Effects of novel non-bloat legumes on C and N pools in pasture systems

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Effects of grazing on SOC

- **Grazing in pastures:**
  - increases SOC stock
    - stimulates aboveground production, root respiration and root exudation rates
    - increases tillering & rhizome production
  (Schnabel et al., 2001; Schuman et al., 2002)

- **Overgrazing**
  - decreases SOC grasslands/pastures
    - decreased primary production and increased soil erosion
  (Su et al., 2005)
Pasture rejuvenation mechanisms

- Degraded pastures can be rejuvenated by:
  - Fertilization at soil-test recommended rates
  - Mechanical aeration
  - Direct/sod-seeding
  - Including legumes
Conventional vs. sod-seeding

- Potential implications:
  - loss of wildlife habitat,
  - erosion, N leaching,
  - decreased in microbial diversity, and
  - re-salinization on marginal land

Sod-seeding of different legumes may affect soil C and N stocks.

- loss of SOC
My PhD Research

Impacts of forage quality improvement strategies on GHG emissions and C sequestration.

Short-term C and N dynamics study
Research Objective

To determine the impacts of novel non-bloat legumes on C and N dynamics

- $^{15}$N-N$_2$-fixation study
- $^{13}$C-labelling study
- Soil organic carbon study
- N cycling study using $^{15}$N tracer
- Soil disturbance/forage termination study
Research concept

(Frothy bloat)

Pasture

Microbial biomass

Soil organic matter formation

(Rhizodeposition)

CO₂, CH₄

Dung, Urine

CO₂, N₂O

(Modified from Rumpel et al., 2015)
Study Site Layout

Lanigan, SK @WBDC
15 paddocks ~ 5 acre each
3 Replicates of Sod-Seeded
Alfalfa (control legume)
Sainfoin (novel non-bloat)
Cicer milkvetch (novel non-bloat)
Today's presentation

Impact of novel non-bloat legumes on C and N dynamics

- $^{15}$N-$N_2$-fixation study
- $^{13}$C-labelling study
- Soil organic carbon study
- N cycling study using $^{15}$N tracer
- Soil disturbance/forage termination study
**N₂-fixation study Methodology**

- Phytotron study.
- RCBD study in pots with soil moisture maintained at 80% of field capacity.
  - **Alfalfa (Algonquin)**
  - **Cicer Milkvetch (Veldt)**
  - **Cicer Milkvetch (Oxley II)**
  - **Sainfoin (Common)**
  - **Sainfoin (Mountainview)**
  - **Meadow bromegrass (Armada)** refer as reference sp.

- Two months following seeding, plants were thinned to six plants per pot.
  - ¹⁵N-enriched NH₄⁺NO₃⁻ (10-atom % excess) was applied at a rate of 5 kg N ha⁻¹.

- Four months after enrichment, plants were harvested from the soil level.
  - %Ndfa and total N-fixed were estimated.

\[
%Ndfa = 1 - \frac{(\text{atom}\%^{15}\text{N excess}_{\text{fixing crop}})}{(\text{atom}\%^{15}\text{N excess}_{\text{nonfixing crop}})} \times 100\%
\]

All data were analyzed using ANOVA by the PROC MIXED procedure.
Alfalfa fixed significantly more atmospheric N$_2$ than the other species in all the plant parts measured. 

**Alfalfa > Cicer Milkvetch > Sainfoin**

- %Ndfa: 92% vs 87% vs 81%
- g N pot$^{-1}$: 5.3 vs 3.4 vs 1.7
- kg N ha$^{-1}$ fixed: 200 vs 128 vs 65

No significant difference between cultivars of sainfoin.
C and N dynamics Methodology

- Soil sampling: 0-15 cm, 15-30 cm, 30-60 cm and 60-100 cm in 2017 and 2018.
  - Total soil organic carbon (SOC) using LECO C632 after acid pre-treatment.
  - Water extractable C and N (DOC and TDN) determined in 5mM CaCl$_2$ extract.
Soil Organic Carbon Results

- No significant effects of legume type or varieties on total SOC.
- As expected, slope and depth had significant effect on SOC.
  - upper >> Lower; Surface >> subsurface (70 % SOC within 0-30 cm)
❖ Soil under alfalfa had highest water extractable C and N on upslopes, milkvetch higher on mid.
❖ Both slope position and soil depth had significant effects on DOC and TDN.
❖ upper >> Lower; Surface >> subsurface
Discussion

- Introduction of legumes did not significantly affect total SOC:
  - C status of soil before sod-seeding was high

- N$_2$ fixation, easily decomposable organic matter (WEOM) higher under alfalfa than novel non-bloat legumes.

- Similar C and N values compared to previous studies:
  - efficiency of C and N cycling due perennial legumes.
  - similar inputs and outputs.

- Short period of the experiment
  - detect management effects (WEOM/LFOM).

- Reverse trend in SOC/WEOM
  - Upper slope $>>$ Lower slope

Continued measurements over longer time would be useful to reveal any SOM changes.
Conclusion and Take Home Message

❖ Alfalfa fixed more atmospheric N than Cicer Milkvetch and Sainfoin.
❖ Cicer Milkvetch and Sainfoin are viable alternatives to alfalfa for pasture rejuvenation:
   ❖ No adverse impact on C and N pools compared to alfalfa.
   ❖ Efficient protein utilization (absence of frothy bloat).
❖ Considering the whole system, the non-bloat legumes (milkvetch and sainfoin) may have lower GHG emission footprint due to:
   ❖ Reduced enteric methane (CH$_4$) emission.
   ❖ Lowered soil GHG (CO$_2$, N$_2$O, and CH$_4$) emissions.
   ❖ Efficient protein utilization.
   ❖ No negative impact on soil C and N stores and cycling.
❖ Preliminary ranking for pasture rejuvenation and lower GHG footprint:
   ❖ *Cicer Milkvetch > Sainfoin > Alfalfa*
Future Studies

To determine the impacts of novel non-bloat legumes on C and N dynamics

- $^{15}$N-$N_2$-fixation study
- $^{13}$C-labelling study
- Soil organic carbon study
- N cycling study using $^{15}$N tracer
- Soil disturbance/forage termination study
Acknowledgements

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  ❖ Scholarships and Bursaries.

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Committee members: Derek Peak, Melissa Arcand, Bart Lardner and Kate Congreves.

Lab groups 5E19, 5C21 and AGGP II project group members.
SHHH... Questions?
Carbon sequestration in progress
Table 1: ANOVA on the effects of Slope position (SLP), Legume varieties (LEG) and their combined interactions on bulk density and short-term C and N changes in the 2017 and 2018 growing seasons in a pasture system sod-seeded with novel non-bloat legumes.

<table>
<thead>
<tr>
<th>Analysis of variance</th>
<th>Water-extractable OM</th>
<th>Light Fraction</th>
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<tr>
<td></td>
<td>Bulk density</td>
<td>SOC</td>
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<td></td>
<td>Mg m⁻³</td>
<td>Mg C ha⁻¹</td>
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<td>LEG</td>
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<tr>
<td>SLP x LEG</td>
<td>NS</td>
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</tbody>
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¹Asterisk indicates significant difference between treatment means according to Tukey’s HSD (P < 0.10; *P<0.10, **P<0.01, ***P<0.001, ****P<0.0001; NS, not significant at P<0.10). ²Slope position refers to upper, mid and lower slope positions. ³Legume refers to the annual non-bloat cultivars and alfalfa seeded in the paddocks. Data were pooled across slope position (n = 9) and for each individual treatment (slope position; n = 9 and legume; n = 3).
Table 2: ANOVA on the effects of Soil depth (DEP), Legume varieties (LEG) and their combined interactions on bulk density and short-term C and N changes in the 2017 and 2018 growing seasons in a pasture system sod-seeded with novel non-bloat legumes.

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Table 3: ANOVA on the effects of Slope position (SLP), Legume varieties (LEG) and their combined interactions on bulk density and short-term C and N changes in the 2017 and 2018 growing seasons in a pasture system sod-seeded with novel non-bloat legumes.

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