

## Grazing Green Manures to Optimize Nitrogen Supply on the Canadian Prairies

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**Key words:** green manures, grazing, annual forages, forage utilization, soil nitrate.

### Abstract

Returns from annual forages can be optimized when multiple benefits are drawn from them: soil fertility, weed competition and animal live weight gains from grazing forage biomass. An experiment was conducted in Manitoba, Canada between 2009 and 2011 to investigate the productivity, weed competitiveness and livestock utilization of seven green manure species and mixtures. We hypothesized that soil NO<sub>3</sub>-N levels will be greater when green manures are grazed than when they are left ungrazed. Hairy vetch, pea/oat mix and oats produced the greatest forage biomass in two of three years. Soybean and lentil failed to compete with weeds; containing 30 to 73% weed biomass in all years. Utilization by sheep for all crops ranged from 28% to 86%. Total soil NO<sub>3</sub>-N (0-120 cm) was significantly greater in grazed compared with ungrazed plots in the first year of all three experiments. Therefore, instead of single benefit of soil fertility, two benefits were reaped from green manures; potential livestock live weight gain and soil fertility.

### Introduction

Grazing of green manures by ruminants has been suggested as a way to improve economic and soil fertility building value of green manures. Grazing accelerates N mineralization from plant material and may improve the N availability to following cash crops. Although forage potential of many annual forage species has been evaluated, very few studies used actual grazing as a management effect. Particularly in organic systems, where soil management history may produce different soil fertility and weed pressure than conventional systems, such information is critical. Therefore, selection criteria for annual forages in organic systems should include: i) sufficient dry matter biomass production for livestock, ii) nitrogen contribution to following cash crops, iii) weed competitiveness, and, iv) nutritional quality and palatability. The objectives of the present experiment were to investigate: i) productivity, weed competitiveness and livestock utilization of seven green manure types, and ii) effects of grazing on soil NO<sub>3</sub>-N.

### Material and methods

The trial was conducted at University of Manitoba Ian Morrison Research Station located at Carman, Manitoba, Canada (49° 49' N, 98° 00' W) on a Hochfeld fine sandy loam soil. Trial was started in 2009 and was repeated in 2010 and 2011. Green manure species were hairy vetch (*Vicia villosa* L.), lentil (*Lens culinaris* cv. Indianhead), oat (*Avena sativa* cv. Legget), soybean (*Glycine max* cv. Prudence), sweet clover (*Melilotus officinalis* cv. Norgold), and, the mixes were pea/oat mix (*Pisum sativum* cv. 40-10/ *Avena sativa* cv. legget) and cocktail mix of barley (*Hordeum vulgare* cv. Cowboy), field pea (*Pisum sativum* cv.40-10), red millet (*Pennisetum glaucum* L.), radish (*Raphanus sativus* cv. Groundhog), soybean (*Glycine max* cv. Prudence), purple top turnip (*Brassica rapa* L.), sunflower (*Helianthus annuus* L.). Green manure species were grazed by 3 ewes and 2 lambs for 24 hours (1667 sheep d/ha). The plot size was 2m in width and 9m long and was surrounded by metal fence for precision and protection. Both sides were tandem disked at the same time upon the completion of grazing.

For experiment 1, soil samples were only taken from pea/oat and oat plots. In experiment 2, mixture plots were also sampled. In experiment 3, hairy vetch plots were sampled as well. Soil samples were taken using Dutch auger at four 30cm increments up to 120cm depth and analyzed for NO<sub>3</sub>-N using KCl extraction method. Above ground biomass of green manures and wheat was collected from 2x 0.4 m<sup>2</sup> areas within each plot. Samples were sorted and dried for 2 days at 60 °C and weighted for dry matter content. The ground dry matter samples were subsampled and analyzed for N concentration by combustion analysis using a LECO FP-528 (LECO, St. Joseph, MI). Percent forage utilization was determined by taking residual

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above ground biomass ( $2 \times 0.4 \text{ m}^2$ ) from grazed plots. Residual biomass was washed and dried for 2 days at  $60^\circ \text{C}$  and weighted for dry matter content. The experimental design was randomized complete block design in split plot arrangement with four replicates. The main plots were management type (i.e. grazed and soil incorporated) and the subplots were the species (Table 3). Differences were considered significant at  $P < 0.05$ . Means were separated using a Fisher protected LSD test.

## Results and Discussions

The growing season precipitation (April to October) over three year was very sporadic and averaged 386 mm, 607 mm and 297 mm in 2009, 2010 and 2011, respectively. The 30-year average in this location is 386 mm (Environment Canada 2012). Hairy vetch, pea/oat mix and oats produced the greatest forage biomass in two out of three years. In 2010, sweet clover produced a similar amount ( $5813 \text{ kg ha}^{-1}$  Table 1). Soybean and lentil failed to compete with weeds; containing 30 to 73% weed biomass in all years. Utilization by sheep for all crops ranged from 28% to 86% but the most common range was between 60% and 80% (Table 1), which are higher than managed pasture utilization rates of 30-45% (Bardgett, 2005). Lower utilization rates in 2009 can be attributed to the methodological omission, where post-grazing residual biomass were not washed before drying and weighing. Lower utilization of sweet clover in 2010 (33 %) may be result of high biomass production and consequent woody stem of sweet clover. In the present study, sheep completely rejected Canada fleabane (*Conyza canadensis*) but consumed other weed species present.

Soil  $\text{NO}_3\text{-N}$  was measured after green manure grazing (in autumn) to determine whether grazing increased the short-term N availability in the 0 to 120 cm soil profile. Greatest soil  $\text{NO}_3\text{-N}$  content ( $226 \text{ kg ha}^{-1}$ ) was observed in grazed pea/oat plots in experiment 1 and lowest ( $44 \text{ kg ha}^{-1}$ ) was in ungrazed mixture plots in experiment 3. Most of the soil  $\text{NO}_3\text{-N}$  content difference between grazed and ungrazed plots was at the top layer of soil (0-30 cm). Total soil  $\text{NO}_3\text{-N}$  (0-120 cm) was significantly greater in grazed compared with ungrazed plots in the first year of all three experiments (Figure 1). In experiment 1, total profile soil  $\text{NO}_3\text{-N}$  level in pea/oat plots was greater than in oat plots. In experiment 2, oat plots contained less  $\text{NO}_3\text{-N}$  than pea/oat and mixture plots. In experiment 3, there was significant species and management effect where soil in grazed hairy vetch plots contained the greatest amount of  $\text{NO}_3\text{-N}$ . This interaction indicated that increase in soil  $\text{NO}_3\text{-N}$  availability is greater when hairy vetch is grazed than grazing of other crops. Hairy vetch biomass is known to have low C:N ratio (Parr *et al.* 2011). Kyvsgaard *et al.*, (2000) showed that N concentration of faeces was highly correlated with C:N ratio and apparent digestibility of the feed.

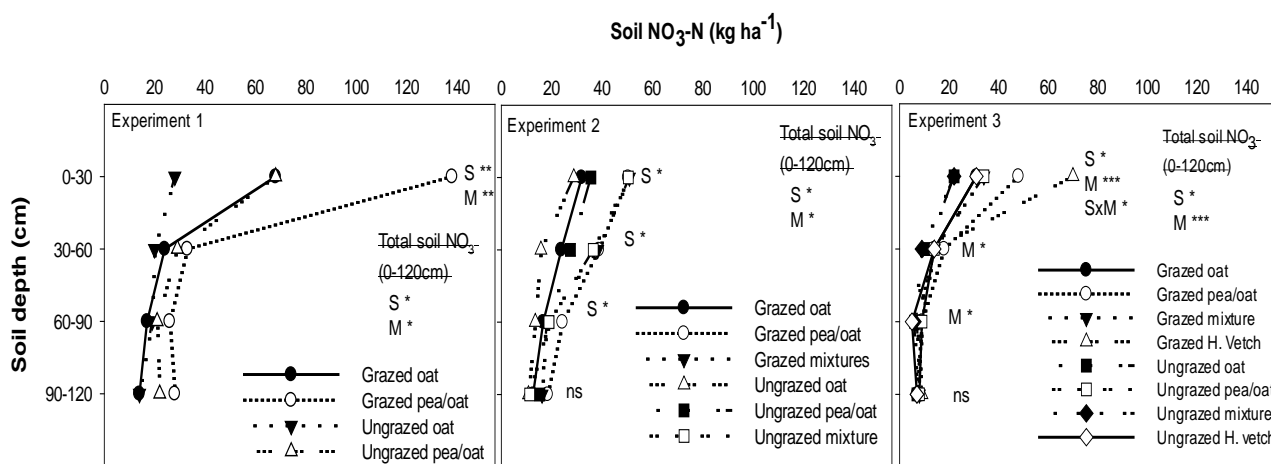
**Table 1: Green manure species biomass production, percent weed content and percent utilization for experiments 1, 2 and 3.**

Species	Biomass <sup>†</sup>			Weeds			Utilization		
	Exp1	Exp2	Exp3	Exp1 <sup>‡</sup>	Exp2	Exp3	Exp1	Exp2	Exp3
	-----kg ha <sup>-1</sup> -----			-----%-----			-----%-----		
Hairy vetch	6202a <sup>§</sup>	4260bc	4645a	<10	36b	0d	28b	81a	71bc
Pea/oat	6157a	5589ab	3352bc	<10	9c	15cd	45b	68a	65c
Oat	4337b	5570ab	4916a	<10	9c	12cd	54b	67a	74ab
Lentil	3442b	3536cd	3789ab	-	73a	64a	82a	71a	84a
Soybean	3540b	2606d	3376bc	30	70a	62a	40b	73a	85a
Mixture	- <sup>¶</sup>	3869cd	3234bc	-	16c	39b	-	76a	80ab
Sweet clover	-	5813a	2316c	-	n/a	30bc	-	40b	86a
<i>P&gt;F</i>	0.0004	0.0015	0.0143	-	<.0001	<.0001	0.0008	0.033	0.0055

† With weeds. ‡ Visual ratings.

§ Within columns of same main effect, numbers followed by the same letters are not significantly different according to Fisher LSD test ( $p < 0.05$ ).

¶ Mixture and sweet clover were not seeded for experiment 1



**Figure 1: Soil nitrate as affected by green manure species (S) and green manure management ([M] grazing and incorporation) at depths of 0-30, 30-60, 60-90 and 90-120 cm for experiments 1, 2 and 3. \*Significant at  $p \leq 0.05$ . \*\* Significant at  $p \leq 0.01$ . ns not significant.**

Animal diet rich in N may increase the risk of N losses through leaching (Ryden *et al.*, 1984) and gaseous emissions (Oenema *et al.*, 1997). The size of a ruminant animal species can have a direct impact on N cycling. For instance N loading under urine patches for sheep is usually half that of cattle, which reduces the risk of N losses (Di and Cameron, 2002). In the absence of grazing rate of N release from green manures is mainly a function of residue placement. For instance, soil incorporated green manures released N faster than herbicide terminated (Mohr *et al.*, 1998) or surface-mulched green manures (Vaisman *et al.*, 2011). Faster N mineralization from soil incorporated green manure biomass has been attributed to greater contact with soil microorganisms. An advantage of an integrated crop-livestock system is that additional processes (i.e., rumen function) can be brought to bear on decomposition of green manures.

## Discussion

This study established the value of pea/oat and hairy vetch as annual forages for grazing. Pea/oat and hairy vetch produced high levels of biomass, competed with weeds, and were readily utilized by sheep. Lentil and soybean failed to compete with weeds, produced little biomass. Based on high utilization values, legumes and mixtures tested in the present study show promise as annual forages. Even though lentil and soybean forage biomass contained high proportion of weed biomass, palatability by sheep was not decreased relative to less weedy forages. Palatability and nutritional properties of some annual and perennial weeds have shown to be comparable to common forage species (Marten and Anderson 1975). It appeared that soil  $\text{NO}_3\text{-N}$  can be significantly increased with the selection of appropriate species with low C:N. In situations with low legume biomass productivity, grazing may be used to increase the N benefit from legume green manures to the following crops. Therefore, instead of single benefit of soil fertility, two benefits were reaped from green manures; potential livestock live weight gain and soil fertility.

## Suggestions to tackle with the future challenges of organic animal husbandry

Arable and rangelands all around the world are under constant pressure from urbanization, climate change related stresses and human mismanagement. Feeding of animals has become a major challenge because of the conflict between food production for humans and forage for animals. These challenges instigated some to adopt new methods of farming where animals and crop productivity complement one another. Crop-livestock integrated systems have the potential to capitalize on the synergies of resulting from integration of production systems. Such integrated systems not only address critical issues in animal husbandry, but also in crop production.

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