Season-long Grazed Green Manure Systems:
Making biological nitrogen fixation practical, flexible and economically viable on organic grain farms

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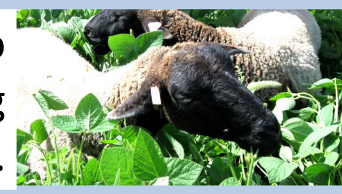
Introduction

Annual legume green manures (GMs) are a key source of biological nitrogen fixation (BNF) in organic grain production systems.

However, taking a year out of commercial crop production is an **economic barrier** to green manure adoption.

Grazing GMs maintains the N benefit to subsequent crops while also producing livestock products (Cicek et al. 2015).



However, the period between peak biomass production and maturity of most annual GMs is very short, **making grazing impractical**.

To make grazed annual GM systems **economically feasible and practical** for farmers while maintaining the **N benefit** to other crops in rotation, two goals must be met:

1. **A minimum 100 kg/ha N through biological fixation**
2. **Sufficient high quality forage for season-long grazing**

The **objective** of this study was to **investigate strategies for extending forage availability throughout the growing season while achieving high levels of BNF**:

1. Overwintering crops for early-season forage supply
2. Relay- and double-cropping to optimize use of growing season resources
3. Intercropping of determinate legume green manures with grazing-tolerant forage grasses for late-season forage supply
4. Staggered seeding dates to extend mid-summer forage supply
5. Indeterminate annual legumes for repeated grazing

Materials and Methods

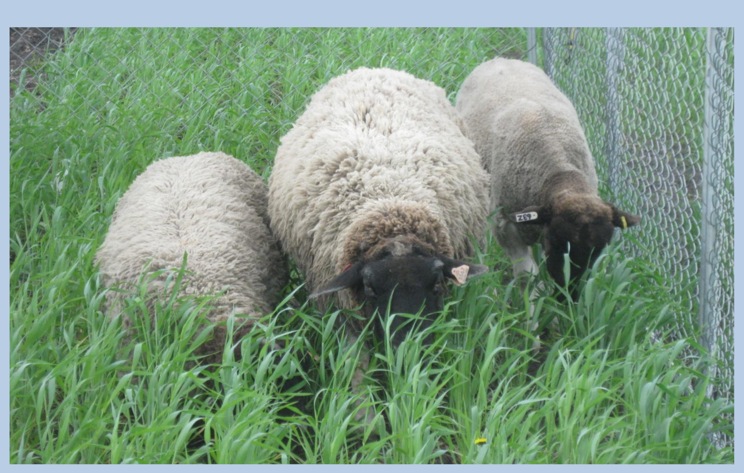
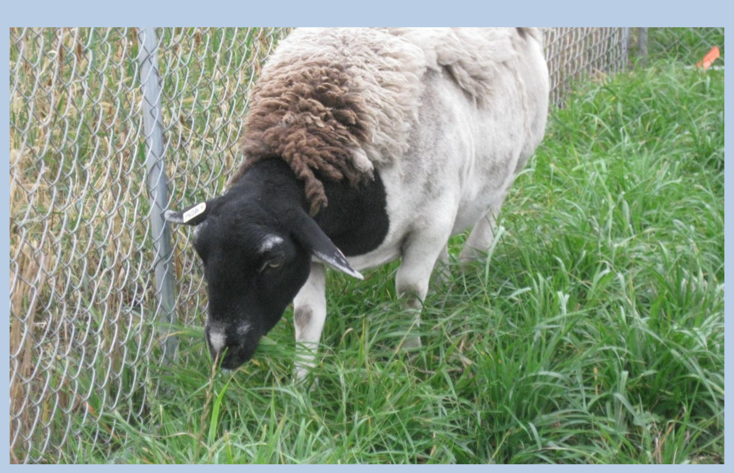
Grazed GM systems using one or more of the strategies above were conceptualized and tested in field experiments in Manitoba, Canada in 2009-2013 on organically managed land.

- Legume GM / forage systems were established in spring of Year 1 or the preceding fall.
- Dorpor sheep were used to graze forages and GMs in Year 1 of experiments examining nutrient cycling and plant response to grazing.
- Spring wheat was grown in Year 2 of selected experiments to observe effects on nutrient availability to subsequent crops (data not shown).

Highlights and key findings of selected experiments are presented here, along with a summary of the potential application of the research.

Table 1. Four grazed green manure systems were tested in Manitoba, Canada for their ability to provide N fixation and season-long forage supply.

	Forage / green manure crop components	Key grazing periods	Comments
System 1	1. Fall-seeded fall rye (FR) 2. Annual green manure (e.g. pea-oat-soybean mix)	1. May 2. August	FR terminated after grazing to allow for establishment of legume GM crop.
System 2	Overwintering legume (e.g. alfalfa, red clover or sweet clover)	June	Potential for repeated grazing throughout season, depending on legume species and grazing management.
System 3	1. Spring-seeded annual GM (e.g. pea-oat mix) 2. Underseeded with regrowing forage grass (e.g. Italian ryegrass)	1. July 2. Sept-Oct	Grazing window extended by staggering seeding dates and grazing at a range of maturities. Italian ryegrass established successfully as an understory crop in a grazed pea-oat GM.
System 4	Spring-seeded hairy vetch and winter cereal mix	Repeated grazing July through Oct	Short-duration, light grazing required to allow for hairy vetch regrowth after grazing.


Dorpor sheep grazing fall rye in System 1 (left), Italian ryegrass in System 3 (centre) and hairy vetch in System 4 (right).

Key Findings

Table 2. Summary of the ability of grazed GM systems to provide N fixation and forage.

System (Year 1)	Green manure performance: Biomass (% legume)	Green manure performance: Estimated N fixation†	Total forage supply‡
	kg/ha	kg/ha	kg/ha
System 1. Grazed FR + grazed pea-oat-soy (2012)	4400 (43%)	95	2780
System 1. Grazed FR + grazed pea-oat-soy (2013)	6000 (42%)	126	3320
System 2. Overwintering alfalfa + orchardgrass (2013)	2200 (25%)§	28	1110¶
System 2. Overwintering hairy vetch (2013)	1700 (87%)§	43	860¶
System 3. Pea-oat + ryegrass – grazed at 61-65 and 125 DAP (2013)	4900 (>50%)	123	5410
System 3. Pea-oat + ryegrass – grazed at 71-75 and 125 DAP (2013)	6900(>50%)	173	6360
System 4. Hairy vetch grazed once, late summer (2010)	7600 (>50%)	190	4460
System 4. Hairy vetch grazed rotationally 3 times (2010)	5800 (>50%)	145	2633

† Nitrogen fixation estimated at 2.5% of total biomass for green manures with legume content ≥50% and 2.5% x (% legume / 50%) for green manures with legume content <50%.
‡ Total forage supply is forage utilization by grazing sheep, except as indicated.
§ Measured in late June. Additional biomass production later in the season was not measured.
¶ Estimated based on 50% utilization of June forage biomass accumulation.

System 1:
- Provided sufficient N fixation (Table 2)
- Was the only system to provide forage in May (Figure 1) .
- Provided abundant forage in August (Figure 1).

System 2:
- Did not provide adequate N fixation in this study (Table 2). Continued legume growth throughout the season may achieve the desired level of N fixation.
- Was the only system to provide forage in early to mid-June (Figure 1).

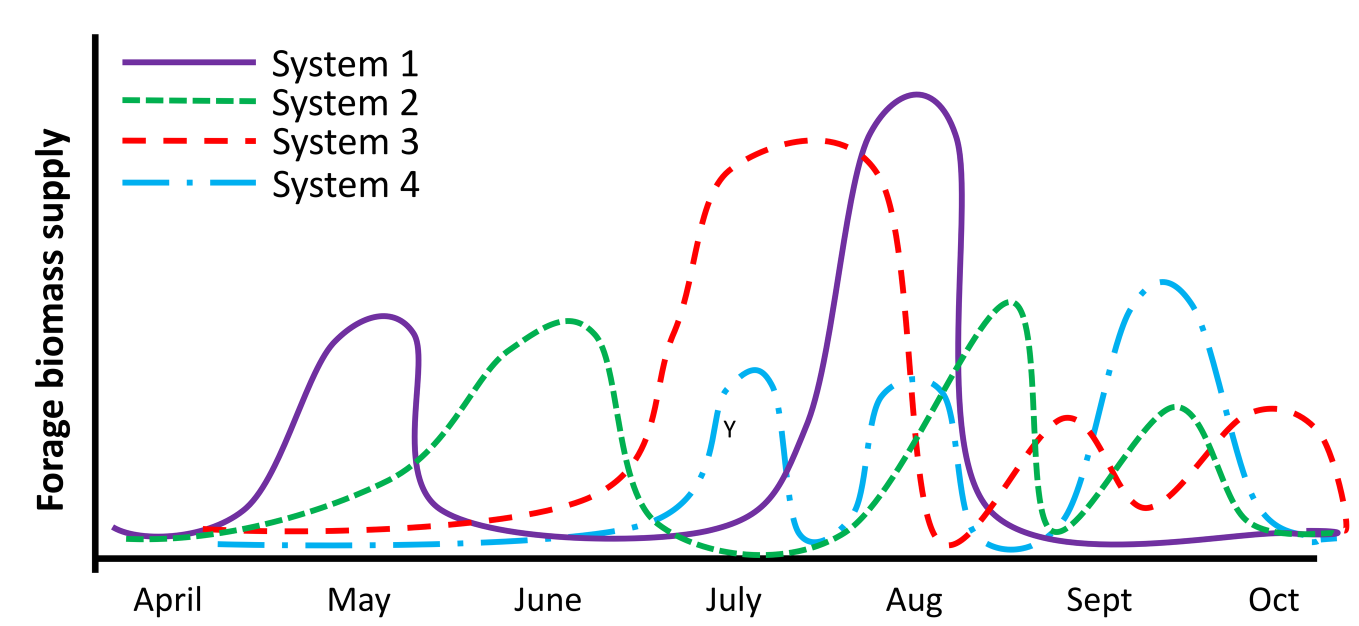


Figure 1. Schematic representation of forage supply provided by four grazed green manure systems.

System 3.
- Provided sufficient N fixation (Table 2).
- Provided abundant forage in mid- to late July when seeded in mid-May. Staggered seeding dates could extend this period from early July to early August (Figure 1).
- Grazing at early bloom (61-65 DAP) vs. full bloom (71-75 DAP) reduced forage supply and N fixation by pea-oat, but increased fall forage supply by ryegrass. Total forage supply was still lower for early-grazed than late-grazed pea-oat (Table 2).
- Cycling of N in pea-oat to underseeded Italian ryegrass appeared to be improved with longer grazing times (1100 ewes ha^{-1} for a full day vs. half day; data not shown).

System 4
- Provided sufficient N fixation (Table 2).
- Provided flexible grazing throughout the mid- to late summer (Figure 1).
- Rotational grazing of hairy vetch was successful only when initiated early in the season (65 DAP) and when grazing intensity was low (data not shown).

Summary and Conclusions

Each system investigated partially achieved the desired goals.
- Systems 1, 3 and 4 produced sufficient legume growth to provide 100 kg ha^{-1} of fixed N to subsequent crops
- No single system provided continuous season-long forage supply
- A combination of three or more systems on separate pieces of land could provide a season-long forage supply
- Individual systems could be used alongside perennial pasture systems

Farmers can create grazed GM systems to fit their forage supply needs by diversifying GM crops, overlapping crop life cycles, and altering seeding dates.

REFERENCE

Cicek, H., J.R. Thiessen Martens, K.C. Bamford and M.H. Entz. 2015. Forage potential of size leguminous green manures and effect of grazing on following grain crops. Renew. Agric. Food Syst. 30: 503-514. doi:10.1017/S1742170514000349

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