Common bean cultivar mixtures

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FOOD FROM THOUGHT

CANADA FIRST RESEARCH EXCELLENCE FUND

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Challenges ...

- ***Agricultural intensification and specialization*** (since the 1950s) led to fertilizer- & pesticide-intensive monoculture crop production.
- ***Consequences***: significant increase of atmospheric CO_2 concentration, water pollution and biodiversity loss.
- ***To meet future*** climatic, economic and social challenges, agriculture needs to be made more productive and stable (resilient) - while minimizing environmental impacts.
- ***More sustainable cropping systems*** are needed - the application of ecological principles to agroecosystems has been proposed - entails the environmentally friendly replacement of anthropogenic inputs and/or enhancement of crop productivity, by integrating the management of *ecosystem services* delivered by *biodiversity* into crop production systems.

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FFT research project will use high-tech information systems to help produce enough food for a growing human population while sustaining (preserving) the Earth's ecosystems.

Cropping Systems – with the objective to increase crop production and ecosystem services, simultaneously. This will be addressed by:

A. testing the agronomic and ecosystem effects of increasing crop diversity by using bean ***cultivar mixtures*** instead of monocultures in cropping systems and
B. reducing inputs and making crops less dependent on ***nitrogen fertilizers*** by identifying and breeding cultivars of dry bean that are more efficient at fixing atmospheric nitrogen through a symbiotic association with Rhizobia.

A. Intercropping

- Intercropping (mixed cropping) is growing two or more crops (***or cultivars***) with a spatial and temporal association
- Ways to intercrop (composition & spatio-temporal arrangement):
  - ***Group A*** - *MIXTURES* (synchrony, same location) – crops are grown simultaneously in the field during the growing season
    - Total mixtures (same row) intercropping
    - Alternate rows/ strips intercropping
  - ***Group B*** - *RELAY/SEQUENTIAL* (asynchrony, same location) - crops are planted sequentially
  - ***Group C*** (synchrony, different location) - crops are surrounded by grass strips, hedges or trap plants (that have a specific role)
- Selection of intercrop system depends largely on socioeconomic conditions and access to input, machinery and labor.
- Aims:
  - to use biotic interactions to reduce chemical inputs and
  - provide more ecosystem services than just provisioning (food, fiber)
- Benefits:
  - Biodiversity (above and below ground) and stability of fields
  - Productivity/ yield
  - Soil quality (complementary sharing of plant resources)
  - Weed/ disease/ pest control (reduction in fertilizer/ pesticides)
  - Energy use efficiency
  - Resilience to heavy rains/ hurricanes

A ***Mixed***

Rows

Strips

B ***Relay***

Bean cultivar mixtures

Objectives: to compare bean crops grown in mixtures with pure stands and to determine the effects of increasing bean crop diversity on agronomic performance (including yield) and ecosystem services.

Year 1 - 2017

- Environments: 2 (ERS, WRS)
- Genotypes: 4/ Entries 10
  - Pure stands
  - Binary mixtures (1:1)
- Design RCBD, 4 reps, 80 (8-row) plots

Year 2 - 2018

- Environments: 3 (ERS1, ERS2, WRS)
- Genotypes: 7/ Entries 49
  - Pure stands
  - Binary mixtures (1:1)
- Design: 7x7 lattice, 4 reps, 588 (8-row) plots

Woodstock Research Station (WRS)
(2,890 CHU)

Elora Research Station (ERS)
(2,680 CHU)

Data collection

1. Conventional above ground crop data: flowering, maturity, plant height, harvestability, seed weight, yield, Ant, SPAD
2. *In collaboration*
   - above ground ecosystem data
   - below ground data
   - novel plant to plant relationship data

Bean cultivar mixtures: 2017

1. *Genotype selection*

Mesoamerican (small seeded)

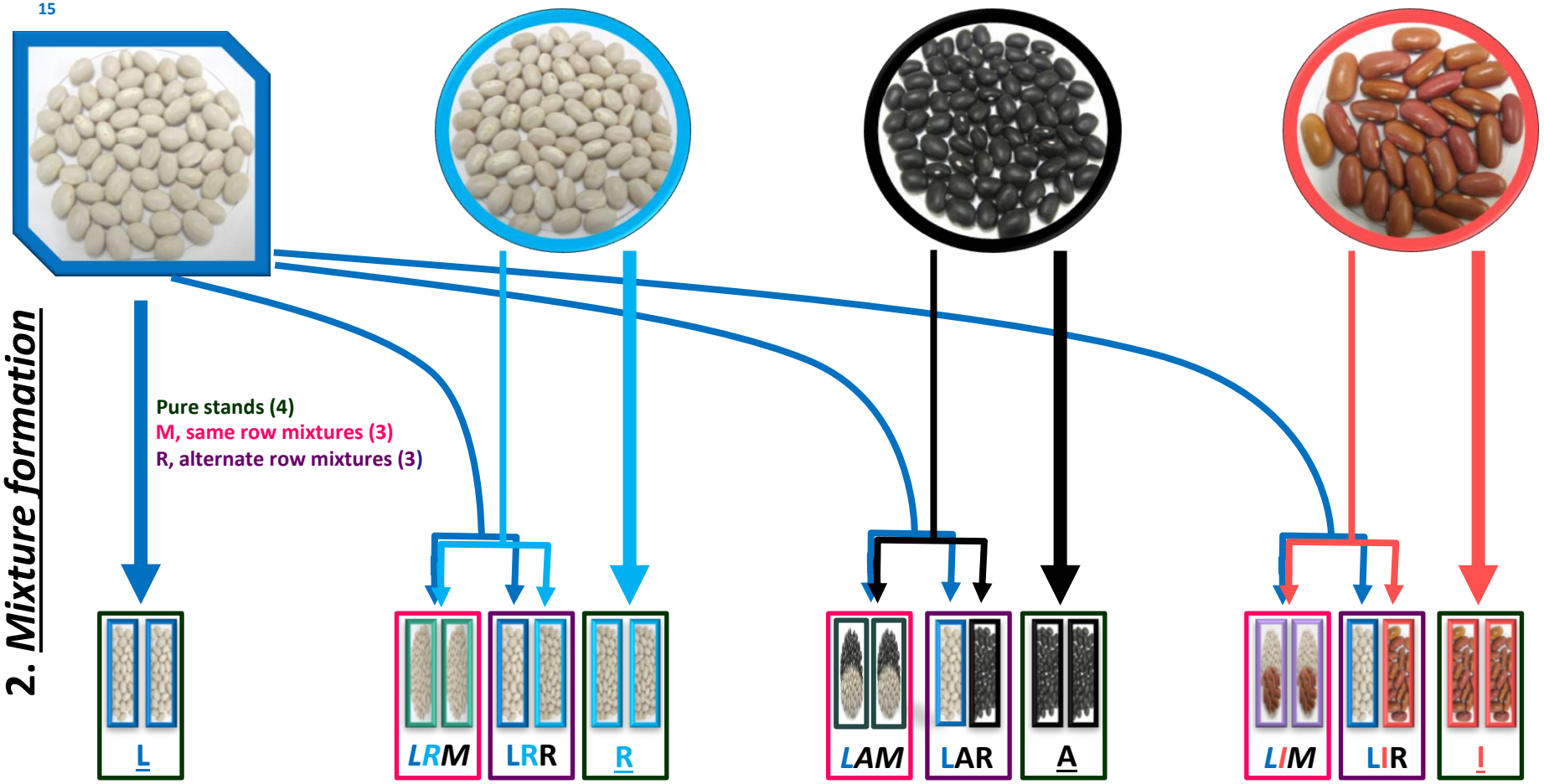
Lighthouse - L (white)
- Indeterminate, a full-season navy bean
- Developed from the conical cross: spscbbr136/PI207262//ICB-17 10/Vax4///OAC Speedvale /Avanti//OAC 99-1/OAC Rex (tested as OAC 09-4)
- Registered in 2012
- High yield potential & good cooking quality
- Resistant to CBB, Anth race 23, BCMV races 1 & 15

Rexeter – R (white)
- Upright, a full-season navy bean
- Developed from the cross: OAC Rex/AC Kippen (tested as OAC 07-2)
- Registered in 2011
- High yield potential & acceptable cooking quality
- Resistant to CBB, BCMV race 1

ACUG 15-B4 - A (black)
- Breeding line (OPPC supported)
- Developed from the cross: HR199-4587/Zorro
- High yield potential
- Resistant to CBB (+ Zorro resistance)

Andean (large seeded)

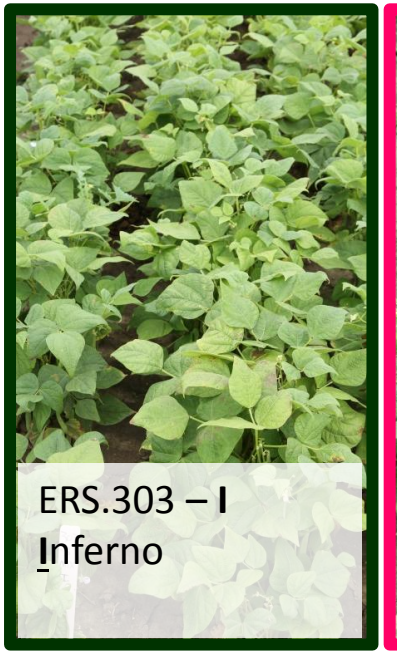
OAC Inferno - I (LRK)
- Determinate, mid to a full season maturity light red kidney (LRK) bean
- Developed from the conical cross: HR85-1885/Montcalm//USWA-39/AC Litekid///Foxfire/AC Elk//Sacramento/AC Calmont (tested as OAC 07-L1)
- Registered in 2011
- Good yield potential & acceptable cooking quality
- Resistant to Anth races 17 & 23, BMCV race 1



3. Field evaluation - ERS mixture plots - 2017

ERS.301 – **LRR**
Lighthouse/
Rexeter/**R**ows

ERS.302 – **LAR**
Lighthouse/
ACUG15-4/**R**ows

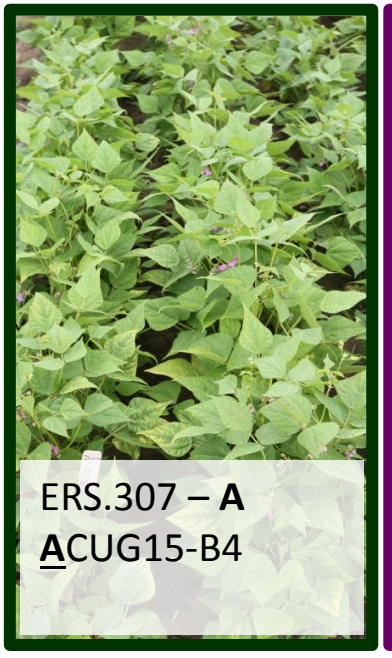


ERS.303 – **I**
Inferno

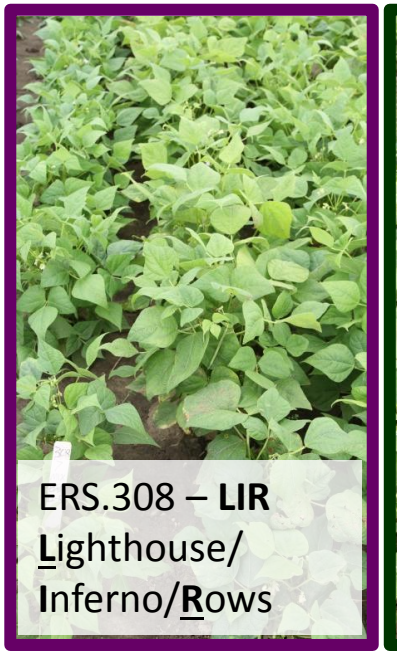
ERS.304 – **LRM**
Lighthouse/
Rexeter/**M**ix

ERS.305 – **LIM**
Lighthouse/
Inferno/**M**ix

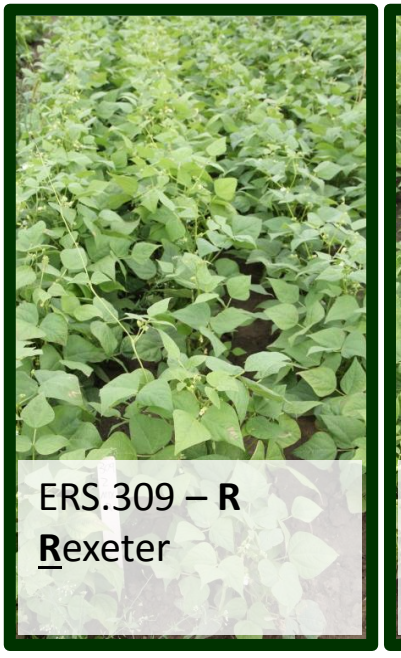
ERS.306 – **LAM**
Lighthouse/
ACUG15-B4/**M**ix



ERS.307 – **A**
ACUG15-B4



ERS.308 – **LIR**
Lighthouse/
Inferno/**R**ows



ERS.309 – **R**
Rexeter

ERS.310 – **L**
Lighthouse

4. Mixture research findings – Year 1

Expected:

- Yield increase
- Greater yield stability
- Lower risks of crop failure

Yield advantages **:**

- ***the presence of complimentary effects,***
- ***better resource use efficiency of the mixed components and***
- ***the buffering effects of the mixture against diseases and weeds***

Potential buffering effects

ACUG 15-B4
(black bean)

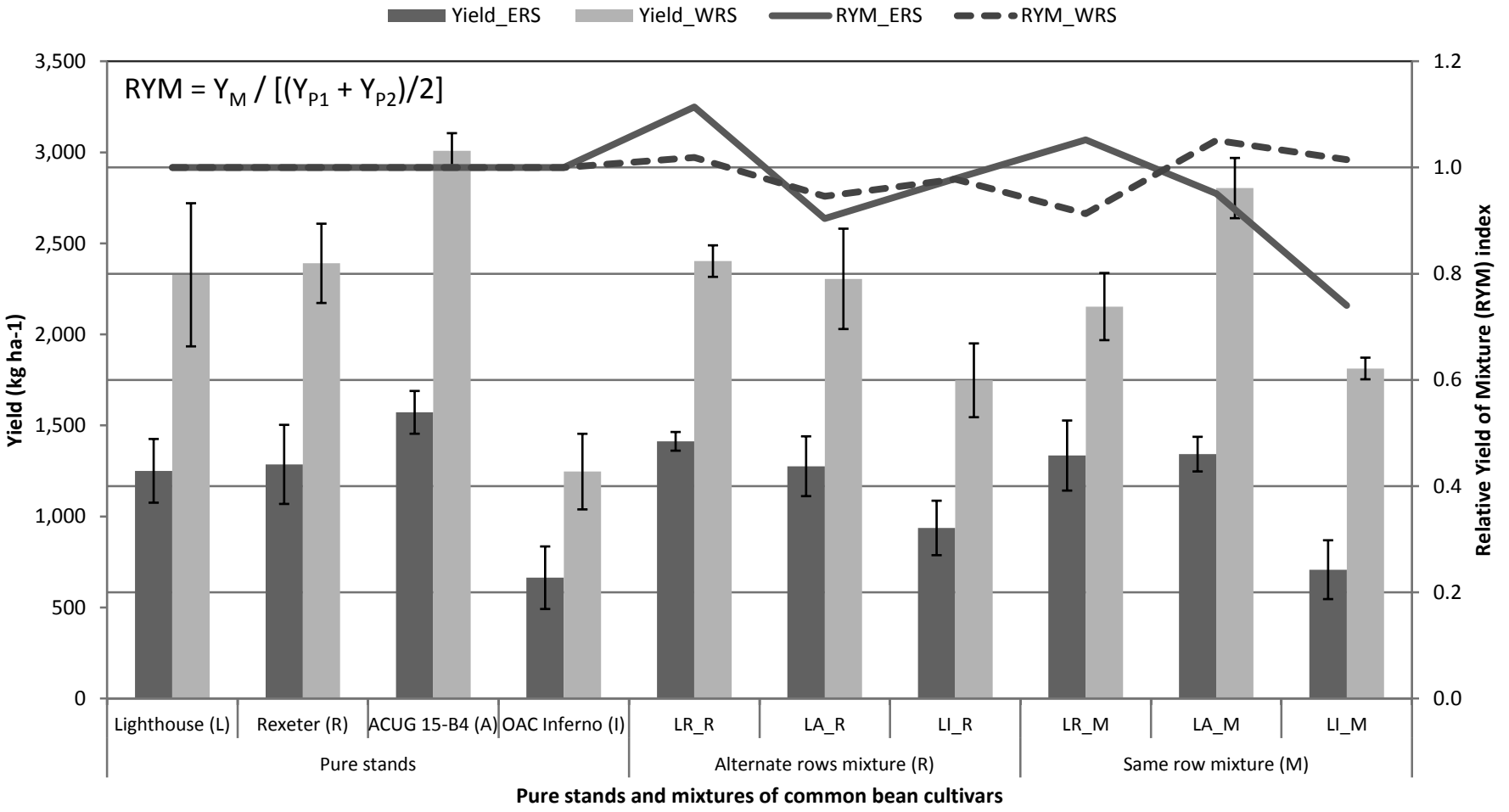
Lighthouse
(white bean)

Flood damage of black beans (alternate rows mixture at ERS)

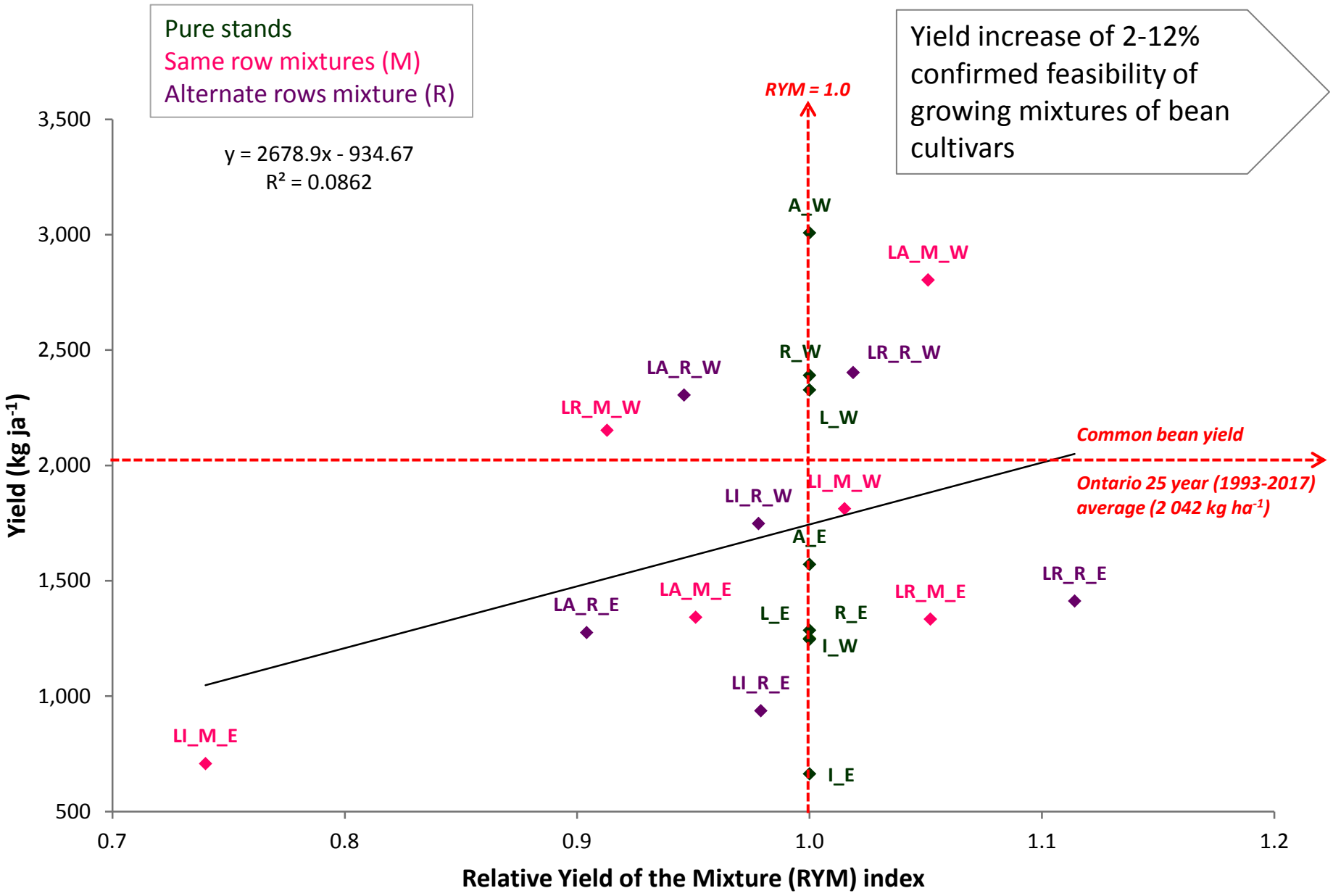
Flood damaged black beans rows compensated by white bean rows

Yield and mixing efficiency of bean mixtures – Year 1

- Significant differences among four genotypes and their mixtures were identified in both locations for all analyzed traits.
- Beans evaluated at the WRS matured earlier and had higher yields compared to the mixtures grown at the ERS.
- The results of the first year study indicate multiple benefits of planting mixtures compared to monoculture, including higher RYM (Relative Yield of the Mixture, calculated from the yield data).



Yield and RYM ratios – 2017 bean cultivar mixtures



Bean cultivar mixtures: 2018

1. L

Lighthouse - L (white, tested as OAC 09-4)

- Indeterminate, a full-season navy bean
- Developed from the conical cross: spscbbr136/PI207262//ICB-17 10/Vax4///OAC Speedvale /Avanti//OAC 99-1/OAC Rex
- Registered in 2012
- High yield potential & good cooking quality
- Resistant to CBB, Anth race 23, BCMV races 1 & 15

2. R

Rexeter - R (white, tested as OAC 07-2)

- Upright, a full-season navy bean
- Developed from the cross: OAC Rex/AC Kippen
- Registered in 2011
- High yield potential & acceptable cooking quality
- Resistant to CBB, BCMV race 1

3. A

ACUG 15-B4 - B (black)

- Breeding line (OPPC supported)
- Developed from the cross: HR199-4587/Zorro
- High yield potential
- Resistant to CBB (+ Zorro resistance)

4. I

OAC Inferno - I (LRK, tested as OAC 07-L1)

- Determinate, mid to a full season maturity light red kidney (LRK) bean
- Developed from the conical cross: HR85-1885/Montcalm//USWA-39/AC Litekid///Foxfire/ AC Elk//Sacramento/AC Calmont
- Registered in 2011
- Good yield potential & acceptable cooking quality
- Resistant to Anth races 17 & 23, BMCV race 1

new in 2018

5. B

Bolt- N (white, tested as ACUG 10-1)

- Upright, early-season maturity
- Derived from the cross OAC Rex/A98083//AC Compass/B98143///RESW2138/B981045//B98213/Kippen
- Registered in 2013
- High yield potential
- Resistance to Anth race 73; BCMV races 1 &15

6. D

Dynasty - D (DRK , tested as OAC 07-6D1)

- Mid to late season maturity dark red kidney (DRK) ban
- Derived from a double-cross between HR85-1885 and Montcalm and USWA-39 and AC Litekid
- Registered in 2012
- Excellent yield potential & superior seed size
- Good cooking quality
- Resistant to Anth races 17 & 73; BCMV race 1

7. RR

Red Rider- C (cranberry, selected as H4099-23481)

- Determinate, medium-late season maturity
- Derived from the cross SVM Taylor Horticulture and Dolly
- Registered in 2008
- Large seed size, acceptable cooking and canning quality
- Resistant to BCMV race 15


L*


R*


A*


I*


B


D


RR


LR**


RA


A I


IB


BD

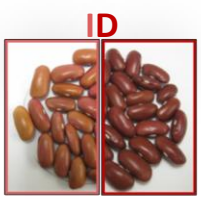

DRR

x 2
- alternate rows
- same row


LA**

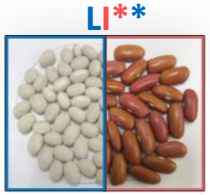

RI


AB


ID


BRR

x 2
- alternate rows
- same row


LI**


RB


AD


IRR

x 2
- alternate rows
- same row


LB


RD


ARR

x 2
- alternate rows
- same row


LD


RRR

x 2
- alternate rows
- same row


LRR

x 2
- alternate rows
- same row

2018 → 49 entries

7 pure stands

21 alternate rows mixtures (1:1)

21 same row mixtures (1:1)

2017 → 10 entries *

4 pure stands

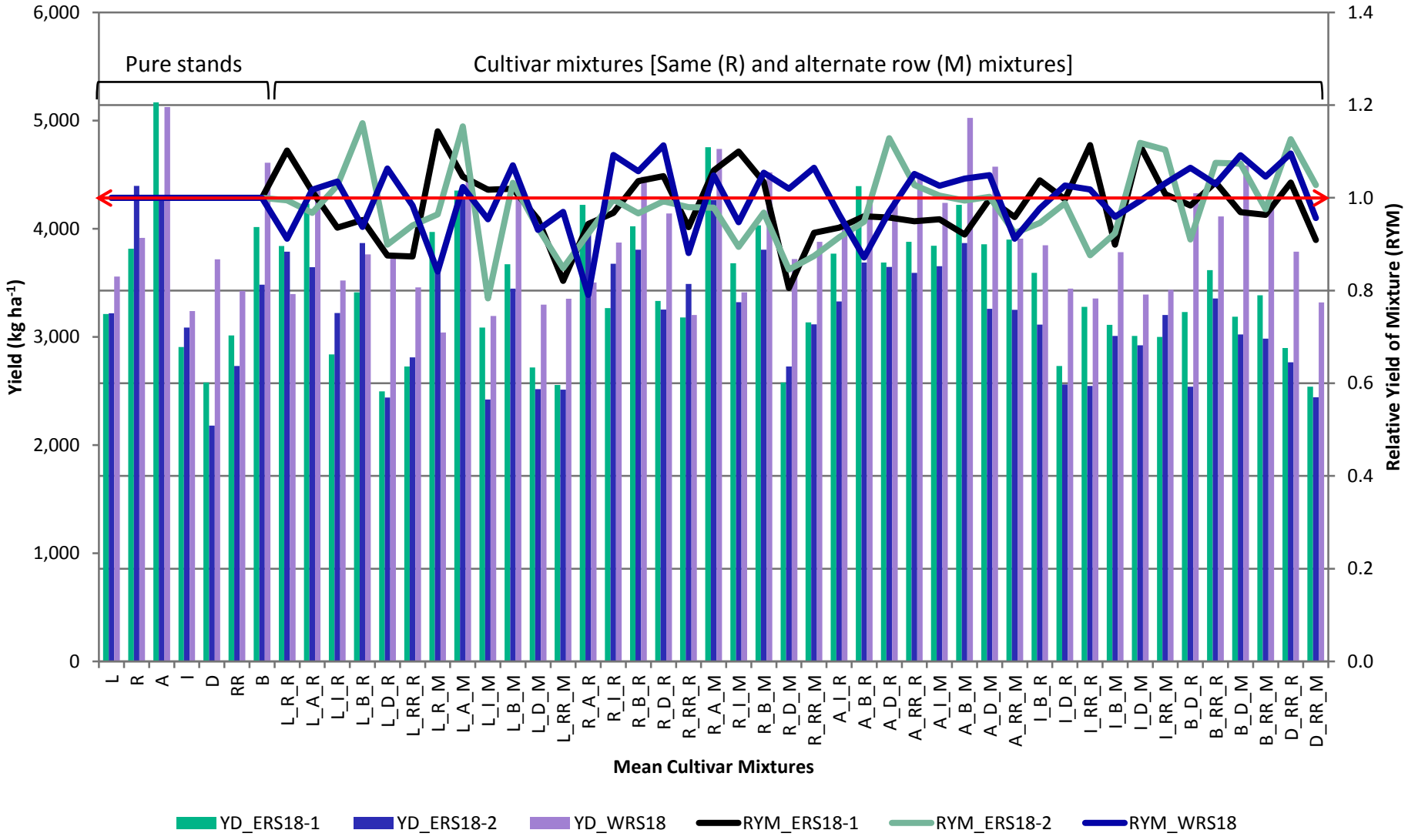
3 alternate rows mixtures (1:1)

3 same row mixtures (1:1)

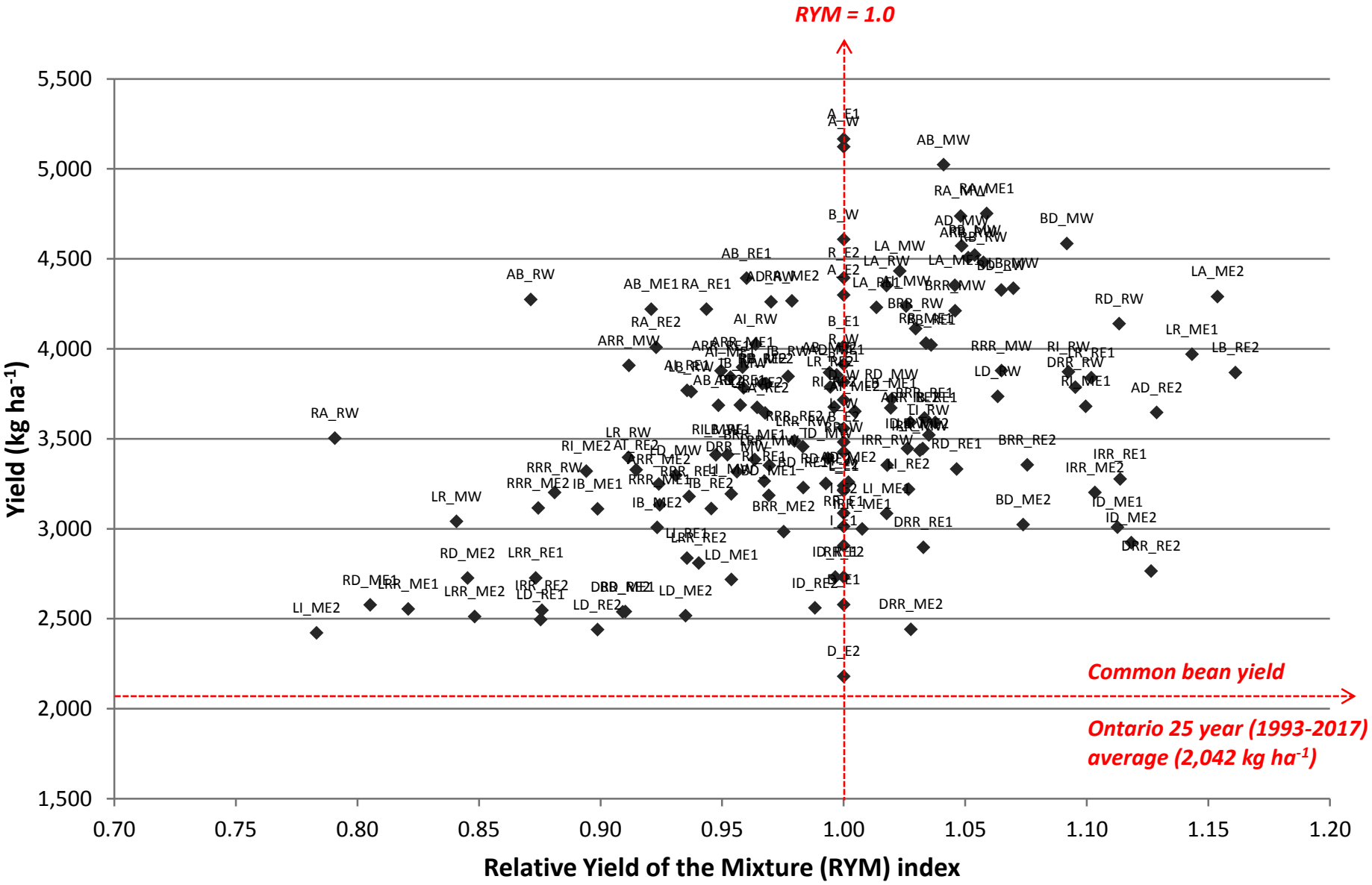
Mixture fields: 2018

Yield and mixing efficiency of bean mixtures – Year 2

$$RYM = Y_M / [(Y_{P1} + Y_{P2})/2]$$



Yield and RYM ratios - 2018 bean cultivar mixtures



Mixture collaboration (2018)

Below ground ecosystem (in-field) data (*K. Dunfield, School of Environmental Sciences*)

- bacterial communities
  - 2 cultivars and their same row mixture (M)
  - 5 plants/plot/rep (at flowering)
  - 2 locations (ERS1, WRS)

1. Bolt (navy)

2. Dynasty (DRK)

3. Same row mixture (M)

Above ground (in-field & hedge) data (*D. Steinke, Department of Integrative Biology*)

- abundance of pests & pollinators
  - 2 cultivars and their same (M) and alternate rows mixtures (R)
  - separate blocks at WRS
  - traps set up at full flowering
  - weekly checks & trap replacements

1. Lighthouse (navy)
2. Dynasty (DRK)
3. Same row mixture (M)
4. Alternate rows mixture (R)

Mixture study - Key insights and future directions







A. Diversity of common bean is declining (similar to other major crops).

B. Canadian beans (*especially large seeded cultivars of Andean origin*) have relatively narrow genetic diversity.

C. A cost effective way to increase genetic diversity is to grow mixtures of bean cultivars (*a common practice in many regions of Africa and South America*).

D. Objective: to determine feasibility of growing bean cultivar mixtures in Ontario environments (increase yield, diversity and ecosystem services).

E. Results: indicate that the higher yields and greater RYMs are possible when beans are planted in mixtures.

- *They can be attributed to a more efficient use of limited plant resources (light, water and nutrients).*

F. The research has the potential to provide a theoretical basis for the use of precision agriculture tools to plant fields with mixtures instead of monocultures.

- *It could lead to greater in-field diversity in the crop and in the above and below ground ecosystems that might provide greater buffering capacity and resiliency to the cropping system.*

G. General adoption of the use of variety mixtures, instead of pure varieties, would revolutionize on farm cropping system practices and supporting research.

- *However, it would require a whole new level of testing for interactions in variety and agrochemical trials and require different approaches to breeding crops* $\rightarrow$