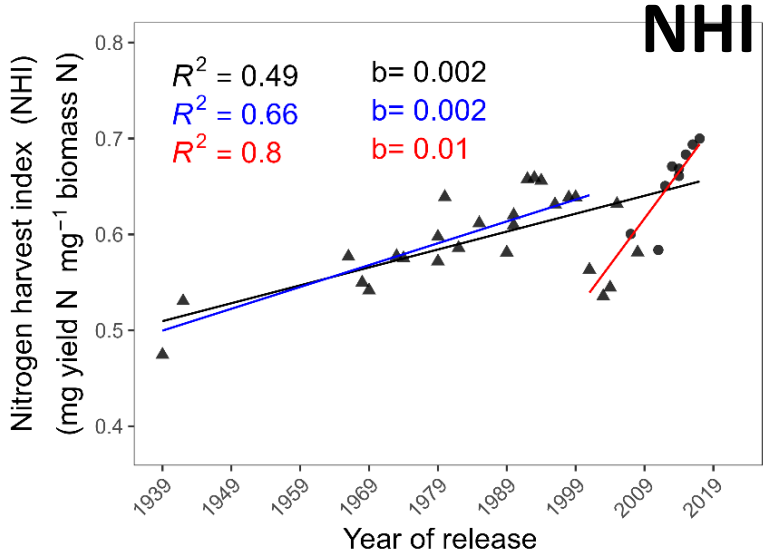
# Canadian Rapeseed to Canola: Segmented Regression

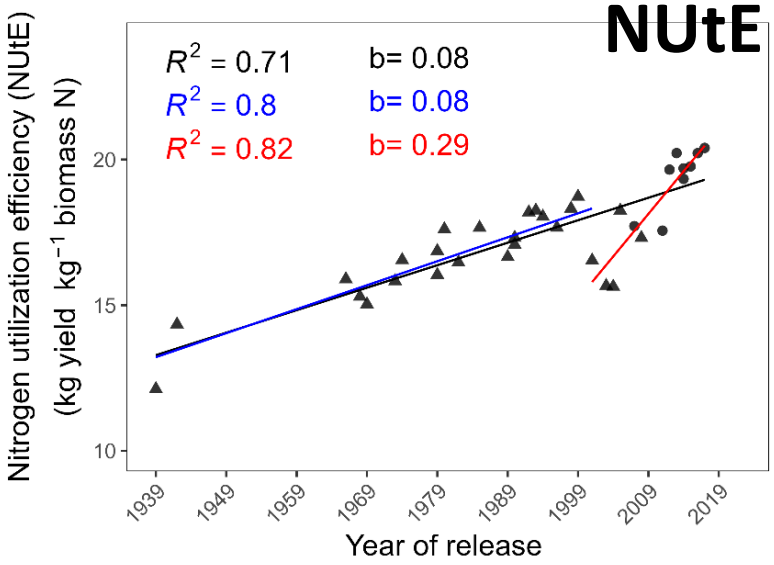


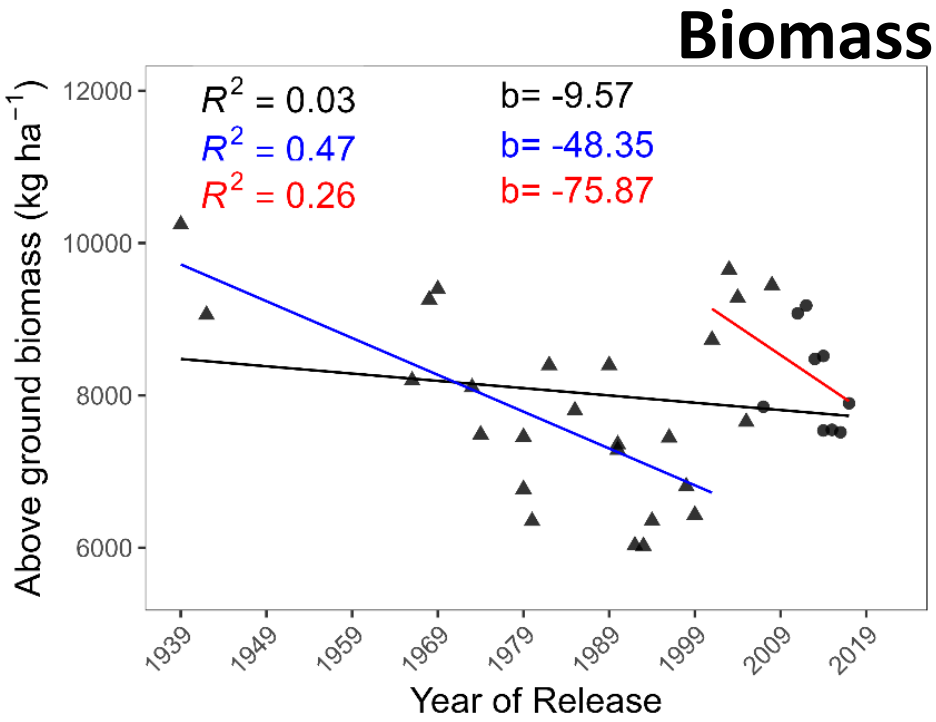



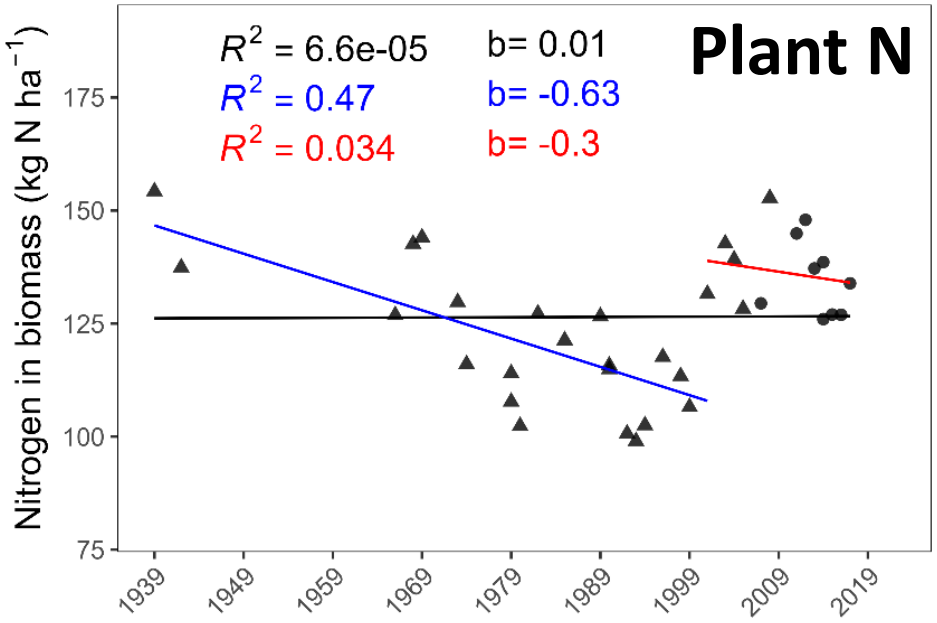



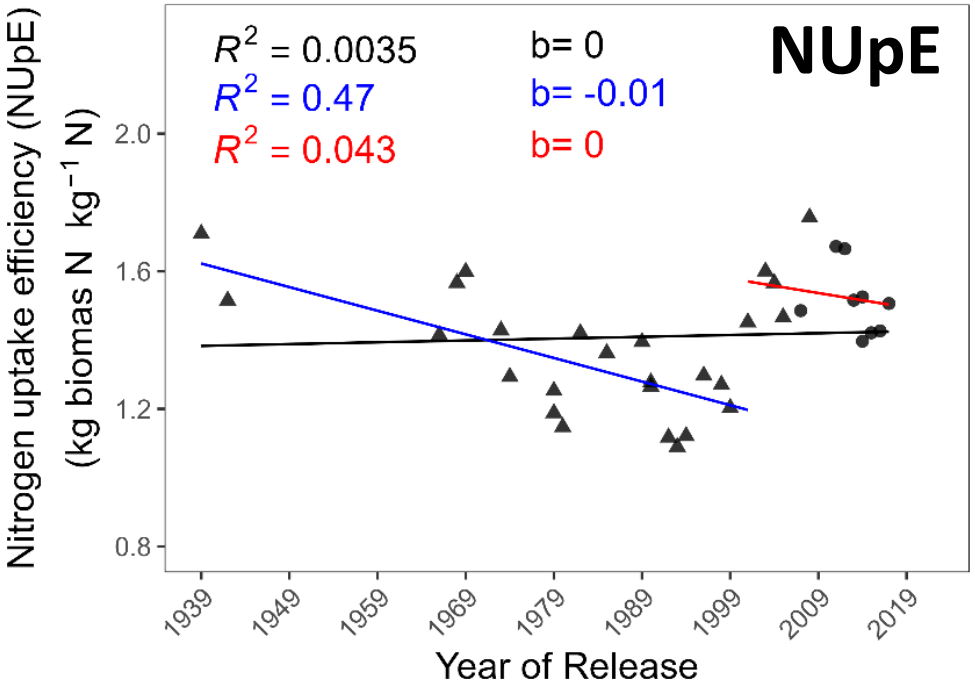




Dhakal *et al.*, in prep.

# Canadian Rapeseed to Canola: Segmented Regression

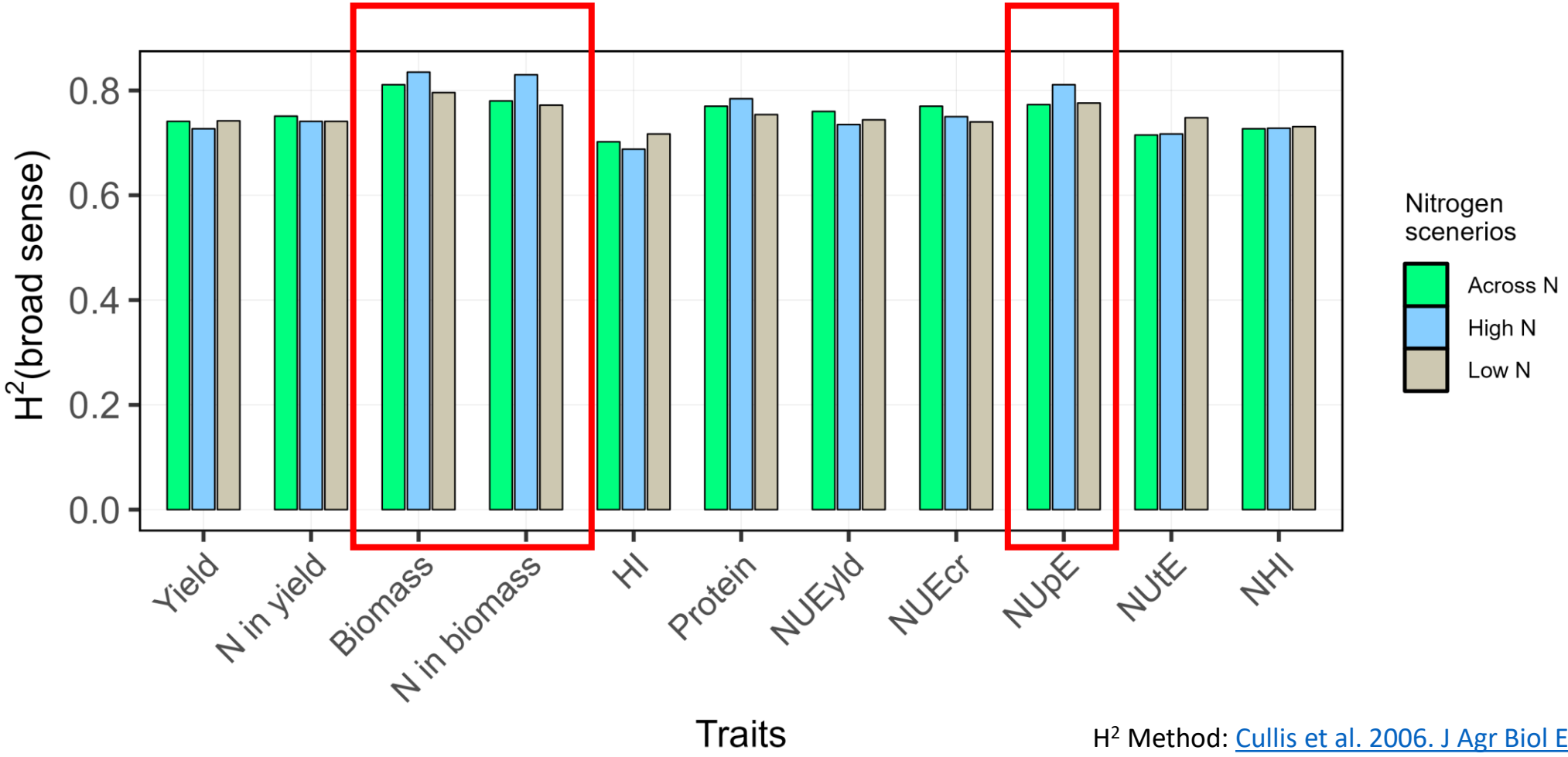



Dhakal *et al.*, in prep.

# Canadian Rapeseed to Canola:
## Broad-Sense Heritability for NUE Indices & Traits




$H^2$ Method: Cullis et al. 2006. J Agr Biol Envir Ss. 11:381

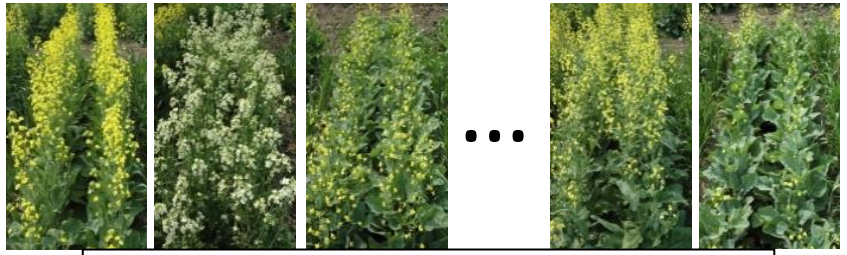
# Prospects for improved NUE:
## Diversity for NUE-related traits in spring *Brassica napus*

- **NAM Founder Lines Grown:**
  - 2019, 2020 & 2024
  - Saskatoon, SK
  - Fertilization rates:
    - Low (60Kg/ha)
    - High (120 Kg/ha)
  - Measured for:
    - Yield and seed quality
    - Standard agronomic traits
    - N-Uptake, in-plant distribution and N partitioning, throughout lifecycle
    - NUE Indices:
      - $NUE_{YIELD}$, $NUE_{CROP}$, NUtE, NUpE, NHI
    - Digital phenotyping traits

**Isobel Parkin**
Brassica Genomics

**Steve Robinson**
Plant Physiology & Genomics

**Spring *B. napus* NAM Population**



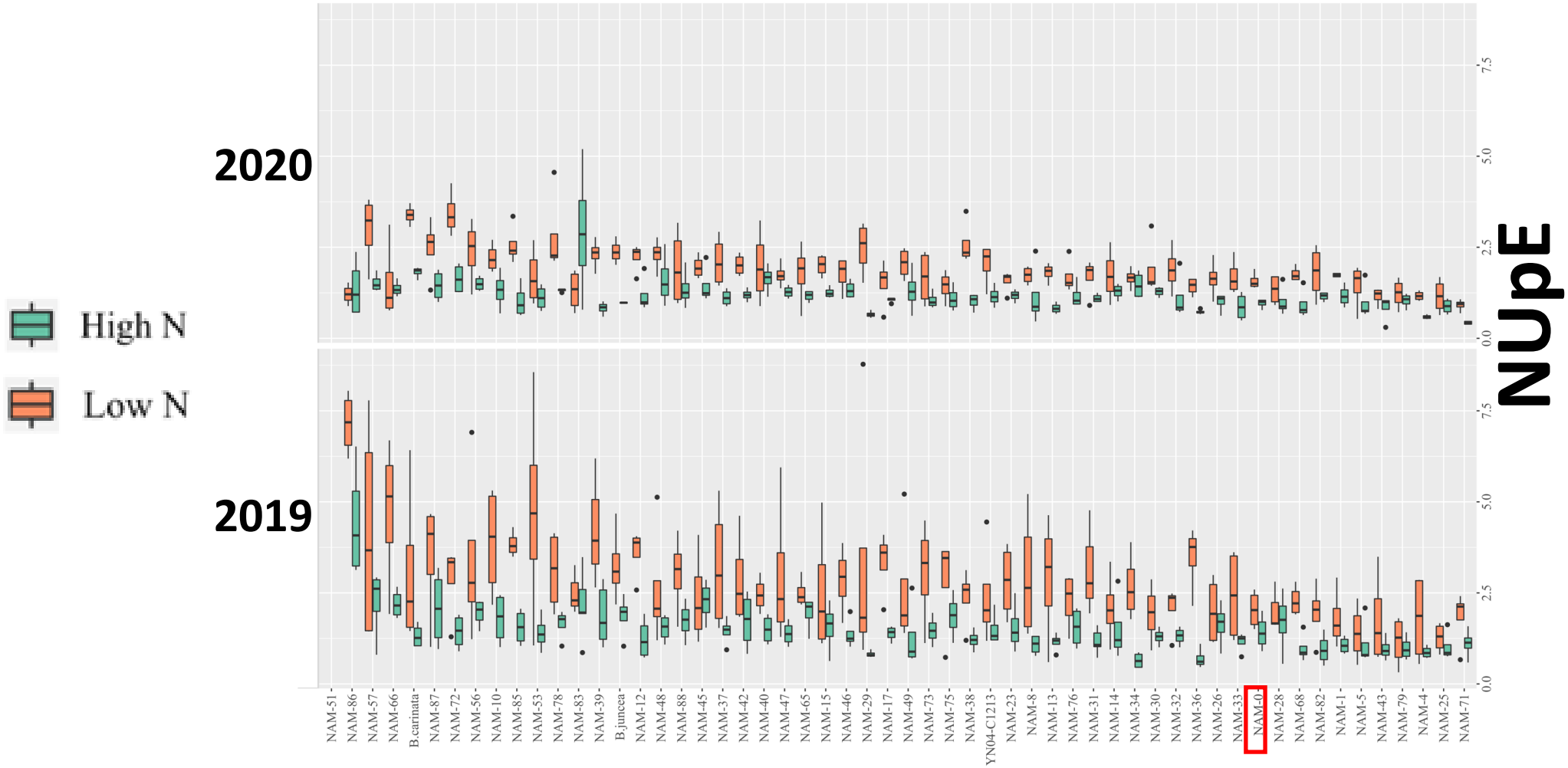
50 Diverse Founder Lines

X

Reference Line

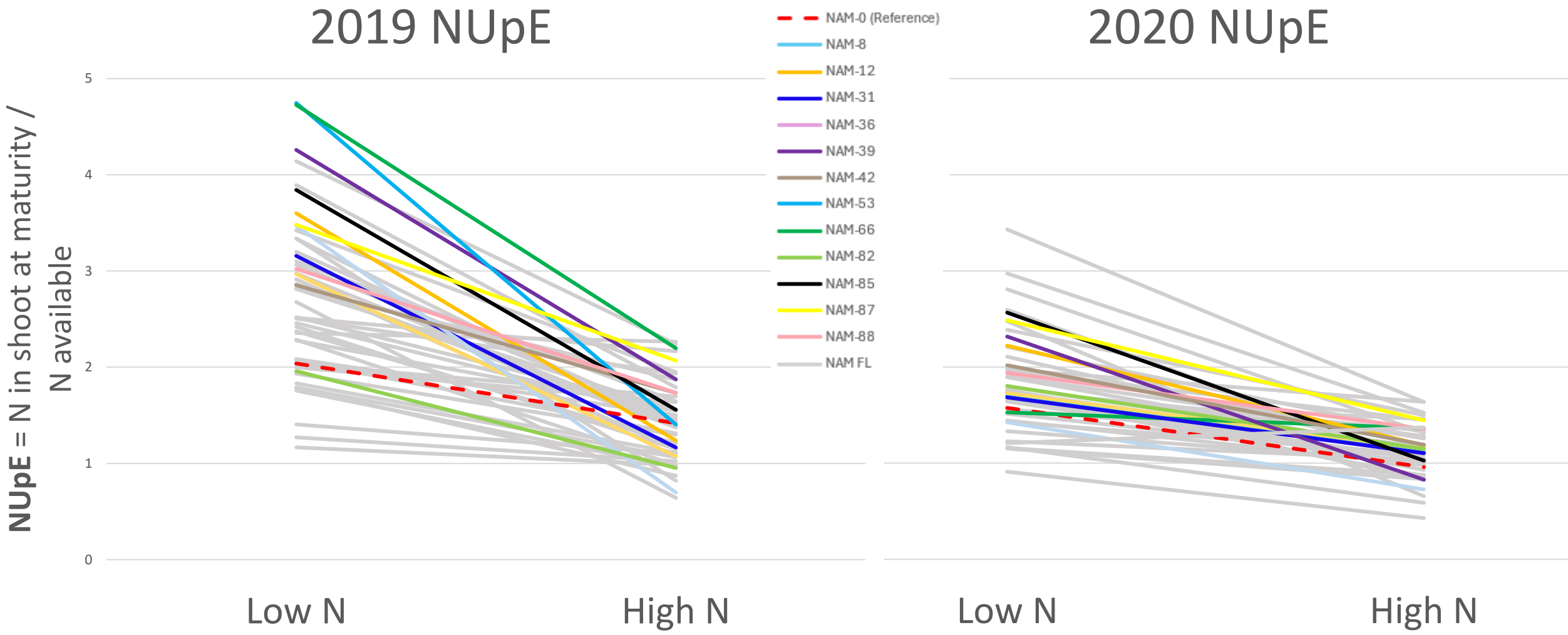
2500 Lines

# Prospects for improved NUE: Diversity for NUpE




van Steenbergen *et al.*, in prep.

# Prospects for improved NUE: Diversity for N-responsiveness in NUpE



# Overcoming the technical challenges: NUE Tools

## Aerial Digital Phenotyping

DJI M600 Pro

RedEdge-MX & Blue (Multispectral)

plot vision

OPAL Omics and Precision AGRICULTURE LABORATORY

P²IRC Plant Phenotyping and Imaging Research Centre

**Sarah van Steenbergen, MSc**

<u>Established Indices</u>

OSAVI=Optimized Adjusted Vegetation Index
WDRVI=Wide Dynamic Range Vegetation Index
NDVI=Normalized Difference Vegetation Index
NDRE=Normalized Difference RedEdge
CCCI=Canopy Chlorophyll Content Index
CIrededge=Chlorophyll Index Rededge

<u>New Indices</u>

NRGBrt=NIR, Red, Green Blue ratio

## NIR Calibrations for Tissue N

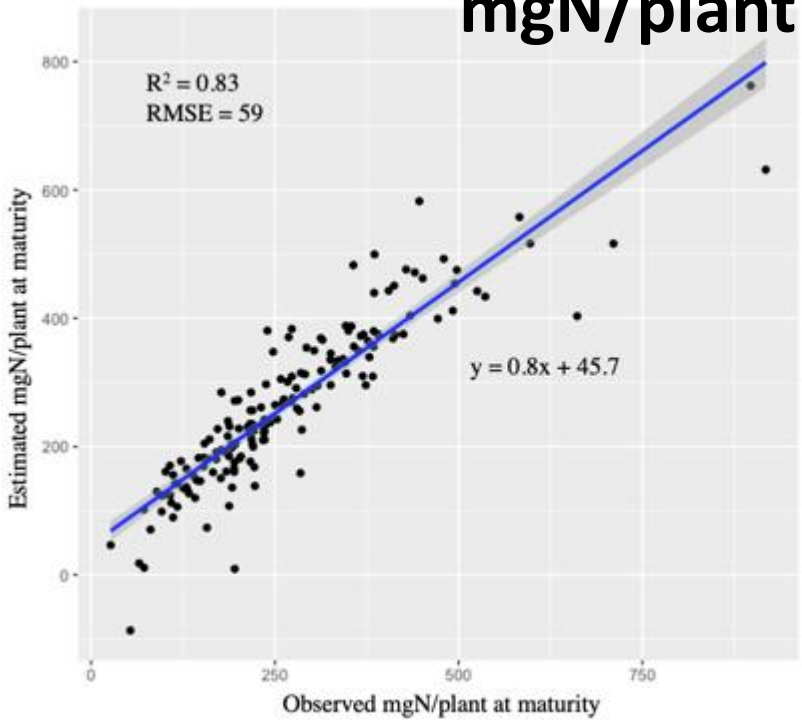
| Plant tissues | Total no. of samples | Calibration Set | | Validation Set | |
|---|---|---|---|---|---|
| | | $R^2$ | [a]SECV | $R^2$ | [b]SEP (c) |
| **Leaf** | 368 | 0.882 (n=323) | 0.120 | 0.991(n=45) | 0.089 |
| **Stem** | 728 | 0.994 (n=685) | 0.066 | 0.992 (n=40) | 0.075 |
| **Silique husk** | 312 | 0.998 (n=272) | 0.045 | 0.979 (n=40) | 0.053 |

[a]SECV: Standard Error of Cross Validation
[b]SEP (c): Standard Error of Prediction, corrected for bias

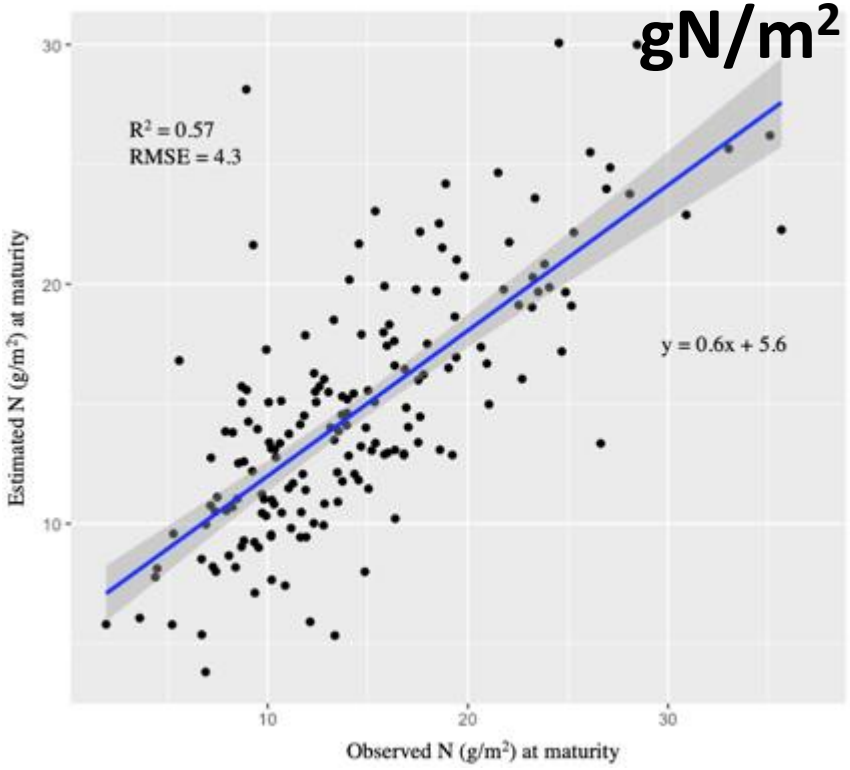
van Steenbergen *et al.*, in prep.

# NUE Tools: UAV Digital Phenotyping Predictions

**mgN/plant**




**gN/m²**




**Model Inputs**

Manual: Days to Flower, Days to Maturity, Reproductive Duration, Single Plant Biomass
Digital: F.OSAVI, F.WDRVI, F.NRGBrt, F.NDVI, F.NDRE, P.CCCI, P.NDVI

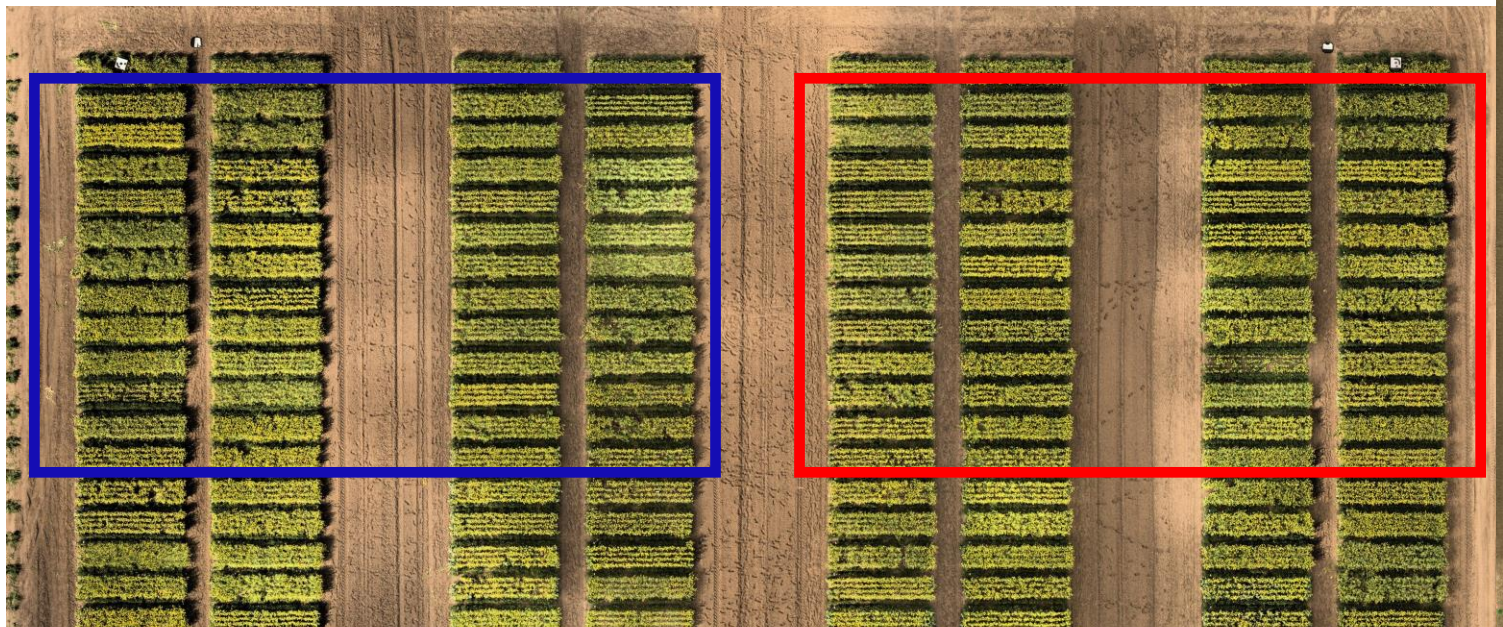
Manual: Days to Flower, Duration of Flower, Reproductive Duration
Digital: F.height, F.CIrededge, F.OSAVI, F. NRGBrt, P.NDVI, P.NDRE, P.NDYI

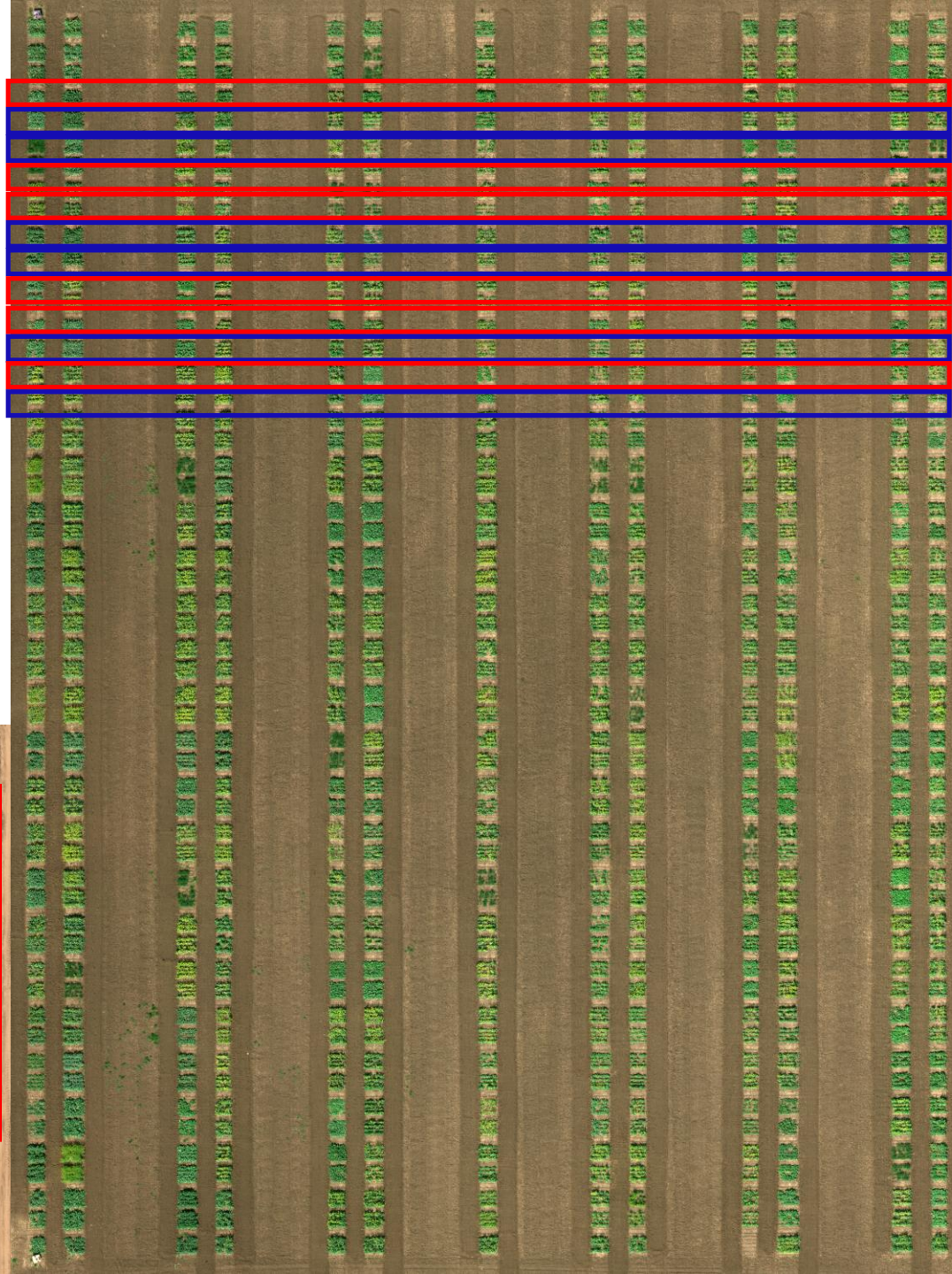
UAV Flight Timing:
F=Flowering
P=Pod-Filling

van Steenbergen *et al.*, in prep.

# NUE Tools: Trial Design

- **NAM parental panel (n=55):**
  - Yield plots
    - 6.9m$^2$, ~300 plots/ha
  - Split-plot design, 4 replications
- **NAM RIL families (n~500):**
  - Micro-plots
    - 1m$^2$, ~850 plots/ha
  - Split-block design, 3 replications





# Summary

- **Canadian Rapeseed to Canola:**
  - Little to no improvement in NUpE / Plant N / Plant Biomass
- **Prospects for improved NUE:**
  - Wide range in NUpE and N-responsiveness across spring *B. napus* available for trait-development
- **Overcoming the technical challenges:**
  - NIR calibrations and UAV-supported predictions for total plant N

# Funding & In-Kind

Canola seed companies supplied open-pollinated and hybrid seed under MTAs

Corteva supplied irrigation water in 2019

This research was initiated as part of the Canadian Agriculture Partnership 2018-2023

ALBERTA CANOLA

Manitoba Canola Growers

canolacouncil OF CANADA

Canada

Sustainable Canadian Agricultural Partnership

# University of Saskatchewan Collaborators

- **Crop Physiology lab** (Bueckert): Denys Solskyi, Evelyn Osorio, Endale Tafesse, Mohsen Ghamari, summer students
- **Grains Innovation Laboratory**: Connie Briggs
- **P²IRC Digital Phenotyping**: Ian Stavness, Steve Shirtliffe, John Sulik (University of Guelph)
- **OPAL Phenotyping and Genomics**: Andrew Sharpe, GIFS
- **Soil Science Collaborators**: Drs. Melissa Arcand and Bobbi Helgason, Department of Soil Science

University of Saskatchewan

plot vision

OPAL Omics and Precision Agriculture Laboratory

P²IRC Plant Phenotyping and Imaging Research Centre

# AAFC Collaborators & Technical Support

- **AAFC Saskatoon canola field team** (Vail): Brad Hope, Stacey Lingelbach, Greg Ford, Paul Prodahl, Caroline Brown, David Sarich, Len Chester, Julie Tench, Morgan Lindman-Hovland, summer and coop students
- **AAFC Saskatoon farm staff**: Ryan Vetter, Ryan Luciuk and Stacy Shirley
- **AAFC Digital Phenotyping**: Hema Duddu, Kiran Baral, Theron Cory
- **AAFC Melfort field team**: Brett Mollison, Brett Hrynewich, Keely Tallon, Colleen Nielsen and summer students
- **Oilseeds Quality Lab**: Rong Zhou, Ning Xu
- **Soolanayakanahally lab**: Shankar Pahari
- **Parkin lab**: Erin Higgins, Jana Ebersbach, Sampath Perumal, Yogendra Khedikar, Adrian Cabral, Brian James
- **Robinson lab**: Kyla Horner, Tricia Bender
- Reynald Lemke, AAFC Soil Nutrient Cycling
- Jennifer Town, AAFC Soil Microbiology