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Crop Rotations: Economics & Benefits

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Canada

Presentation coverage

- **Review of literature**
  - Most studies in the Peace region
  - Some studies in western Canada
  - Few studies in the USA
- **Results of current study at Beaverlodge**

Agro-ecological merits of perennial crops

Agro-ecological properties	Study context	Reference
Carbon sequestration:		
➢ Perennial grassland had **3-7 times greater root biomass** & **2 times greater root length** than in cropland.	Long term and conversion studies in North Kansas, USA	Dupont et al (2014)
➢ Diverse perennial grassland had **500 - 600% more soil C & N** than monoculture.	Cedar Creek Ecosystem Science Reserve, Minnesota, USA	Fornara et al (2009)

Agro-ecological merits of perennial crops

Agro-ecological properties	Study context	Reference
Soil conservation: ➢ The rotation that included fescue seed crop had a cumulative **reduction of run-off** and **soil losses** by over **35%** and **400%**.	A six-year rotations with annual crops & red fescue seed crop in Fort St. John, BC	Van Vliet & Hall (l99l)
Soil structural improvement: ➢ Integration of grasses in the annual cereal rotation had positive effects on the **development of discrete granular structures** in the Luvisol.	Breton, 100 km southwest of Edmonton, AB	Pawluk (1980)
➢ Forage based sequences had **greater soil aggregate stability** than the annual crop sequences.	Peace region (Beaverlodge), AB	Broersma et al (1997)

Agro-ecological merits of perennial crops

Agro-ecological properties	Study context	Reference
N fixation & soil enrichment:		
➢ Annually, alsike & red clover fixed nitrogen in the range of **21–143 kg ha^{-1}**, & **15–77 kg ha^{-1}** respectively.	Peace region (Beaverlodge), AB	Rice (1980)
➢ Continuous leguminous sequence (1968-1984) of red clover had **10-fold higher N mineralization rate** than the non-legumes crop sequences.	Peace region (Beaverlodge), AB	Broersma et al (1996)

Agro-ecological merits of crop rotations

Comparative benefits	Study context	Reference
Suppression of crop pests:		
➢ Canola grown after **two break crops** in rotation had **54% less incidence of blackleg disease** & **6% less damage by root maggot**.	Multi-location study at Beaverlodge, Lacombe Edmonton, AB; Melfort, SK; Brandon, MB	Harker et al (2015)
➢ Canola preceded by two break crops had **less incidence of brown girdling root-rot** and concomitantly **higher seed yield** than the unbroken sequence of canola.	Peace region (Beaverlodge), AB	Soon et al (2005)

Agro-economic benefits of crop rotations

Yield & economic advantages	Study context	Reference
Canola grown after **two break crops** in rotation **yielded 22% higher** compared with continuous canola & wheat-canola-canola rotation.	Multi-location study at Beaverlodge, Lacombe Edmonton, AB; Melfort, SK; Brandon, MB	Harker et al (2015)
Canola & wheat yield advantages due to **two break crops** of pea, barley or flax were **19.4%** and **7.2%** over the unbroken sequence of canola & wheat, respectively.	Peace region (Donnelly), AB	Gill (2018)
Replacement of a wheat by lentil & dry bean from **canola-wheat-wheat-wheat** sequence resulted in **higher economic returns** accompanied with **reduced environmental effects**.	Data from western Canada, US & European Ecoinvent v2.0 database	MacWilliam et al. (2014)

On-going study at Beaverlodge

Research Questions

- Can forage seed crops be profitably integrated in the annual cropping systems?
- Can forage seed crops improve soil health?

An ongoing cropping sequence study (2013-2020)

- Split-plot field experiment
- **Main plots**: 8 cropping sequences
  - C-C-C-C-P-Mb-Mb-Mb-C
  - Cf-Cf-Cf-C-P-Cf-Cf-Cf-C
  - Rc-Rc-W-C-Rc/W-Rc-W-C-W
  - Ac-Ac-W-C-Ac/W-Ac-W-C-W
  - *in*Rc-Rc-W-C-Rc/W-RC-C-W-C
  - *in*Ac-Ac-W-C-Ac/W-Ac-Cf-Cf-Cf
  - P-B-W-C-P-W-C-P-W
  - W-C-W-C-W-C-W-C

C = canola
P = pea
Mb = meadow bromegrass
Cf = creeping red fescue
Ac = alsike clover
Rc = red clover
W = wheat
in = inoculated with bio-fertilizer

- **Sub plots**: 3 levels of N
  - 0, 45 & 90 kg N ha-1

Four-year crop sequences: Economic analysis in two scenarios

Scenario 1: average price of forage seed & low price of annual grains

Scenario 2: average price of forage seed & average price of annual grains

Canola equivalent yield

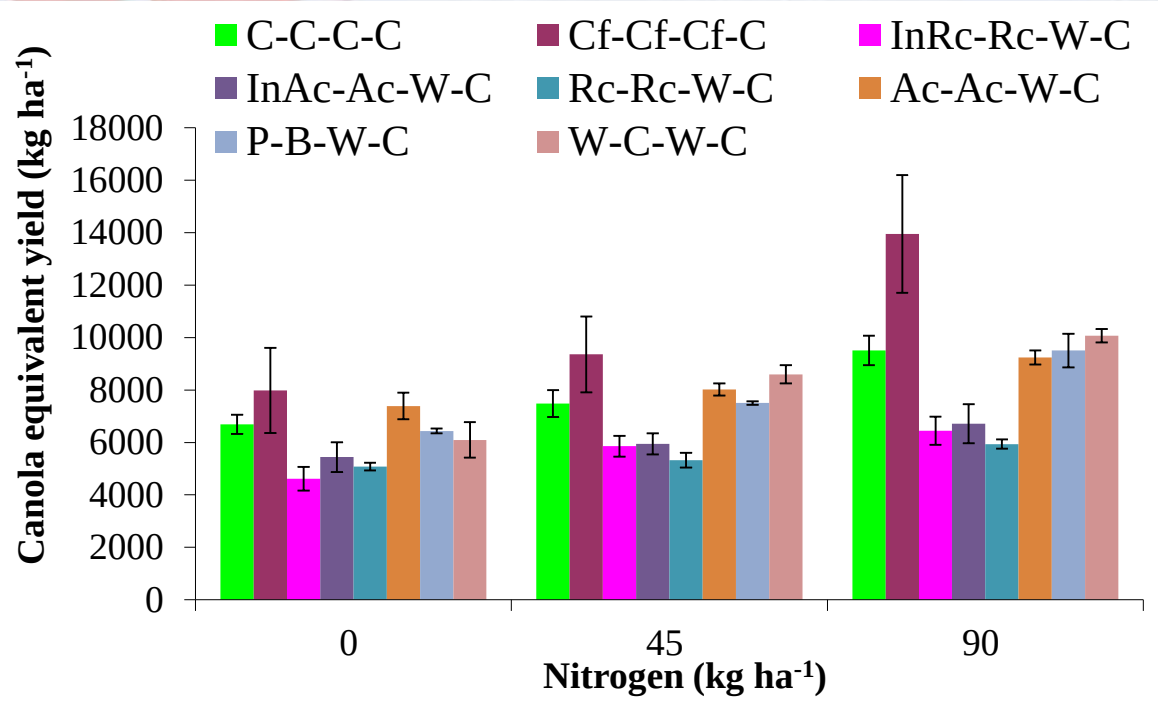
$$= (Noncanola\ price \div Canola\ price) \times Noncanola\ yield$$

Gross margin

$$= \ Total\ revenue - Variable\ costs\ differning\ between\ treatments$$

4-year crop sequences: Canola equivalent yield

Scenario 1: average price of forage seed & low price of annual grains



C = Canola

Cf = Creeping red fescue

In = Inoculated

Rc = Red clover

Ac = Alsike clover

P = Pea

B = Barley

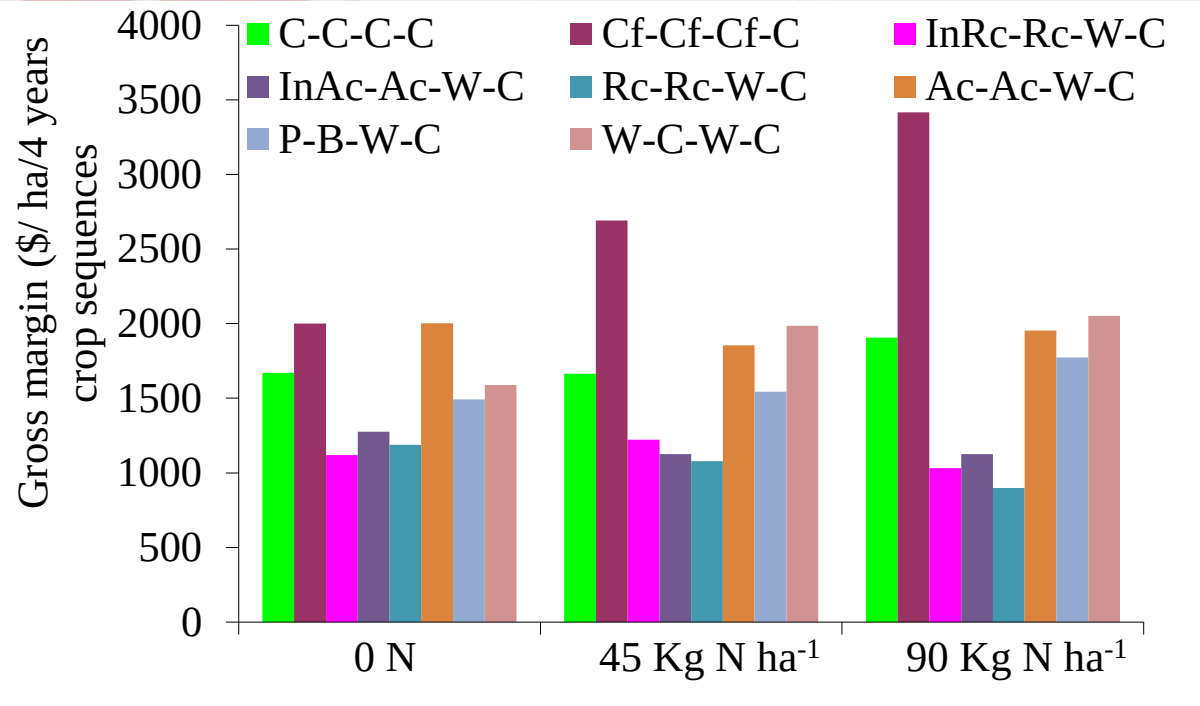
W = Wheat

Based on cumulative canola equivalent yield (CEY) of 4-year crop sequences with 90 kg N ha^{-1}:

- creeping red fescue followed by canola generated CEY of **13.95 t ha^{-1}**.
- wheat-canola rotation generated CEY of **10.07 t ha^{-1}**.
- continuous canola cropping provided a gross margin of **9.5 t ha^{-1}**.

4-year crop sequences: Gross margin analysis

Scenario 1: average price of forage seed & low price of annual grains



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In = Inoculated

Rc = Red clover

Ac = Alsike clover

P = Pea

B = Barley

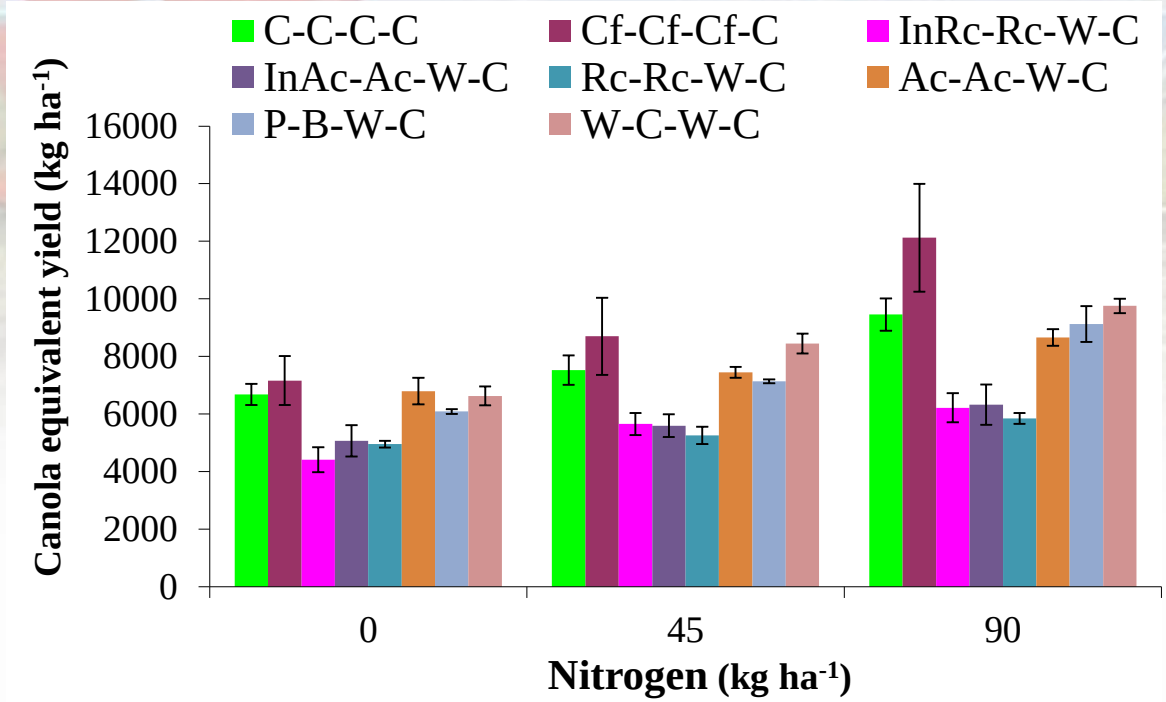
W = Wheat

Based on cumulative gross margin analysis of the 4-year crop sequences with 90 kg N ha^{-1}:

- creeping red fescue followed by canola provided gross margin of **$3416 ha^{-1}**.
- wheat-canola rotation provided gross margin of **$2052 ha^{-1}**.
- continuous canola cropping provided a gross margin of **$1907 ha^{-1}**.

4-year crop sequences: Canola equivalent yield

Scenario 2: average price of forage seed & average price of annual grains



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Ac = Alsike clover

P = Pea

B = Barley

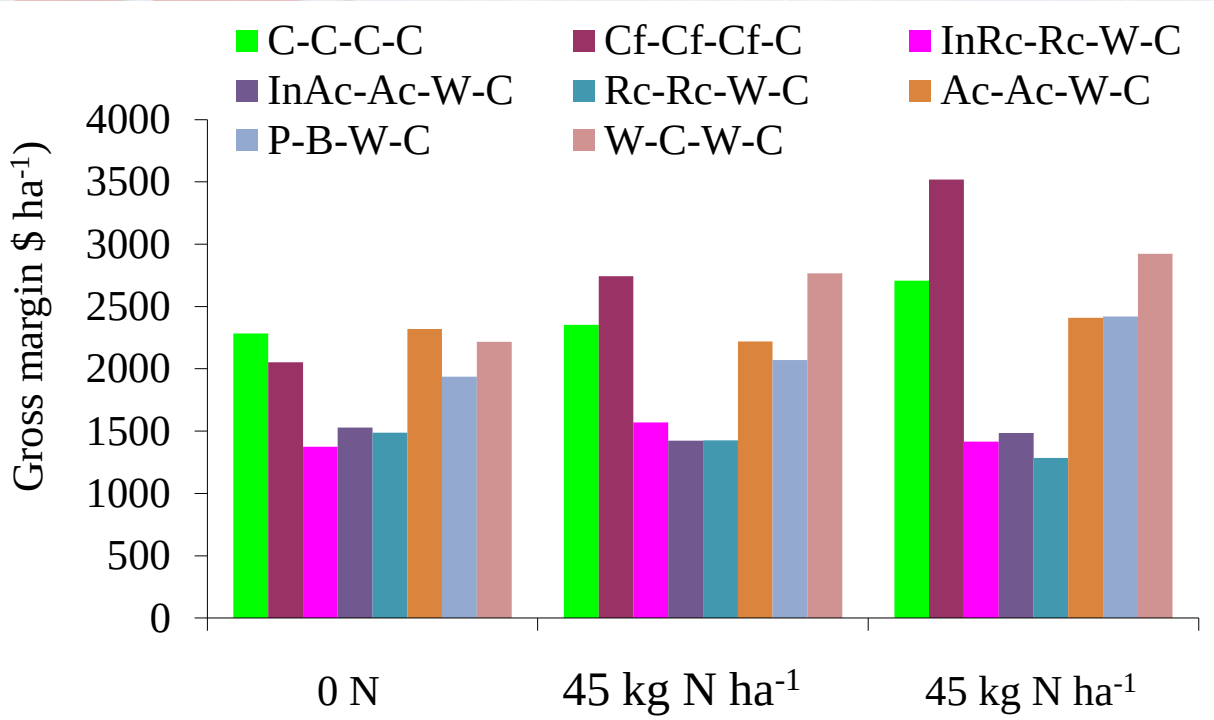
W = Wheat

Based on cumulative canola equivalent yield (CEY) of 4-year crop sequences with 90 kg N ha^{-1}:

- creeping red fescue followed by canola generated CEY of **12.12 t ha^{-1}**.
- wheat-canola rotation generated CEY of **9.07 t ha^{-1}**.
- continuous canola cropping provided a gross margin of **9.5 t ha^{-1}**.

4-year crop sequences: Gross margin analysis

Scenario 2: average price of forage seed & **average price** of annual grains



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Cf = Creeping red fescue

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P = Pea

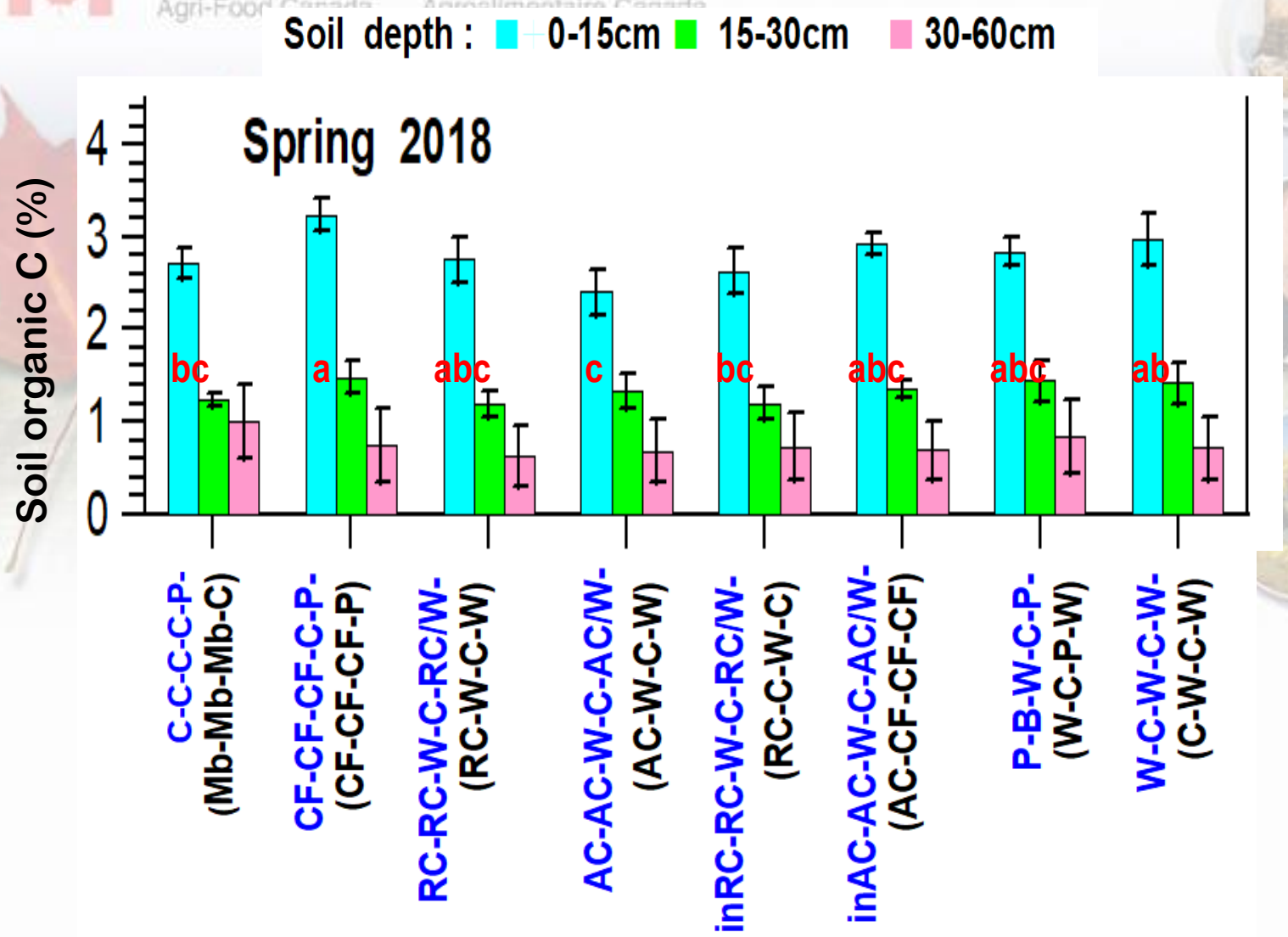
B = Barley

W = Wheat

Based on cumulative gross margin analysis of the 4-year crop sequences with 90 kg N ha^{-1}:

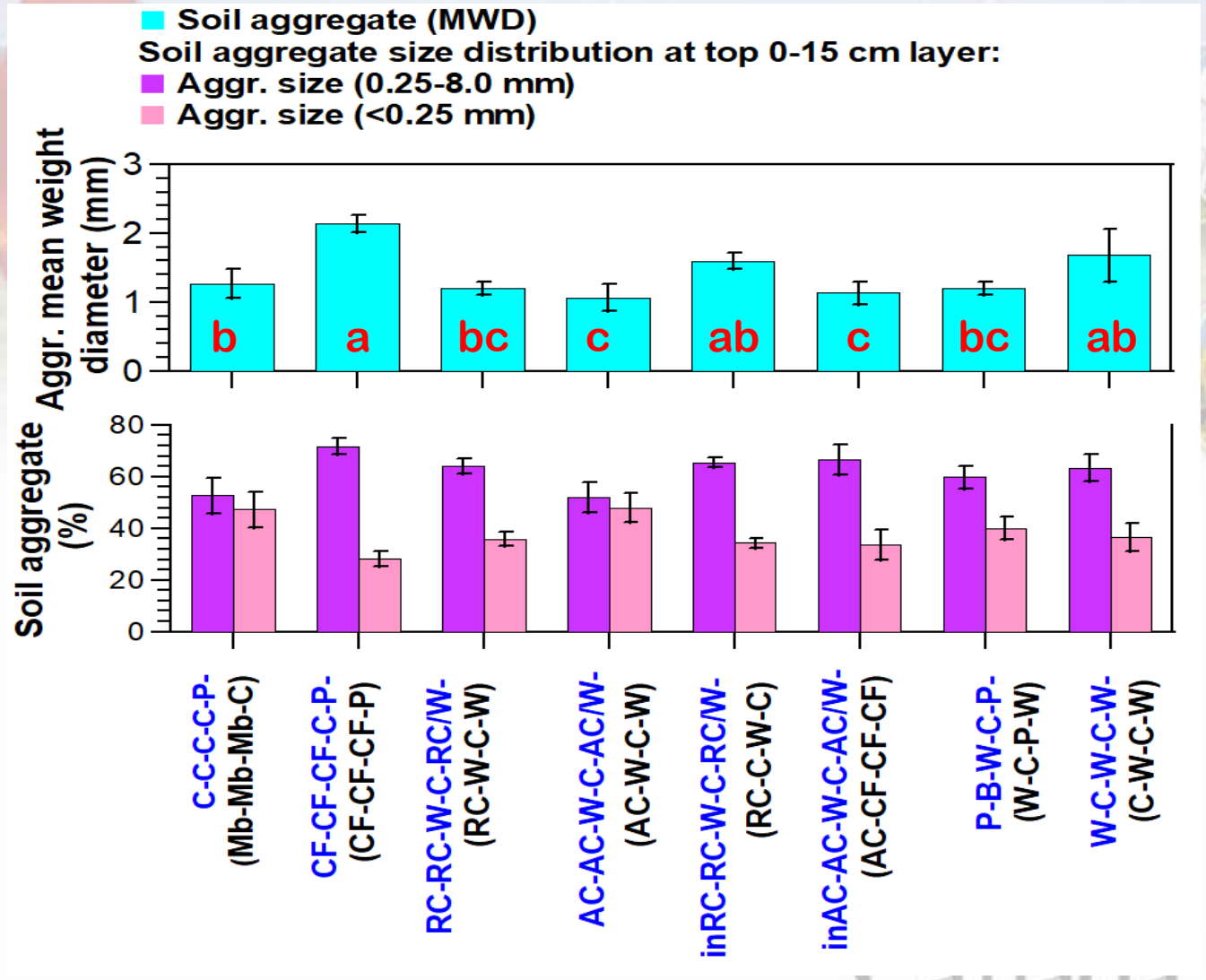
- **creeping red fescue** followed by canola provided gross margin of **$3518 ha^{-1}**.
- **wheat-canola rotation** provided gross margin of **$2923 ha^{-1}**.
- **continuous canola** cropping provided a gross margin of **$2706 ha^{-1}**.

Some soil health indicators after 5 crops under different cropping sequences

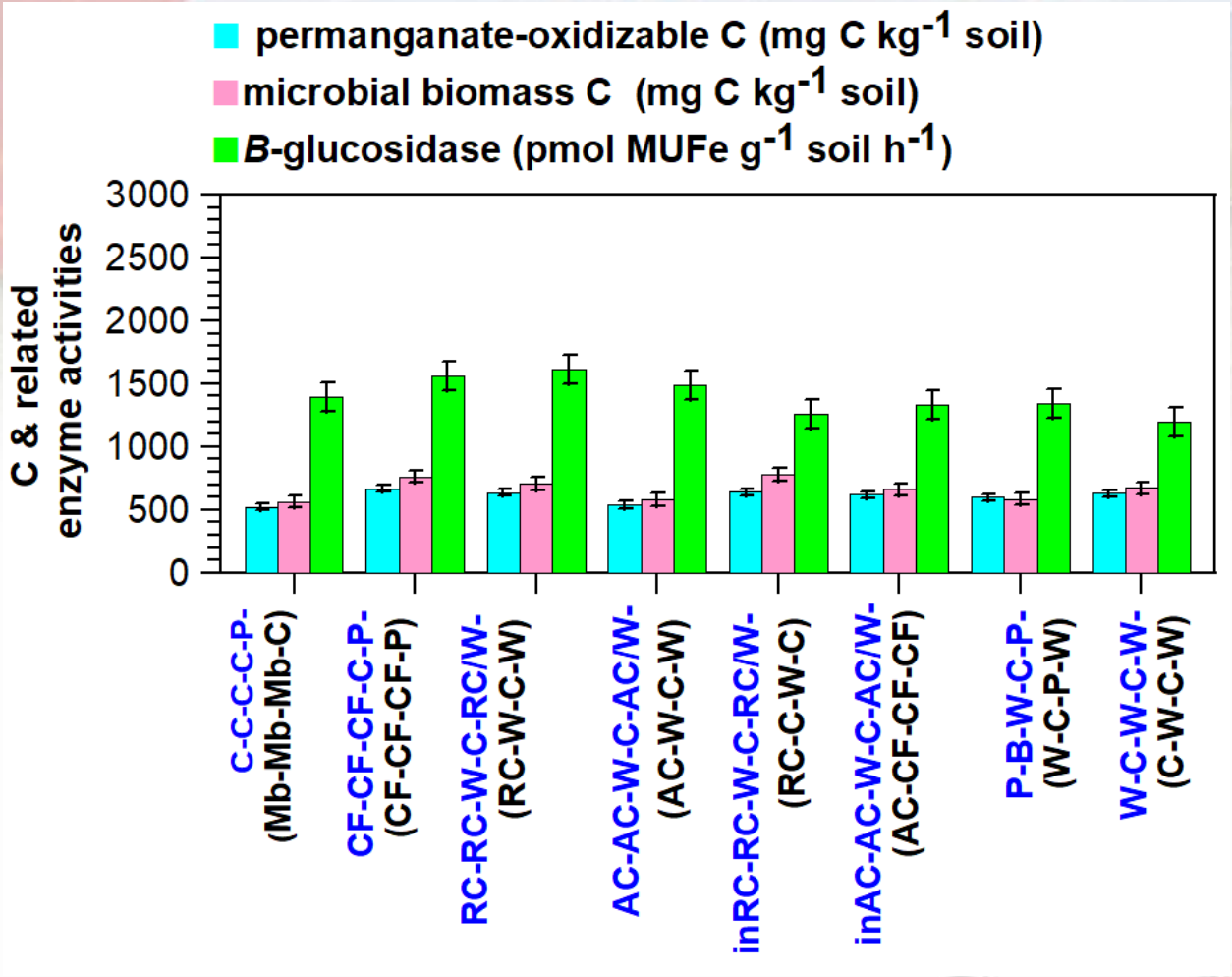


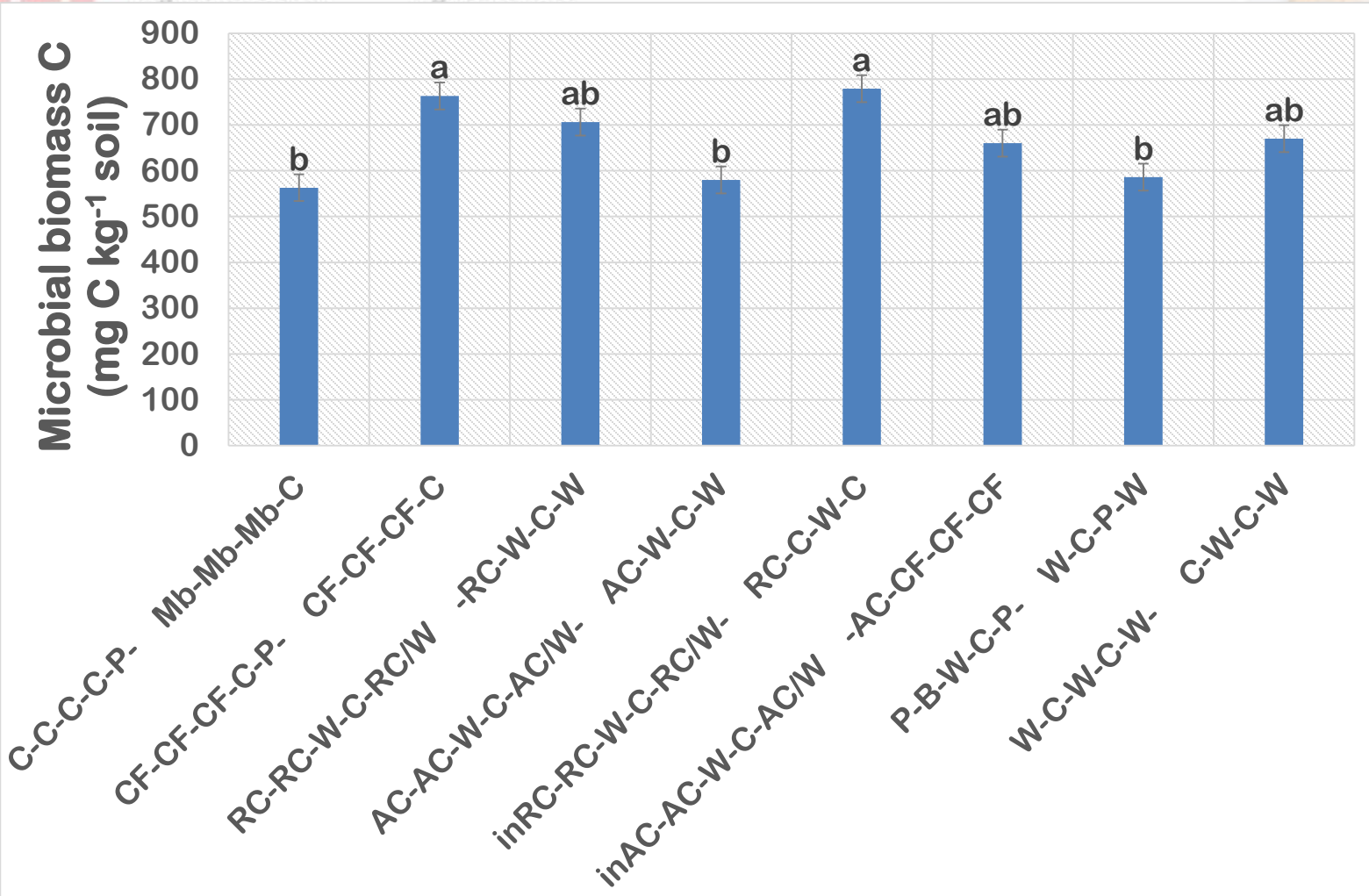
C = canola; P = pea; Mb = meadow bromegrass;
CF = creeping red fescue; AC = alsike clover;
RC = red clover; W = wheat; in = inoculated with bio-fertilizer

Soil aggregate diameters & size distribution in top 0-15 cm layer, after first five crops in different crop sequences.



Soil active C (permanganate-oxidizable C), microbial biomass C and activity of B-glucosidase enzyme involved in C-cycling





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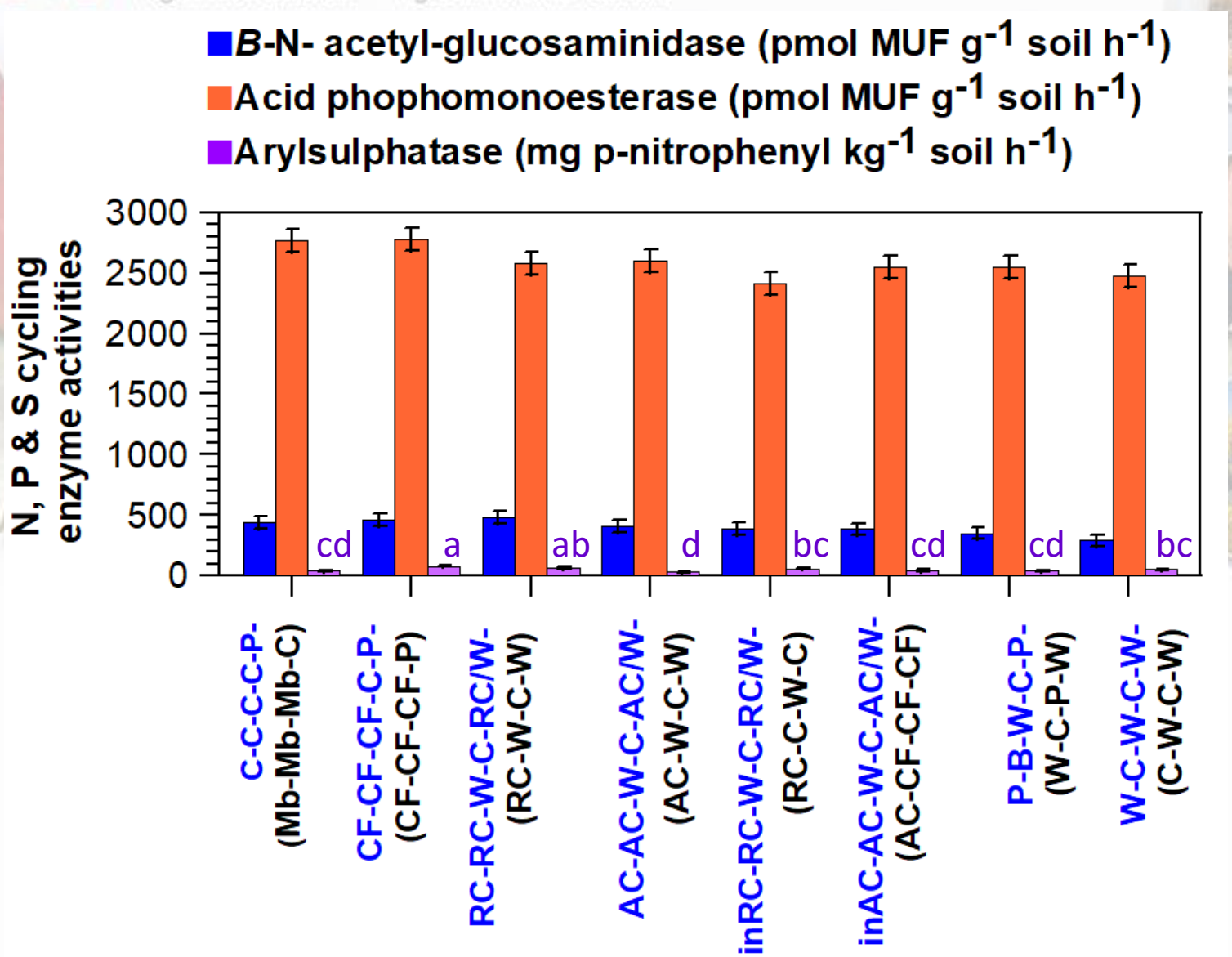
B-N- acetyl-glucosaminidase (pmol MUF g-1 soil h-1)
Acid phophomonoesterase (pmol MUF g-1 soil h-1)
Arylsulphatase (mg p-nitrophenyl kg-1 soil h-1)
N, P & S cycling enzyme activities
3000
2500
2000
1500
1000
500
0
cd
a
ab
d
bc
cd
cd
bc
C-C-C-C-P- (Mb-Mb-Mb-C)
CF-CF-CF-C-P- (CF-CF-CF-P)
RC-RC-W-C-RC/W- (RC-W-C-W)
AC-AC-W-C-AC/W- (AC-W-C-W)
inRC-RC-W-C-RC/W- (RC-C-W-C)
inAC-AC-W-C-AC/W- (AC-CF-CF-CF)
P-B-W-C-P- (W-C-P-W)
W-C-W-C-W- (C-W-C-W)

Conclusions

- Changes in agroecological properties take long time horizon
- Forage seed crops can serve as profitable break crops in the annual cropping sequences with beneficial effects on soil properties
- Cropping systems with forage seed crops require less input, hence lower cost of production
- The prices of forage seeds & food grains are major determinants of the profitability (e.g. the case of red clover & barley)
- Prudent choice of cropping sequences can help avert both production risks posed by biotic & abiotic factors, & price risks due to fluctuating market.

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Summer Students

Thank you !

Questions ?