Feedpea (*Pisum sativum* L.) based green feed forage:

A new option for organic wheat cropping system?

Project # 20030543

2007 Final Report

March 2007

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a) Abstract/Summary:

A three-year field experiment examined the impact of various cropping options on soil fertility and soil quality. Green forage was examined to determine if it could replace green manure in an organic system. Legume green manure treatments benefit subsequent crops by improving the N status of soils due to mineralization of previously fixed N. Although legume-based green manure crops are demonstrably valuable in a crop rotation, there is a net economic loss during the year that the green manure is grown. As an alternative, farmers may consider growing similar crops as 'green forage', thereby gaining some limited economic return. We asked whether green forage crops could be grown for an economic return and still have a positive impact on the nutrient status of the soil for subsequent crop growth.

The experiment consisted of 16 treatments in which feed pea, oat and triticale were grown alone or in combination, and managed either as green manure or green forage. Wheat and fallow (tillage) served as cropped/uncropped controls. Wheat yields following green manure treatments typically were higher than yields achieved after green forage, irrespective of the crop or intercrop grown as a forage/green manure. Although green forage crops were managed similarly to the green manure crops and were harvested at a relatively early growth stage, the plant material already had accumulated significant amounts of N and P resulting in net losses of these nutrients for the subsequent crop. Furthermore, additional moisture usage associated with the green forage crop likely limited wheat yields in the following year.

Of the treatments examined, feedpea grown as green manure conferred the greatest and most consistent advantage to the subsequent wheat crop. The benefits of feedpea were related to both enhanced N and P availability. It is likely that enhanced N availability associated with N_2 fixation, improved the ability of the subsequent crop to explore the soil for P.

Few differences were detected among the soil chemical and microbiological parameters associated with the green manure and green forage treatments. The benefits conferred by the green manure treatments were relatively short-term and reflect immediate affects related to residue inputs from the two treatments together with differences in soil moisture use.

In conclusion, this study demonstrated the value of including a N-fixing legume as a green manure in organic systems. Moreover, it was concluded that green forage is not an acceptable substitute for green manure.

b) Introduction:

A wide range of soil management practices, aimed at maintaining or enhancing soil fertility, currently are used by Saskatchewan organic farmers. Among these soil management practices is the inclusion of green manure crops into the rotation (Wander et al., 1994), largely as a measure to enhance soil fertility and soil quality (Edmeades, 2003). Although annual legumes frequently are grown as green manures specifically to enhance soil N reserves (Khan et al. 2003), recent reports have suggested that some green manure crops also can enhance soil biological activity and consequent soil P availability (Oberson et al., 2001). Because soil P availability is often viewed as a significant limitation to sustainable organic production in Saskatchewan, improved P availability is a highly desirable outcome of an effective green manure system.

Although some Saskatchewan organic farmers currently use green manure as a component of their organic cropping systems, others have yet to adopt this practice. One reason that some farmers do not include green manure crops in their rotation is the loss of income from the crop in the green manure plough- down year. An alternative to a traditional green manure crop could be the use of a legume crop as a green feed forage source for use on-farm or for sale to local livestock producers. This additional income could improve the economics of organic crop production if sufficient N is added to the system. Thus one objective of our study was to examine the economic feasibility of green forage versus green manure. Specific objectives of our study were:

1) To evaluate and compare feed pea and feed pea intercropped with a cereal as green manure crops for improving soil fertility and soil quality;

2) To determine if the choice of the cereal (i.e., oat vs. triticale) intercropped with feed pea affects the productivity of the green manure and consequent measures of soil fertility and quality;

3) To evaluate if N utilization by the intercropped cereal affects N accumulation and yield in the feed pea and determine the impact of seeding densities of the intercropped cereal;

4) To compare green manure and green forage systems for affects on soil fertility and quality.

c) **Methods:**

Experimental Design

Two field experiments were established, one in May 2004 on a commercial organic farm near Vonda, SK, and the second in May 2005 on a commercial organic farm near Delisle, SK. Both sites are located in the Dark Brown soil zone on Chernozemic soils. Each experiment was conducted over a two-year (i.e., two field seasons) period.

The experiment consisted of 16 treatments in which feed pea (*Pisum sativum* cv 40-10 silage pea), oat (*Avena sativa* L. cv AC Morgan) and triticale (X *Triticosecale* Wittmack cv Pika) were grown alone or in combination, and managed either as green manure (GRMN) or as green forage (GF) (Table 1). Three planting densities of the oat intercropped with the feed pea were included to test the hypothesis that available soil N supply influences the productivity of the intercropped system. Specifically, we compared the impact of increasing cereal density (i.e., a N "sink") on levels of N_2 fixation in feed pea. Continuous wheat and fallow (tillage) served as cropped/uncropped controls. All of the GrMn and GF treatments were followed by spring wheat (*Triticum aestivum* cv AC Barrie) in 2005 (Vonda) and 2006 (Delisle).

The 16 treatments were arranged in a randomized complete block design with four replicates.

Soil Characterization

Prior to seeding, soil samples were collected for initial characterization of the fields (Tables 2 & 3). A composite soil sample (0-to 30-cm and 30-to 60-cm depth at Vonda; 0-to15-, 15- to 30- and 30 - to 60- cm depth at Delisle) was collected for each of the four experimental blocks by combining 10 randomly selected cores from within each block. Soils were analysed for inorganic N, P, K and S, bulk density, pH, EC, organic C and texture.

Table 1. Crop treatments seeded in 2004 at Vonda and 2005 at Delisle under Green Manure (GrMn) and Green Forage (GF) organic management systems.

Management System	**Year 1 – treatment year**
Green manure (GrMn)	Feed pea
	Feed pea + Oat1 [1]
	Feed pea + Oat2 [1]
	Feed pea + Oat3 [1]
	Oat
	Feed pea + Triticale
	Triticale
Green feed forage (GF)	Feed pea
	Feed pea + Oat1 [1]
	Feed pea + Oat2 [1]
	Feed pea + Oat3 [1]
	Oat
	Feed pea + Triticale
	Triticale
Controls	Fallow
	Wheat (continuous)

[1]Oat 1, 2, 3 – 50, 100 and 150 plant m^{-2} respectively

Table 2. Chemical and physical characterization of the field soil at Vonda prior to seeding in the spring of 2004..

Soil Property	Depth of Sampling	
	0-30 cm	**30-60cm**
NO_3-N (μg g^{-1})	11	7
P (μg g^{-1})	8.5	3
K (μg g^{-1})	460	255
SO_4-S (μg g^{-1})	20	23
Bulk density (g cm^{-3})	1.15*	
pH	7.9	8.1
EC (mS cm^{-1})	0.3	0.3
Organic C (%)	1.6	-
Texture	Loam	Clay Loam

*surface 15 cm

Table 3. Chemical and physical characterization of the pre-seeding soil at Delisle, SK in the spring of 2005.

Soil Property	Sampling depth		
	0-15 cm	**15-30cm**	**30-60cm**
NO_3-N (μg g^{-1})	25	26	42
P (μg g^{-1})*	24	-	-
K (μg g^{-1})*	>600	-	-
SO_4-S (μg g^{-1})	26	48	86
Bulk density (g cm^{-3})			
pH	7.2	8.1	8.1
EC (mS cm^{-1})	0.3	0.4	1.8
Texture	Loam	Loam	Clay loam

*only analysed in the surface 0- to 15-cm soil layer

Field Operations:

Treatment years:

Prior to seeding, the fields were tilled using a tandem disk to incorporate previous crop residues and control early weed growth. Seeding was accomplished using a small plot air seeder. Treatment plots measured 4 m by 8 m, with 0.2 m row spacing.

Monocropped seeding rates were as follows: 157 kg ha^{-1} feed pea; 88 kg ha^{-1} oat; 94 kg ha^{-1} triticale; and 90 kg ha^{-1} wheat. These seeding rates provided recommended target populations of 95 plants m^{-2} feed pea and 250 plants m^{-2} for oat, triticale and wheat. Where crops were intercropped, seeding rates were adjusted as follows: 100 kg ha^{-1} feed pea; 18, 35 and 54 kg ha^{-1} oat; and 150 kg ha^{-1} triticale. The target plant densities were 60 plant m^{-2} feed pea; 50, 100 and 150 plant m^{-2} oat; and 150 plant m^{-2} triticale, respectively.

Pea seed was inoculated with Tagteam (Philom Bios Inc, Saskatoon, SK) immediately prior to seeding. The peat-based inoculant contains a P-solubilizing fungus, *Penicillium bilaiae* and *Rhizobium leguminosarum.* Inoculant was applied according to the manufacturer's recommendations (i.e., 2.2 kg inoculum to 1360 kg pea seed).

Seeding depth was approximately 5 cm for all crops. Weed control was conducted manually twice during the growing season.

Green manure plots were incorporated using a small plot tractor equipped with tandem disks when the feed pea was at full bloom (8 to 9 weeks after seeding). Green forage plots were harvested approximately 4 weeks later when at least 50% of the cereals were in the dough stage of development.

Test crop (wheat) years:

Prior to seeding, the fields were tilled using a tandem disk to incorporate previous crop residues and control early weed growth. The sites were seeded to wheat (*Triticum aestivum* cv AC Barrie) at a rate of 90 kg ha^{-1} in May of 2005 (Vonda) and May of 2006 (Delisle).

Plant Sampling

Treatment years:

The GrMn plots were sampled for biomass production and nutrient uptake and accumulation approximately 8 weeks after seeding, In 2004 at Vonda, the plough-down was delayed one week after initial sampling (i.e., 9 weeks after seeding) due to rain. In 2005 at Delisle, the plough-down crops were sampled the day before the crop was ploughed down. Aerial biomass plant tissue samples were collected from five 0.5 m rows. The shoots were cut approximately 5 cm from the soil surface. The samples were oven dried (48 h at 60°C) and subsequently weighed and ground (<1 mm).

Plants in the GF plots were sampled approximately 4 weeks later, when at least 50 % of the cereals were in the dough stage of development. Prior to harvesting the GF, five 0.5 m rows were sampled. The plants were cut approximately 5 cm from the soil surface. Samples were oven-dried for 48 h at 60^{o}C and weighed and ground (< 1mm).

Test crop (wheat) years:

Wheat was subsampled five times throughout the growing season to quantify biomass production, N and P uptake throughout the season. Wheat harvested at maturity was analysed for dry matter production, grain yield, and N and P contents.

Soil Sampling:

Surface soils (6 cm diameter x 15 cm depth) were sampled from each treatment plot in the fall of each year. Eight cores were extracted from each treatment plot using a soil hand auger. The cores were bulked to form one composite sample per treatment plot, sieved (2mm), and sub-divided into three sub-samples. One sub-sample was used for gravimetric moisture determination, one sub-sample was air dried and the third sub-sample was frozen (-20°C).

Laboratory Analyses:

Soils were analysed for pH (Hendershot et al., 1993) and electrical conductivity (EC) (Janzen, 1993) using a 1:2 (soil:water) extraction. Soil texture was determined using the hydrometer method (Gee and Bauder, 1986). Percentage of organic carbon (OC) in soils was measured using a LECO carbon analyser. Available soil NO_3^- and NH_4^+ were extracted with a 2.0 *M* KCl solution (10:1) (Maynard and Kalra, 1993) and analysed colorimetrically with autoanalyser. Phosphorus was extracted using the modified Kelowna method (Quian et al., 1994) and the PO_4 measured colorimetrically with an autoanalyser. NO_3 and PO_4 supply rates were determined using anion exchange membranes (AEM). Soils were incubated with the AEM for 24 h to assess short-term availability and for 7 d to assess longer-term availability. In addition a 2 h incubation of the AEM with a $NaHCO_3$ extractant was performed to estimate the immediately available nutrient supply. Light fraction organic matter was estimated according to Gregorich and Ellert (1993).

Soil microbial biomass C and N were estimated using a chloroform fumigation-extraction method (Voroney et al., 1993) followed by persulphate oxidation to convert the N to NH_4^+. Carbon from the extracts was quantified using a total organic carbon analyser. Nitrate in the extract was quantified colorimetrically using an autoanalyser. Microbial biomass P was extracted according to Myers et al. (1999) and quantified colorimetrically using an autoanalyser. Soil dehydrogenase activity was estimated according to Tabatabai (1982). Metabolic potential was calculated as the ratio of dehydrogenase activity to dissolved organic carbon.

Plant samples were ground (1-mm mesh). Subsamples were acid digested following standard procedures (Thomas et al., 1967). Concentrations of N and P in the digested solutions were determined colorimetrically using an autoanalyser.

Statistical Analyses:

Data from the treatment year were subjected to one-way analysis of variance (ANOVA) and least significant difference (Lsd) calculated for each parameter at a probability of 0.05 and 0.10. The $Lsd_{(0.10)}$ was included because of the highly variable nature of the field studies.

Data from the second year (wheat test crop year) was also subjected to one-way ANOVA. Lsd values were calculated at probabilities of 0.05 and 0.10. In addition, because of the complex nature of the treatments a number of orthogonal contrasts were developed to look at specific treatment effects on the subsequent growth of wheat, and soil fertility/quality measurements. Contrast analyses were performed at probabilities of 0.05, 0.10 and 0.20.

d) Results and Discussion:

Year 1 - Crop Biomass and Nutrient Uptake

There was no difference in the amount of biomass produced among the green manure treatments that included feedpea, either in monoculture or intercropped with a cereal, at the Vonda site (Table 4). These same treatments had higher N contents in the plant biomass as well as higher N uptake than the monocultures cereal treatments (oat or triticale). The N content and N uptake measurements in the treatments containing feedpea include a combination of soil available N and N from biological N fixation. Although increasing the amount of oat in the intercrop had little affect on biomass production, the amount of N in the plant biomass tended to decrease with increasing oat rate, indicating a lesser contribution of N fixation by the pea crop to the N fertility of the mix. The field pea/oat intercrop treatments were all seeded to the same rate of pea, and only the oat density varied. Clearly, increasing the oat density did not stimulate the feedpea to fix N more efficiently by using up the available soil N pool as was hypothesized. Instead, increasing the density of the cereal appeared to provide an opportunity for the oat to out-compete the feedpea. Importantly, successful N fixation depends on the ability of the host plant to provide energy, in the form of photosynthates, to the nodules. It is likely that the competition from the oats for light and nutrients/water, reduced the ability of pea to provide sufficient energy to the nodules and consequently, total N accumulation was reduced. Phosphorus content and uptake were less affected by the inclusion of oats than the N parameters. Triticale extracted more P from the soil on a per kg biomass basis than any of the feedpea treatments, but because of its poor productivity this did not translate into higher P uptake on a per hectare basis.

The greenfeed forage treatment crops were grown approximately four weeks longer than the green manure plough-down crops. During this longer growth period, all of the

Table 4. Productivity and nutrient contents of green manure crops and green feed forage crops grown at Vonda in 2004.

Management System	Treatment	Biomass (kg ha^{-1})	N content (g kg^{-1})	N uptake (kg ha^{-1})	P content (g kg^{-1})	P uptake (kg ha^{-1})
Green Manure	Feedpea	2042	31.1	64.7	1.8	3.7
	Feedpea/Oat1[1]	2090	25.4	54.1	1.7	3.6
	Feedpea/Oat2[1]	2067	23.2	47.5	1.8	3.7
	Feedpea/Oat3[1]	2352	18.2	43.6	1.8	4.2
	Oat	2086	12.3	25.7	2.2	4.5
	Feedpea/Trit.	1493	31.5	47.4	1.7	2.6
	Triticale	688	22.1	15.4	3.4	2.3
Forage	Feedpea	5521	27.6	153.7	1.5	8.4
	Feedpea/Oat1[1]	4861	20.6	100.2	1.6	7.7
	Feedpea/Oat2[1]	5212	18.3	99.1	1.8	9.5
	Feedpea/Oat3[1]	4759	17.1	81.6	1.4	6.7
	Oat	3367	7.3	24.2	2.0	6.2
	Feedpea/Trit.	4060	21.4	85.2	1.6	6.4
	Triticale	719	16.6	11.5	2.8	2.0
Lsd (0.05)		1536	8.0	48.1	0.8	3.7
Lsd (0.10)		1180	6.2	36.9	0.6	2.9

[1] Target planting densities: Oat 1 = 50 plants m^{-2}, Oat 2 = 100 plants m^{-2}, Oat 3 = 150 plants m^{-2}

treatment crops, except the triticale, more than doubled their biomass (Table 4). Similarly, N-uptake and P uptake were also approximately double in the green forage treatments than the green manure treatments. This represents a significant removal of nutrients from the site when green forage is harvested. While it may appear that growing the green manure crops for a longer period of time would increase the nutrients returned to the soil, a previous ADF study (Project # 2020198) found that extending the growth period for the green manure depleted soil moisture and increased competition by weeds. Consequently, extending the green manure growth period was generally not economical. Weed competition in the current study was not specifically examined, and the plots were hand-weeded twice during the growing season.

The Delisle site (Table 5) overall was more productive than the Vonda site (Table 4) and reflects the generally more fertile soils at this site (Tables 2 & 3), as well as the higher precipitation amounts received in 2005 compared to 2004. Nonetheless, treatment crops at the Delisle site (Table 5) generally responded similarly as those at Vonda, except that the oat monoculture tended to out-produce the feedpea monoculture (p=0.10) in the green manure treatments. In the green forage treatments, the feedpea intercropped with the intermediate oat density (Feedpea/Oat 2) produced more biomass and took up more N and P than the other intercrop treatments. While the same tendency existed among the green manure treatments, it took the extra month of growth for the difference in biomass to become statistically significant. However, this feedpea/oat green manure treatment extracted more P from the soil that the other treatments containing feed pea. Similarly, P uptake by oat alone was higher than all of the other treatments except the feedpea/oat2 treatment. Unlike N that can be added to the system through N fixation, the P in the biomass simply reflects more efficient extraction of soil P. Over the short-term, this can confer an advantage to the subsequent crop in a rotation, by making previously unavailable P available when the green manure biomass decomposes. Over the long-term this will simply deplete the total soil P supply more rapidly, unless external sources of P are added to the system.

It is important to remember that although higher productivity and nutrient uptake can be advantageous for a green manure crop, it is a disadvantage from a soil fertility perspective for a forage crop because of the removal of these nutrients.

Table 5. Productivity and nutrient contents of green manure crops and green feed forage crops grown at Delisle in 2005.

Management System	Treatment	Biomass	N content (g kg^{-1})	N uptake (kg ha^{-1})	P content (g kg^{-1})	P uptake (kg ha^{-1})
Green Manure	Feedpea	2542	32.7	82.4	2.8	7.0
	Feedpea/Oat1[1]	2958	25.1	74.4	2.9	8.7
	Feedpea/Oat2[1]	3630	25.5	91.6	3.1	11.3
	Feedpea/Oat3[1]	3357	21.8	73.1	3.0	9.9
	Oat	4237	17.2	72.9	2.4	13.1
	Feedpea/Trit.	1865	36.2	67.5	3.4	6.4
	Triticale	1357	32.9	44.5	4.7	6.4
Forage	Feedpea	5210	27.8	144.7	2.3	11.7
	Feedpea/Oat1[1]	5197	23.9	123.4	2.2	11.5
	Feedpea/Oat2[1]	7385	25.8	189.0	2.4	17.4
	Feedpea/Oat3[1]	5683	26.0	148.5	2.5	13.8
	Oat	5757	14.5	83.6	2.5	14.5
	Feedpea/Trit.	3615	27.2	101.2	2.7	9.9
	Triticale	1770	27.4	48.3	3.5	6.3
Lsd (0.05)		2030	6.0	57.4	1.1	5.4
Lsd (0.10)		1560	4.6	31.444.1	0.8	4.2

[1] Target planting densities: Oat 1 = 50 plants m^{-2}, Oat 2 = 100 plants m^{-2}, Oat 3 = 150 plants m^{-2}

Year 1 – Post-harvest Soil Characteristics

Soils were sampled in the fall of the treatment year to assess the short-term affect of the treatment crops on soil parameters. Soils were sampled in the late fall prior to the soils freezing so that we could assess a variety of soil microbiological factors. By collecting the samples late in the season, we were able to examine microbial properties unaffected by freezing winter conditions, as well as chemical soil properties relating to soil fertility.

Overall, soil moisture levels in the surface soils were not affected by the treatment crops grown at either site (Tables 6 & 7). There was a tendency at Vonda for the soils under the forage treatments to be slightly drier than the green manure treatments reflecting the longer time period they were grown. It appears that moisture was generally not limiting at the Delisle site. Not surprisingly, inorganic N and extractable P levels were generally higher under the green manure treatments than the forage treatments (Tables 6 & 7) suggesting that considerable mineralization of the plough-down material had occurred prior to sampling. At both Vonda and Delisle the feedpea intercropped with the lowest density of oat (feedpea/oat1) as a green manure treatment resulted in the highest amounts of soil inorganic N of all of the treatments. This higher availability of inorganic N probably reflects an optimal C:N ratio of the crop residues for microbial decomposition. At Vonda this intercrop treatment had significantly higher inorganic N levels in plant tissues (i.e., concentrations) than the feedpea green manure monoculture (Table 6), even though the monoculture treatment had the highest N uptake (Table 4). Mineralization typically is favoured by high N concentrations in the plant tissue and thus the quality (i.e., the C:N ratio) of plant tissue has a greater impact on early mineralization events as compared to the total N available. Interestingly, extractable P levels and both short-term and longer-term P supply rates at Vonda were highest in this feedpea/oat1 treatment. This observation further supports the notion that the feedpea/oat1 treatment was readily mineralizable, releasing both N and P as decomposition proceeded. In terms of nutrient availability, this feedpea/oat1 green manure treatment appears to be the best.

Light fraction organic matter (LFOM) is the most easily decomposable pool of organic matter for soil microorganisms (Gregorich and Ellert, 1993). There were generally no explainable patterns to differences in LFOM levels associated with the treatments (Tables 6 & 7). The feedpea/triticale treatment under both management systems and at both sites had lower LFOM levels. This implies either that decomposition from this OM pool was faster under this treatment, or that less of this fraction was added to this pool. Considering the low productivity of this treatment (Table 4), it is probably the latter situation. However, it would also be expected that the triticale monoculture treatments which had the lowest productivity, would also have very low LFOM levels, which was not the case. It is possible that the differences in LFOM reflect differences in overall rate of decomposition of easily mineralizable material; in which case the data suggest that the triticale residue was somewhat more resistant to early decomposition events and thus retained LFOM for a longer period of time. Triticale is known to have some allelopathic properties that may affect microbial activity, including early decomposition events. For example, Wilkes et al. (1999) reported that the fungus *Gaeumannomyces graminis* var. tritici (Ggt), which causes the root disease take-all, was inhibited when extracts prepared from triticale and rye roots were incorporated into nutrient media.

Table 6. Analyses for soils sampled in the fall of the treatment year (green manure and green forage) at Vonda in 2004 .

Management System	Treatment	Moisture (%)	Inorg. N ($\mu g\ g^{-1}$ soil)	LFOM[1] (mg)	Extractable P[2] ($\mu g\ g^{-1}$ soil)	P supply rate[3] ($\mu g\ cm^{-2}\ d^{-1}$)	P supply rate[4] ($\mu g\ cm^{-2}\ 7\ d^{-1}$)
Gr. Manure	Feedpea	11.3	13.37	80	2.40	0.37	0.10
	Feedpea/Oat1[5]	11.4	17.48	80	2.85	0.49	0.14
	Feedpea/Oat2[5]	11.0	15.12	80	2.48	0.33	0.10
	Feedpea/Oat3[5]	10.6	14.12	78	2.40	0.32	0.08
	Oat	11.0	14.34	81	2.38	0.28	0.06
	Feedpea/Trit.	10.7	12.58	63	2.55	0.37	0.09
	Triticale	9.8	12.18	88	2.68	0.36	0.11
Forage	Feedpea	10.6	11.09	84	2.43	0.35	0.09
	Feedpea/Oat1[5]	10.5	13.60	81	1.53	0.21	0.05
	Feedpea/Oat2[5]	10.4	12.29	85	1.83	0.30	0.10
	Feedpea/Oat3[5d]	9.8	12.40	77	2.28	0.30	0.08
	Oat	9.3	12.89	87	1.93	0.30	0.09
	Feedpea/Trit.	10.4	11.57	70	1.73	0.34	0.12
	Triticale	9.5	11.26	96	1.98	0.28	0.09
Controls	Fallow-Wheat	9.4	9.09	87	2.30	0.33	0.10
	Wheat-Wheat	10.7	13.00	82	2.68	0.35	0.10
Lsd (0.05)		3.6	4.84	19	1.51	0.28	0.15
Lsd (0.10)		2.8	3.72	14	1.16	0.22	0.12

[1]Light fraction organic matter
[2]Immediately available - Extracted using anion exchange membranes incubated for 2 hours
[3]Short term supply rate - Extracted using anion exchange membranes incubated for 24 hours
[4]Long- term - Extracted using anion exchange membranes incubated for 7 days
[5]Target planting densities: Oat 1 = 50 plants m^{-2}, Oat 2 = 100 plants m^{-2}, Oat 3 = 150 plants m^{-2}

Table 7. Analyses for soils sampled in the fall of the treatment year (green manure and green forage) at Delisle in 2005 .

Management System	Treatment	Moisture (%)	Inorg. N ($\mu g\ g^{-1}$ soil)	LFOM[1] (mg)	LFOM-C (%)	Extractable P[2] ($\mu g\ g^{-1}$ soil)	P supply rate[3] ($\mu g\ cm^{-2}\ d^{-1}$)	P supply rate[4] ($\mu g\ cm^{-2}\ 7\ d^{-1}$)
Gr. Manure	Feedpea	23.0	27.43	88	19.75	6.72	0.86	0.42
	Feedpea/Oat1[5]	23.0	29.22	116	19.59	6.65	0.90	0.44
	Feedpea/Oat2[5]	22.8	23.60	98	19.26	6.24	0.79	0.38
	Feedpea/Oat3[5]	22.0	17.87	73	19.20	4.79	0.60	0.29
	Oat	23.0	20.43	86	18.51	5.13	0.69	0.31
	Feedpea/Trit.	23.4	13.01	78	20.37	5.38	0.72	0.31
	Triticale	23.3	24.07	116	19.35	6.07	0.72	0.36
Forage	Feedpea	23.6	16.25	100	21.94	7.12	0.79	0.38
	Feedpea/Oat1[5]	22.1	17.20	128	20.29	5.81	0.71	0.35
	Feedpea/Oat2[5]	21.8	13.14	108	20.55	4.38	0.65	0.28
	Feedpea/Oat3[5]	22.5	16.91	118	20.03	5.92	0.82	0.39
	Oat	23.2	14.63	183	16.74	5.80	0.86	0.36
	Feedpea/Trit.	22.1	12.99	93	19.55	5.36	0.70	0.34
	Triticale	23.1	13.46	73	17.55	4.24	0.57	0.26
Controls	Fallow-Wheat	22.2	13.80	103	21.55	5.78	0.71	0.32
	Wheat-Wheat	23.7	13.73	96	18.96	5.80	0.68	0.32
Lsd (0.05)		2.2	10.25	26	4.76	3.83	0.45	0.23
Lsd (0.10)		1.7	7.87	21	3.65	2.94	0.35	0.18

[1]Light fraction organic matter
[2]Immediately available - Extracted using anion exchange membranes incubated for 2 hours
[3]Short term supply rate - Extracted using anion exchange membranes incubated for 24 hours
[4]Long- term - Extracted using anion exchange membranes incubated for 7 days
[5]Target planting densities: Oat 1 = 50 plants m^{-2}, Oat 2 = 100 plants m^{-2}, Oat 3 = 150 plants m^{-2}

Examination of soil microbial biomass properties in the fall of the treatment year at Vonda indicated few statistically significant differences in the measured parameters (Table 8). Trends suggest, however, that the soil microbial biomass was not as active in the green manure treatments as compared to the forage treatments. For example, SMB-N values typically were numerically higher for all forage treatments (overall mean = 83.22 µg NH_4^+ g^{-1} soil) as compared to similar green manure treatments (overall mean = 69.48 µg NH_4^+ g^{-1} soil). The fact that the overall mean for the green manure treatments was very similar to the SMB-N value for the fallow treatment suggests that much of the early microbial flush of activity following plough-down had largely subsided by the late fall sampling time. In contrast, microbial activity and thus population size appeared to remain stimulated in the forage treatments, even at the late sampling time. Presumably, the forage treatments were still in earlier stages of decomposition and thus continued to sustain the microbial population later into the fall. Thus, trends likely reflect subtle differences in microbial activity related to different plough-down and incorporation times. The fact that none of the observed trends were statistically significant suggest that if differences between treatments were real, these differences were not large enough relative to the variability in the data to be detected at either the 0.5 or 0.10 level of significance, and thus these differences were unlikely to have much, if any biological significance.

Results from Delisle similarly indicated few statistically significant differences between estimates of microbial biomass size and activity (Table 9). It is interesting to note, however, that SMB-C levels were higher relative to SMB-N levels than those observed at the Vonda site. The relatively high levels of SMB-C to SMB-N suggests either a shift in the composition of the microbial biomass at this site, likely in favor of a more fungal dominated microbial biomass (i.e., high C:N ratio), or simply an N-starved biomass. Nitrogen starved conditions may be related to the higher biomass production at Delisle resulting in higher returns of plant material back to the soil. The microbial biomass likely would have increased which may have, in turn, resulted in a temporal increase in the immobilization of inorganic N in the soil solution, thereby creating a temporary N deficit in the soil. As a consequence, the burgeoning biomass may have been temporarily N-starved at this site during active decomposition of plant residues. The latter explanation seems unlikely given the generally higher inorganic N levels at Delisle relative to Vonda. Thus the observation of higher SMB-C contents at Delisle likely reflects composition differences in the microbial biomass community. This is consistent with the higher levels of biomass productivity at the Delisle site as compared to the Vonda site. The lower levels of MMPot (Microbial Metabolic Potential) as compared to levels achieved at Vonda, support the idea that the microbial biomass may have been less efficient at Delisle, likely due to N deficiencies caused by temporary immobilization.

Table 8. Soil microbiological analyses for soils sampled in the fall of the treatment year (green manure and green forage) at Vonda in 2004.

Management System	**Treatment**	**SMB[1]-N ($\mu g\ NH_4^+\ g^{-1}$ soil)**	**SMB-C ($\mu g\ C\ g^{-1}$ soil)**	**Deh. Act[2]. (μg TPF g soil day^{-1})**	**MMPot[3]**
Gr. Manure	Feedpea	73.27	722.32	104.26	1.98
	Feedpea/Oat1[4]	74.15	687.58	141.57	2.93
	Feedpea/Oat2[4]	60.63	668.47	141.57	2.23
	Feedpea/Oat3[4]	73.79	646.46	138.04	2.86
	Oat	68.97	639.16	138.53	2.12
	Feedpea/Trit.	70.30	576.43	137.07	2.60
	Triticale	65.25	689.55	147.16	2.77
Forage	Feedpea	79.08	694.28	134.76	2.81
	Feedpea/Oat1[4]	75.37	771.08	135.98	2.37
	Feedpea/Oat2[4]	83.35	763.65	157.73	3.01
	Feedpea/Oat3[4]	96.22	719.73	152.87	3.30
	Oat	89.25	718.61	153.72	3.43
	Feedpea/Trit.	80.41	717.49	146.91	3.40
	Triticale	78.89	739.66	162.47	2.96
Controls	Fallow	70.17	632.81	165.87	3.17
	Wheat	85.04	821.36	149.35	3.42
Lsd (0.05)		37.01	310.20	37.69	1.61
Lsd (0.10)		28.42	238.24	28.94	1.24

[1]SMB-Soil Microbial Biomass
[2] Dehydrogenase activity
[3]MMPot-Microbial Metabolic Potential
[4]Target planting densities: Oat 1 = 50 plants m^{-2}, Oat 2 = 100 plants m^{-2}, Oat 3 = 150 plants m^{-}

Table 9. Soil microbiological analyses for soils sampled in the fall of the treatment year (green manure and green forage) at Delisle in 2005.

Management System	Treatment	SMB[1]-N ($\mu g\ NH_4^+\ g^{-1}$ soil)	SMB-C ($\mu g\ C\ g^{-1}$ soil)	SMB-P ($\mu g PO_4^-\ g^{-1}$ soil)	Deh. Act[2]. (μg TPF g soil day^{-1})	MMPot[3]
Gr. Manure	Feedpea	49.78	803.4	13.01	71.8	1.76
	Feedpea/Oat1[4]	48.76	898.9	11.66	66.1	1.28
	Feedpea/Oat2[4]	35.96	912.7	11.42	70.8	2.59
	Feedpea/Oat3[4]	34.72	832.0	12.09	65.4	2.01
	Oat	42.86	921.0	11.04	69.7	2.55
	Feedpea/Trit.	68.43	946.2	12.63	64.2	1.85
	Triticale	61.13	993.3	14.22	73.1	2.29
Forage	Feedpea	50.94	865.9	10.91	77.2	2.22
	Feedpea/Oat1[4]	53.59	806.8	10.20	66.2	2.25
	Feedpea/Oat2[4]	60.52	972.3	14.23	65.5	1.82
	Feedpea/Oat3[4]	55.76	1027.2	13.34	78.0	3.62
	Oat	46.79	850.8	11.83	67.2	1.98
	Feedpea/Trit.	35.88	703.3	10.04	56.2	1.63
	Triticale	43.29	804.0	10.07	58.1	1.74
Controls	Fallow-Wheat	45.85	851.2	12.29	75.9	1.76
	Wheat-Wheat	52.84	925.2	13.62	69.7	1.95
Lsd (0.05)		65.25	102.3	4.82	28.15	3.47
Lsd (0.10)		50.11	78.5	3.70	21.62	2.67

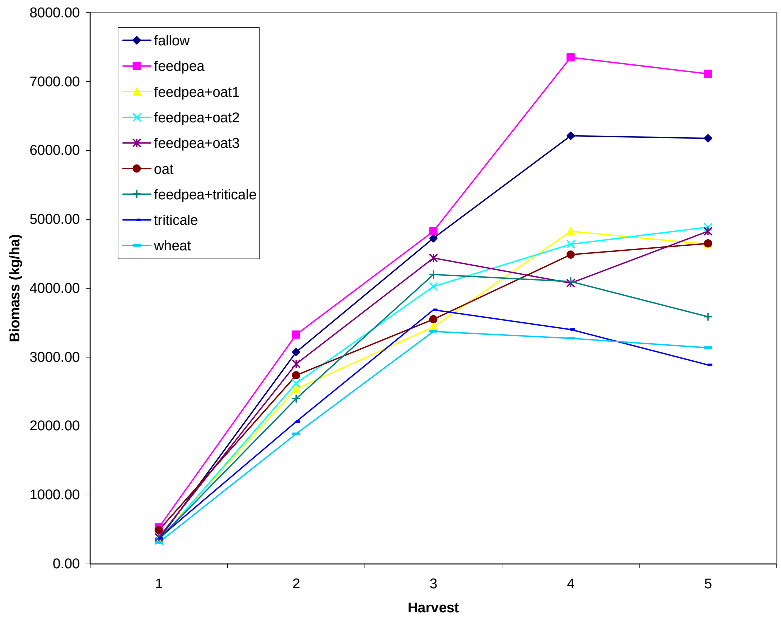
[1]SMB-Soil Microbial Biomass
[2] Dehydrogenase activity
[3]MMPot-Microbial Metabolic Potential
[4]Target planting densities: Oat 1 = 50 plants m^{-2}, Oat 2 = 100 plants m^{-2}, Oat 3 = 150 plants m^{-2}

Year 2 – Wheat Yield and Nutrient Uptake

Wheat was grown as a test crop the year after the green manure and green forage treatments. Wheat biomass production at Vonda (Figure 1) over the growing season was higher for the green manure treatments than the green forage treatments. Under both management systems wheat grown on pea was among the top producers in terms of biomass production. This is consistent with many studies that have reported both N and non-N benefits of growing pea in a cereal based crop rotation (e.g., Stevenson and Van Kessel, 1996a,b; Beckie et al., 1997a, 1997b). Under the green manure system, wheat grown after the feedpea plough-down produced more biomass than wheat grown on fallow, by the fourth harvest date, approximately 8 weeks after the wheat crop had emerged. Presumably, additional N inputs from N_2 fixation and subsequent mineralization of the plant tissue enhanced N availability as compared to increased N availability due to mineralization of native soil organic matter alone (i.e., the fallow treatment).

In the forage system, wheat grown after fallow out-performed all of the crop treatments in terms of biomass production (Figure 1). Interestingly, despite the inorganic nitrogen and phosphorus supplies being higher under the feedpea/oat1 treatment (Table 6), productivity of the wheat grown on this treatment was not higher as might have been anticipated based on soil tests alone. It is possible that there may have been a temporary increase in nutrient supplies under this treatment, but this increase was not sustained throughout the growing season. Alternatively, the feedpea/oat treatment might have reduced the availability of some other factor not measured in this study that consequently limited growth. For example, although soil moisture in the top 20 cm was unaffected by treatment (Table 6), it is possible that moisture extraction at depth was negatively affected by the feedpea/oat treatment as compared to the fallow treatment and thereby limited subsequent wheat crop yield. Final wheat grain yield (Figure 2, Table 10) was higher for wheat crop grown on the feedpea plough-down compared to all other treatments, as also was observed for the green manure treatment.

At Vonda, wheat grown on the green manure treatments consistently out-yielded all of the green forage treatments (Figure 2). Thus, although green forage treatments may confer an economic advantage in terms of producing harvestable material, clearly there is a cost to exporting the green manure material in terms of production of subsequent crops.



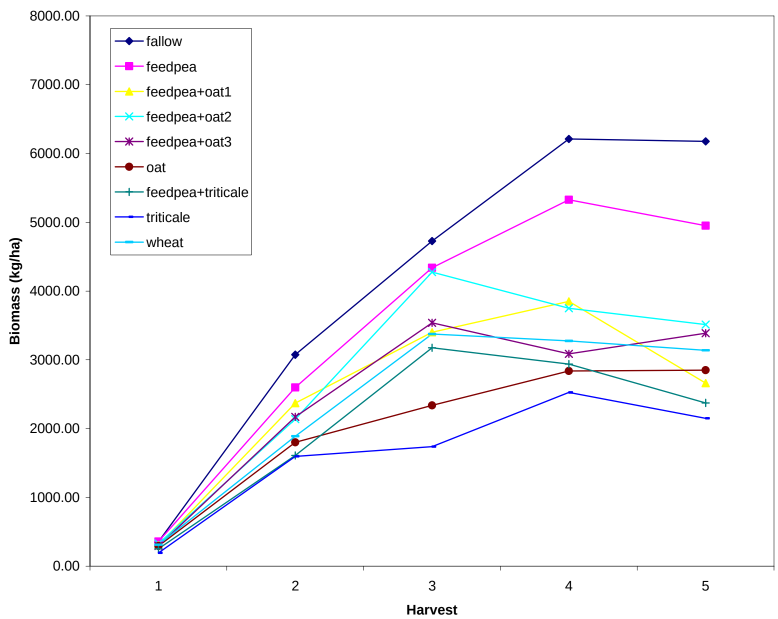


Figure 1: Biomass of wheat grown the year after treatment crops were ploughed down as Green Manures (top) or harvested green as Green Forage (bottom) at Vonda in 2005. Plants were harvested at 2 week intervals after the wheat crops emerged.

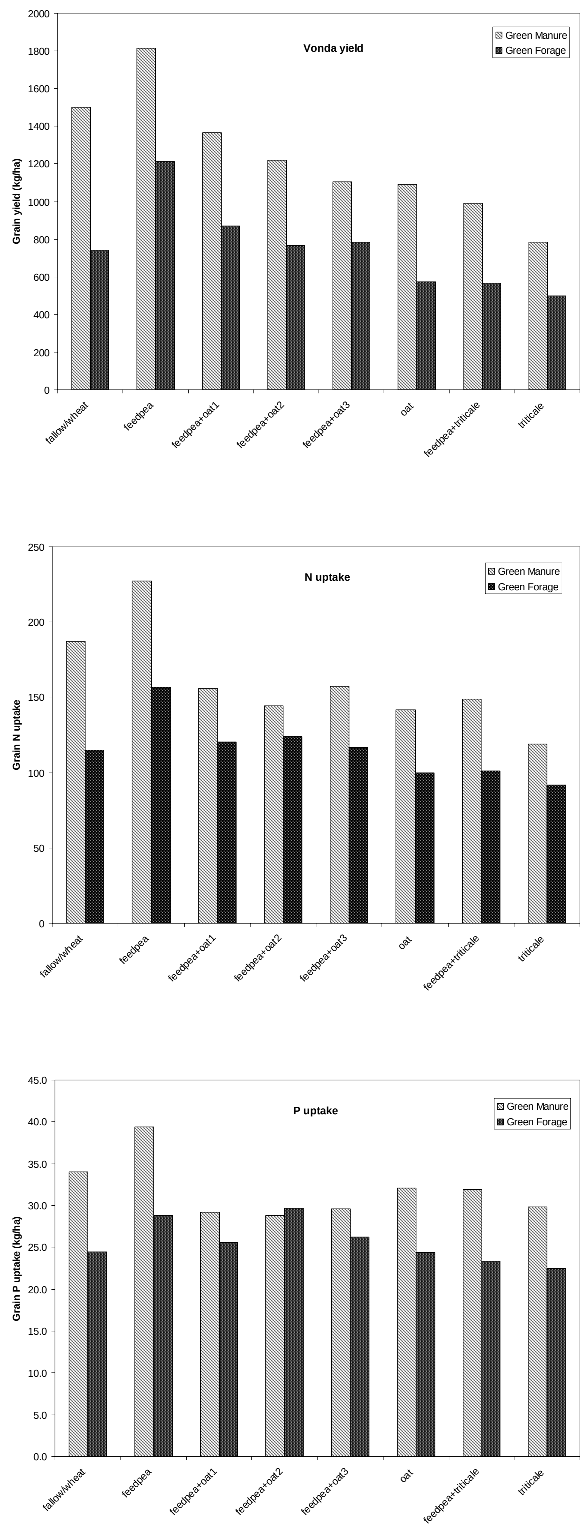
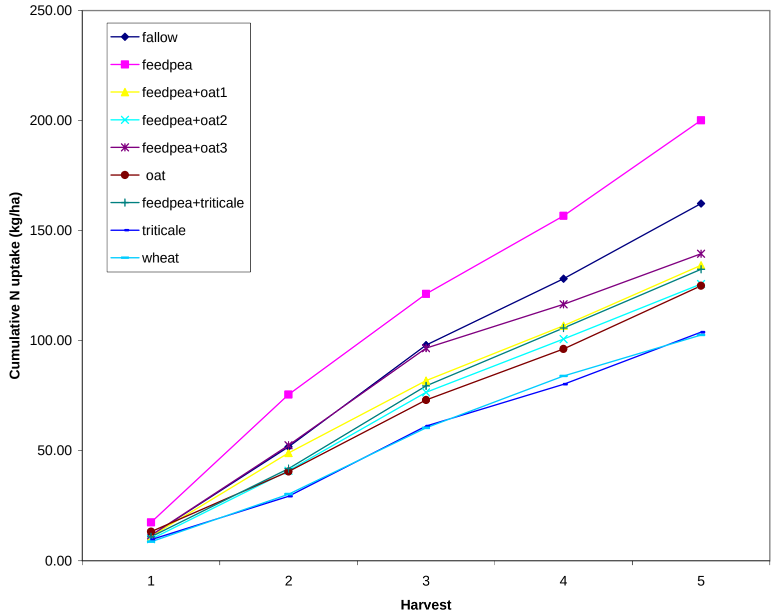


Figure 2: Yield , N and P uptake in wheat grown the year after treatment crops were ploughed down as Green Manures or harvested green as Green Forage at Vonda in 2005. First set of bars are fallow and continuous wheat controls.

Cumulative N uptake (Figure 3) and cumulative P uptake (Figure 4) by the wheat crop followed the same pattern as biomass production suggesting that N and P availability were important determining factors in the production of dry matter. Under both the green manure and the green forage management system, the monoculture pea treatment was the top supplier of both N and P. It is not surprising that the monoculture pea treatment enhanced soil N availability and subsequent N uptake of the wheat crop due to the ability of pea to fix N and the subsequent mineralization of this plant material. Pea residues typically have a relatively low C:N ratio, even when grown to maturity, and thus are rapidly decomposed by the soil microbial biomass. When ploughed down at a relatively early growth stage, the low C:N ratio of the pea material would have favoured rapid and relatively complete mineralization of any fixed N in the plant tissue. It is particularly interesting, however, that this treatment also led to enhanced P uptake. There are three likely reasons for the enhanced P uptake. Firstly, enhanced N nutrition may have stimulated early root development of the wheat and thus the enhanced root system may have had better access to soil P by exploring the soil profile for P more fully. Alternatively, pea is known to be highly mycorrhizal and a combination of enhanced P uptake into the root system together with a stimulated mycorrhizal population in the soil following wheat may have enhanced the ability of the subsequent wheat crop to acquire P. Finally, pea was inoculated with a dual inoculant that supplied both rhizobia and a P-solubilizing fungal inoculant (*Penicillium bilaiae*). The P solubilizing inoculant may have remained established in the soil to provide benefits to the subsequent crop. In the green forage system, however, the fallow treatment apparently supplied more nutrients to the subsequent wheat crop, suggesting an interaction between crop residues and soil moisture availability.

The feedpea/oat intercropped treatments generally provided equivalent amounts of nutrients to the crops (Table 10). The triticale monoculture and feedpea/triticale intercrop treatments were always the lowest N supply treatments, probably reflecting both the low biomass input of these treatments, but also their resistance to degradation and mineralization of N in the plant tissue. Even when N-fixing pea was grown with the triticale, N supply to the subsequent crop was impaired.



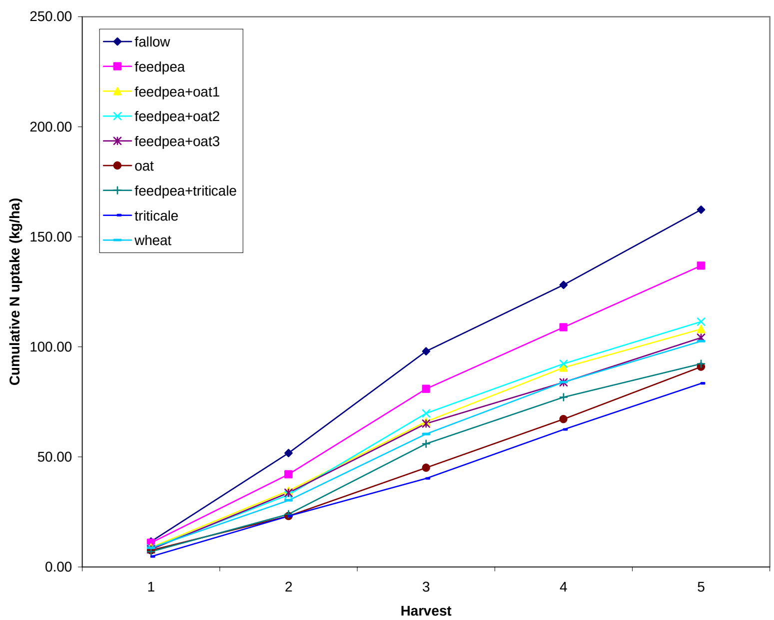


Figure 3: Cumulative N uptake by wheat grown the year after treatment crops were ploughed down as Green Manures (top) or harvested green as Green Forage (bottom) at Vonda in 2005. Plants were harvested at 2 week intervals after the wheat crops emerged.

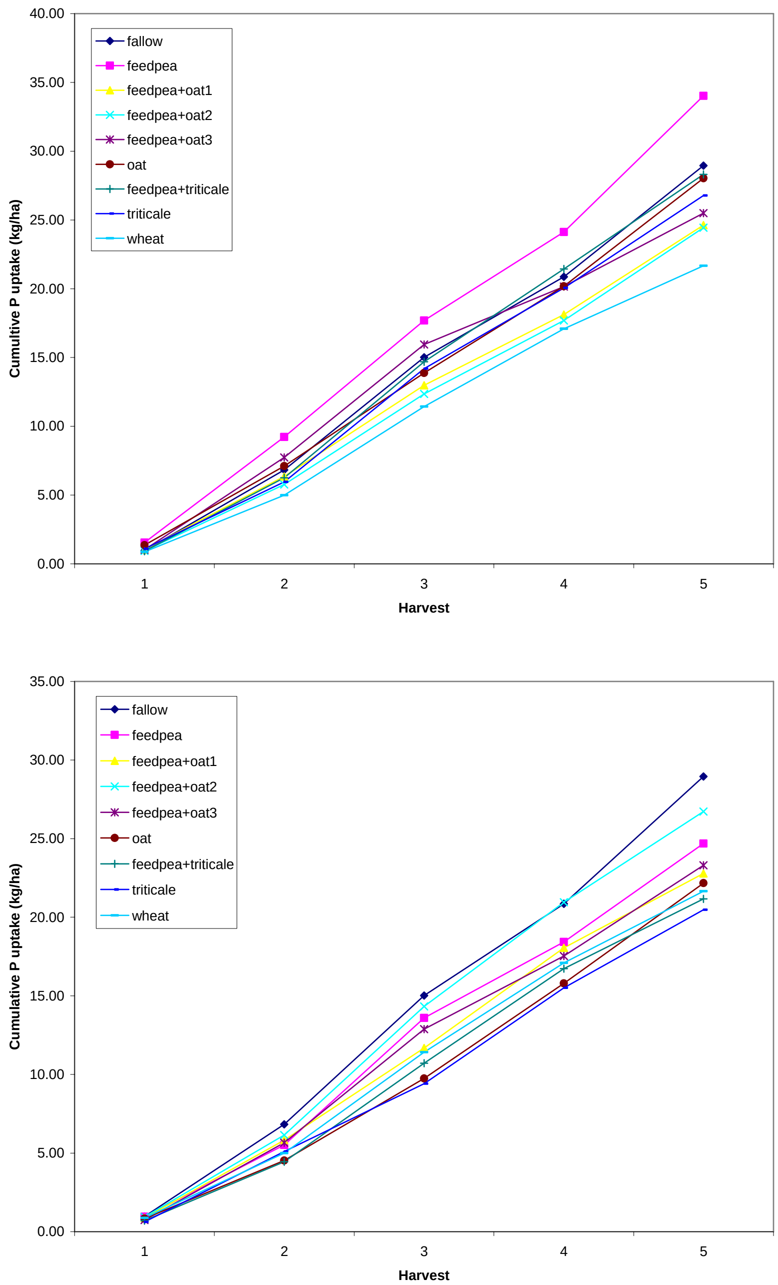


Figure 4: Cumulative P uptake by wheat grown the year after treatment crops were ploughed down as Green Manures (top) or harvested green as Green Forage (bottom) at Vonda in 2005. Plants were harvested at 2 week intervals after the wheat crops emerged.

Table 10. Final grain yield and nutrient status of wheat grown at Vonda in 2005. The green manure and forage treatments were grown the previous year (2004)

Management System	Treatment	Trt No.	Grain yield (kg ha^{-1})	N content (g kg^{-1})	Total N (kg ha^{-1})	P content (g kg^{-1})	kg P/ha (kg ha^{-1})
Green Manure	Feedpea	1	1814.58	22.10	40.14	3.77	6.83
	Feedpea/Oat1[1]	2	1364.58	20.10	27.75	3.70	5.12
	Feepea/Oat2[1]	3	1220.83	19.60	24.05	3.87	4.73
	Feedpea/Oat3[1]	4	1106.25	19.55	21.76	3.76	4.18
	Oat	5	1089.58	19.93	21.80	3.86	4.24
	Feedpea/Trit.	6	991.67	19.73	19.44	3.45	3.44
	Triticale	7	785.42	21.53	16.95	3.88	3.06
Forage	Feedpea	8	1210.42	20.60	24.92	3.42	4.11
	Feedpea/Oat1[1]	9	868.75	20.58	17.86	3.53	3.06
	Feepea/Oat2[1]	10	766.67	20.90	16.02	3.73	2.86
	Feedpea/Oat3[1]	11	783.33	20.55	16.07	3.77	2.95
	Oat	12	575.00	20.03	11.52	3.57	2.04
	Feedpea/Trit.	13	566.67	20.58	11.79	3.49	2.01
	Triticale	14	497.92	21.95	10.99	3.63	1.81
Controls	Fallow-wheat	15	1500.00	20.10	30.30	3.85	5.77
	Wheat-wheat	16	741.67	20.38	15.11	2.89	2.11
Lsd (0.05)			457.88	1.93	10.25	0.63	1.88
Lsd (0.10)			351.65	1.48	7.88	0.48	1.45
Contrasts		**Trt compared**	--------------------------- *Differences Between Means*				--------------------
fallow vs. (GrMn+GF)		15- (1:14)	7358***	-6.30	143.11***	2.40	30.33***
wheat vs. (GrMn+GF)		16 - (1:14)	-3258**	-2.45	-69.51**	-11.0***0	-20.94***
GrMn vs. GF		(1:7)-(8:14)	3104***	-2.65*	62.73***	1.16**	12.74***
Oat vs. Triticale		5,12 - 7,14	381*	-3.53***	5.38	-0.08	1.42*
Pea/Oat vs. Pea/Trit		4, 11-6, 13	331*	-0.20	6.60	0.59**	1.67**
(GrMn vs. GF)(Oat vs. Trit.)		(5,12)(7,14)	227	-0.33	4.32	0.03	0.94
(GrMn vs. GF)(pea/Oat vs. Pea/Trit)		(4, 11)(6, 13)	-102	-0.15	-1.96	0.03	-0.21

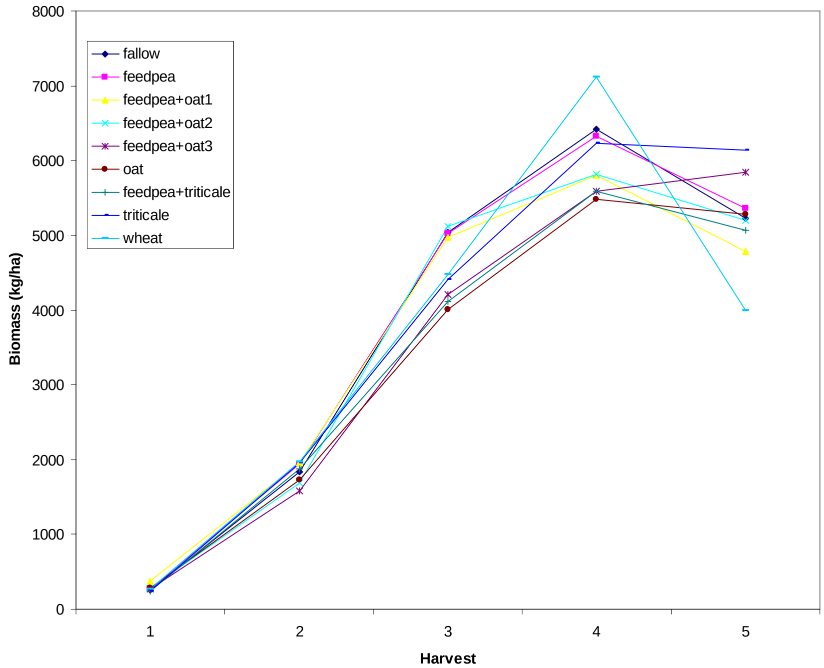
*, **, *** indicate differences are significant at the 0.2, 0.1, and 0.05 levels of significance.
[1]Target planting densities: Oat 1 = 50 plants m^{-2}, Oat 2 = 100 plants m^{-2}, Oat 3 = 150 plants m^{-2}

The pattern of N and P uptake observed over the wheat growing season was reflected in the final grain nutrient contents (Figure 2, Table 10). Wheat grown on feedpea green manure monoculture had both higher N and P uptake into the grain as compared to all other treatments. Similarly, wheat grown on all of the green manure treatments had higher N uptake into the grain as compared to all of the green forage treatments. These results reflect the fact that the green manure treatments conserved and recycled nutrients within the systems. Only in the case of P uptake were the feedpea/oat intercrop green manure treatments not superior to the comparable green forage treatments.

Smaller treatment differences in biomass acquisition were observed at the Delisle site (Figure 5), likely because of the overall higher fertility levels and better growing season conditions at Delisle compared to Vonda. Wheat grown on those treatments that included feedpea, tended to acquire biomass earlier in the season than the cereal monocultures. These results suggest that mineralization of pea plant tissue had largely occurred during the fall and spring prior to seeding wheat, or during very early growth stages resulting in an early supply of mineral N. By the fourth harvest (approximately 8 weeks after emergence) wheat grown on the cereal treatments (especially the wheat and triticale treatments) experienced a spike in biomass production. It is probably at this time that optimal conditions for decomposition and mineralization for the cereal residues (with higher C:N ratios relative to the pea) occurred in the soil. Interestingly, final wheat grain yields at this site were not consistently higher when the treatment crops were ploughed down as compared to treatments harvested as green forage (Table 11). Wheat grown on the green manure feedpea was the highest yielding in terms of biomass production of all the treatments but wheat grown on the cereals–oat, wheat, triticale and the feedpea/triticale intercrop–produced slightly higher yields when harvested as green forage. These observations support the contention that nutrients and soil moisture were not as limiting to yield at Delisle as they were at Vonda.

Despite the less pronounced biomass and yield responses to the treatments observed at Delisle as compared to Vonda, N and P uptake by wheat was strongly influenced by the previous treatments (Figures 6, 7 & 8). Except for the feedpea/oat1 treatment, N and P uptake by wheat grown on the green manure treatments was higher than uptake by wheat grown on the green forage treatments. Moreover, at Delisle, feedpea did not supply more nutrients than the fallow treatment, as had been observed at Vonda. The continuous wheat control was the poorest in terms of biomass production and acquisition of N and P.

Even though wheat yields did not necessarily correspond to the N and P supplies, the cumulative N and P uptake curves still give important information about the relative value of the treatment crops (Figures 7 & 8). Of the crops tested, feedpea monoculture was always the best supplier of both N and P (Table 11). Moreover, the intercrops containing feedpea supplied more N and P than the cereals grown alone.



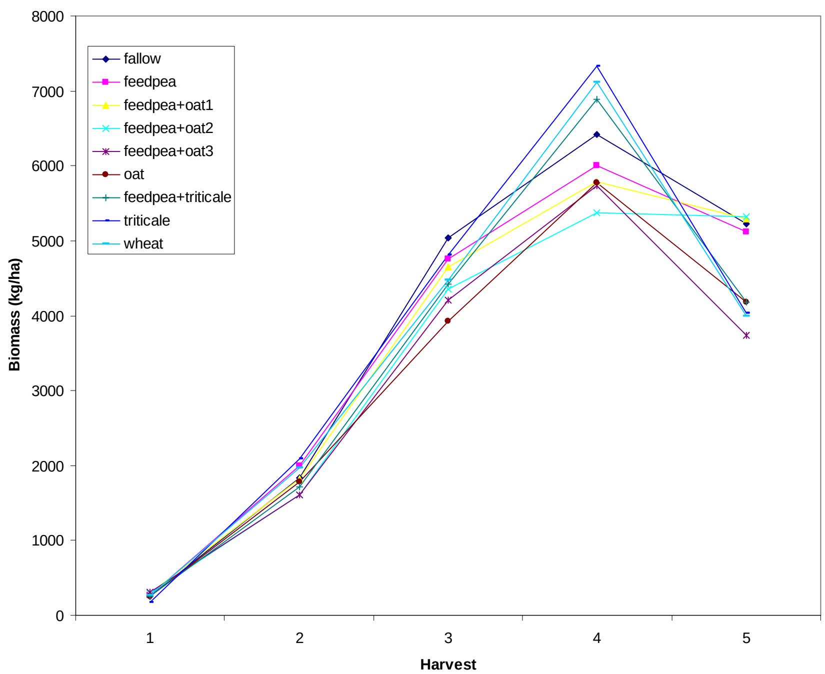


Figure 5: Biomass of wheat grown the year after treatment crops were ploughed down as Green Manures (top) or harvested green as Green Forage (bottom) at Delisle in 2006. Plants were harvested at 2 week intervals after the wheat crops emerged.

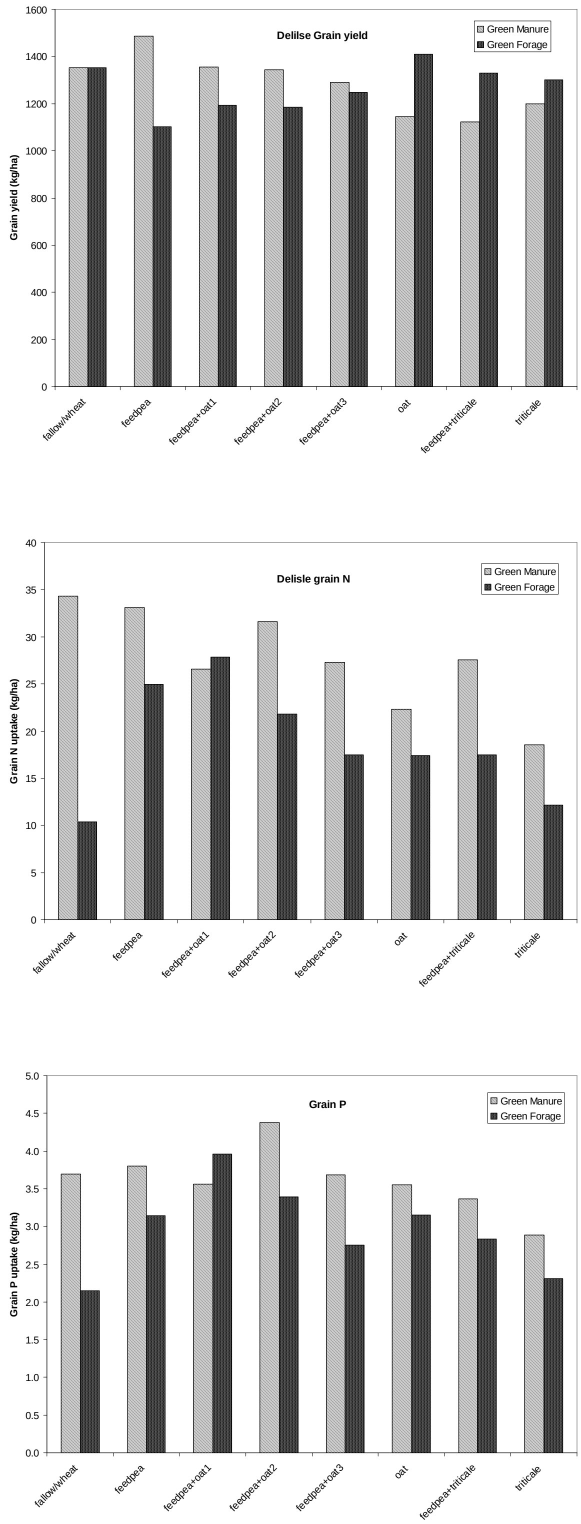
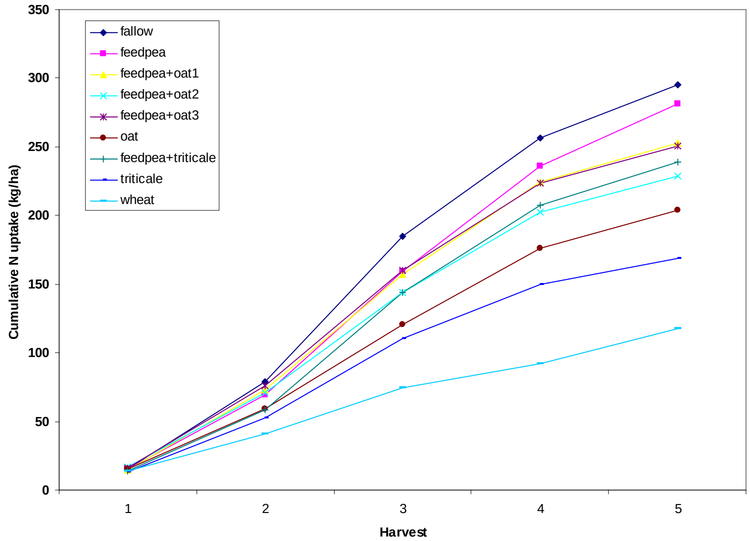


Figure 6: Yield , N and P uptake in wheat grown the year after treatment crops were ploughed down as Green Manures or harvested green as Green Forage at Delisle in 2006. First set of bars are fallow and continuous wheat controls.



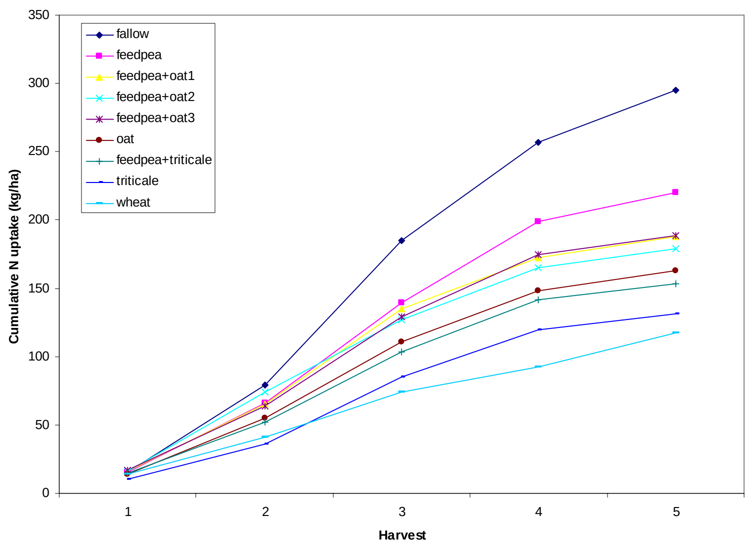
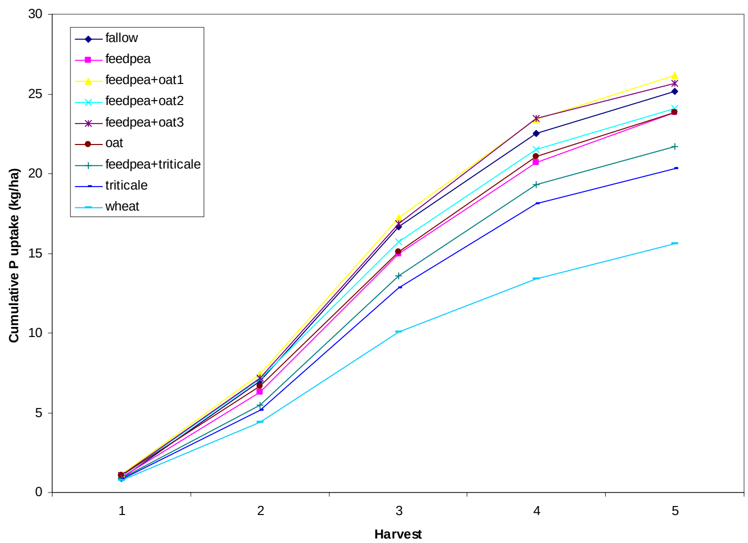


Figure 7: Cumulative N uptake by wheat grown the year after treatment crops were ploughed down as Green Manures (top) or harvested green as Green Forage (bottom) at Delisle in 2006. Plants were harvested at 2 week intervals after the wheat crops emerged.



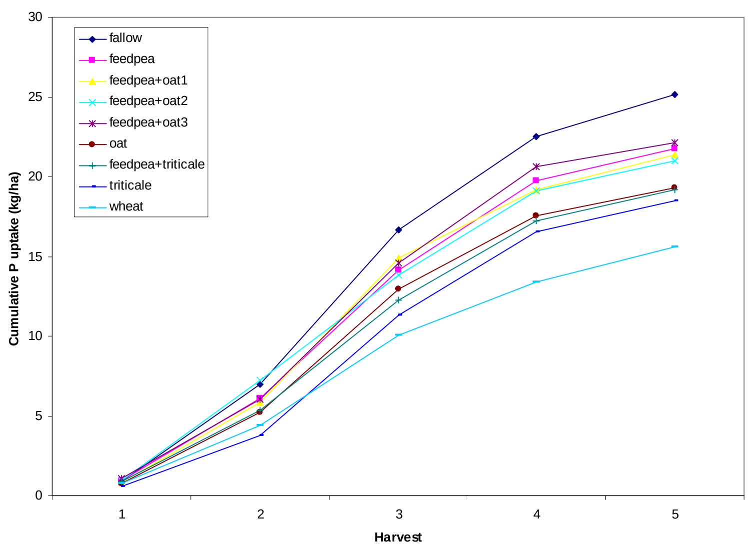


Figure 8: Cumulative P uptake by wheat grown the year after treatment crops were ploughed down as Green Manures (top) or harvested green as Green Forage (bottom) at Delisle in 2006. Plants were harvested at 2 week intervals after the wheat crops emerged.

Table 11. Final grain yield and nutrient status of wheat grown at Delisle in 2006. The green manure and forage treatments were grown the previous year (2005)

Management System	Treatment	Trt No.	Grain yield (kg ha^{-1})	N content (g kg^{-1})	N uptake (kg ha^{-1})	P content (g kg^{-1})	P uptake (kg ha^{-1})
Green Manure	Feedpea	1	1052.60	29.30	30.95	3.41	3.52
	Feedpea/Oat1[1]	2	927.00	27.25	25.27	3.18	2.82
	Feepea/Oat2[1]	3	1045.18	27.10	27.86	3.07	3.19
	Feedpea/Oat3[1]	4	1233.03	27.10	33.93	3.13	3.81
	Oat	5	831.53	27.00	22.77	3.43	2.78
	Feedpea/Trit.	6	882.50	27.65	25.47	3.19	2.64
	Triticale	7	1048.20	28.60	29.26	3.52	6.45
Forage	Feedpea	8	870.63	30.68	25.37	3.55	3.02
	Feedpea/Oat1[1]	9	794.75	28.83	22.00	3.51	2.67
	Feepea/Oat2[1]	10	1294.05	26.70	34.42	3.21	4.08
	Feedpea/Oat3[1]	11	832.30	26.73	21.72	3.37	2.77
	Oat	12	1013.60	29.70	29.90	3.23	3.14
	Feedpea/Trit.	13	897.75	27.10	25.59	3.34	2.79
	Triticale	14	1189.83	27.18	32.08	3.02	3.60
Controls	Fallow-wheat	15	1364.75	25.08	34.87	3.27	4.36
	Wheat-wheat	16	1207.73	25.78	30.12	3.33	3.97
Lsd (0.05)			892.35	7.47	25.02	0.35	2.50
Lsd (0.10)			685.34	5.74	19.22	0.63	1.92
Contrasts	**Trt compared**		----------------------------	*Difference Between Means*		--------------------	
fallow vs. (GrMn+GF)	15- (1:14)		5193*	-39.8*	101.5	-0.35	16.8**
wheat vs. (GrMn+GF)	16 - (1:14)		2995	-30.1	35.1	0.39	11.3
GrMn vs. GF	(1:7)-(8:14)		127	-2.9	4.5	-0.29	0.13
Oat vs. Triticale	5,12 - 7,14		-392	0.9	-8.7	0.12	-1.14
Pea/Oat vs. Pea/Trit	4, 11-6, 13		285	-0.9	4.6	-0.03	1.15
(GrMn vs. GF)(Oat vs. Trit.)	(5,12)(7,14)		-40	-4.1	-4.3	-0.30	-0.19
(GrMn vs. GF)(pea/Oat vs. Pea/Trit)	(4, 11)(6, 13)		416	-0.2	12.3	-0.09	1.19

*, **, *** indicate differences are significant at the 0.2, 0.1, and 0.05 levels of significance.

[1]Target planting densities: Oat 1 = 50 plants m^{-2}, Oat 2 = 100 plants m^{-2}, Oat 3 = 150 plants m^{-2}

Year2 – Post-harvest Soil Characteristics

Soils were sampled in the fall of the wheat year to assess longer-term affects of the green manure/green forage treatments on soil chemical and microbiological factors that potentially could affect long-term fertility. At the Vonda site, none of the individual treatments were different from one another in terms of inorganic N or extractable P levels following the wheat year (Table 12), suggesting that any benefits conferred to the wheat crop were largely exhausted within the first cropping season. The only comparison that was different was the inorganic N level in the soil under the feedpea intercropped with the highest density of oat and the feedpea intercropped with the comparable density of triticale. These treatments behaved differently depending on which management system they were in. In the green manure system, inorganic N under the feedpea/triticale treatment was higher than the comparable density of feedpea/oat, and in the green forage system the opposite was true. However, neither of these treatments produced high yields nor N uptake in the subsequent wheat crop and so these differences likely are of little agronomic significance.

There were only very minor differences among the individual treatments for N and P amounts and supply rates measured with the anion exchange membranes following the wheat crop (Table 13). The fallow treatments had lower available N amounts than the green manure and green forage treatments combined. Wheat grown on fallow ranked in the top two for production and N uptake when grown under the two systems (Figures 1, 2 & 3). Because mineralized N is the only source of N in a fallow soil (i.e., no new N is added by fixation as is the case with the feedpea), it is not surprising that in the longer term, inorganic N in the fallow treatment was somewhat depleted. These observations are important in that they indicate that although native soil organic matter can be an important source of nutrients in the short-term, this N source can be significantly depleted within one cropping season and thus is not a sustainable source of N for organic production systems.

Somewhat surprisingly, the continuous wheat controls had slightly higher ($p<0.20$) available P levels, and short and longer-term P supply rates than the other treatments (Table 13). This might simply reflect differences in timing for when microbial degradation occurs. Soils under the green manure and green forage treatments may have experienced peaks in decomposition earlier than the wheat-wheat controls.

Microbial biomass measurements did not reveal any differences between the wheat controls and the crop treatments at the Vonda site (Table 14). One striking difference among the microbial biomass measurements was the lower C, N and P contents associated with the microorganisms in the fallow treatment (Tables 8 and 9). The root systems of living and decomposing plants have a significant affect on the microbial composition in the soil. The lack of fresh plant material in the fallow treatment year, together with the extraction of mineralized nutrients by wheat following the fallow year, likely influenced the composition of the microbial population. Indeed, the lower levels of nutrients in the microbial biomass support the notion that although the native soil organic matter was mineralized to provide an increase in available N and P during the fallow year, these nutrients were rapidly depleted by the wheat crop, apparently resulting in a nutritional stress in the soil microbial community. Green manuring compared to green forage harvesting did not affect any of the microbial biomass parameters, likely because the nutrients accumulated in the plant tissue supplied the microbial biomass with a ready source of nutrients during decomposition.

Despite the fact that there were less pronounced affects of the treatment crops on yield at the Delisle site, the soils at this site retained some inherent differences into the fall of the wheat crop year (Table 15). Soil water was depleted in all of the treatments relative to the fallow control. In dry regions, this depletion of soil water could be a concern for organic producers. The green manure system maintained inorganic N levels nearly twice those of the comparable green forage treatments. Furthermore the LFOM levels and the LFOM-C in the green manure treatments were lower than in the green forage treatments, indicating that more degradation and mineralization may have occurred in these pools. Additionally, the soil microbial biomass N levels were higher in the green manure as compared to the green forage systems, although SMB-C and SMB-P levels did not differ significantly (Table 17). Similarly, the continuous wheat controls had higher levels of LFOM and LFOM-C than the cropped treatments indicating lower overall degradation from this OM pool. Soil microbial biomass C and P were also higher in the soils from the wheat-wheat treatment compared to the other cropped treatments (Table 17).

The oat and triticale treatments were compared by contrast analysis to examine if the cereals behaved in a similar manner (Tables 12-17). For most of the soil parameters there was no difference between the cereals. However, dehydrogenase activity and microbial metabolic potential were both lower for the oat than the triticale and the enzyme activity for the cereals was different depending on which management system they were in (Tables 14 and 17). In particular, the dehydrogenase activity in soil from the green manure triticale treatment was high compared to the oat under either management system. Dehydrogenase is fairly ubiquitous in soils and often is used as an indicator of overall microbial activity. The high activities in the cereals compared to the feedpea containing treatments probably indicate a lag in optimum degradation activity of the microorganism. The C:N ratios in legumes are optimal for degrading organisms. Degradation in these legume treatments probably peaked earlier in the season than the late fall when the samples were extracted.

Table 12. Soil chemical analyses for fall soils sampled at Vonda in 2005. Samples (0 to 15cm depth) were collected in the fall following the wheat crop harvest. Green manure and forage treatments were grown the previous year (2004)

Management System	Treatment	Trt No.	Soil H_2O (%)	Total inorg N (μg/g)	Extractable P (μg g^{-1})	LFOM[2] (mg)
Green Manure	Feedpea	1	14.16	6.65	3.67	37
	Feedpea/Oat1[1]	2	14.62	5.69	3.39	36
	Feepea/Oat2[1]	3	13.74	6.66	3.37	36
	Feedpea/Oat3[1]	4	14.14	5.63	3.24	35
	Oat	5	14.23	6.68	3.06	33
	Feedpea/Trit.	6	14.94	6.78	3.65	33
	Triticale	7	14.66	6.99	3.79	33
Forage	Feedpea	8	13.93	6.15	2.94	34
	Feedpea/Oat1[1]	9	14.77	6.68	2.91	43
	Feepea/Oat2[1]	10	14.33	6.81	3.12	37
	Feedpea/Oat3[1]	11	13.41	6.63	2.86	37
	Oat	12	14.24	5.79	3.39	36
	Feedpea/Trit.	13	14.91	6.19	3.38	35
	Triticale	14	13.70	6.08	3.41	32
Controls	Fallow-wheat	15	14.21	6.16	3.63	33
	Wheat-wheat	16	14.07	6.72	3.70	41
Lsd (0.05)			5.65	1.82	1.81	
Lsd (0.10)			4.34	1.40	1.39	
Contrasts		**Trt compared**	------------------------------------	*Difference Between Means*	--------------------------------------	
fallow vs. (GrMn+GF)		15- (1:14)	-0.87	-3.14	4.61	-34
wheat vs. (GrMn+GF)		16 - (1:14)	-2.86	4.73	5.64	68
GrMn vs. GF		(1:7)-(8:14)	1.21	0.76	2.16	10
Oat vs. Triticale		5,12 - 7,14	0.11	-0.59	-0.75	4
Pea/Oat vs. Pea/Trit		4, 11-6, 13	-2.31	-0.71	-0.93	4
(GrMn vs. GF)(Oat vs. Trit.)		(5,12)(7,14)	-0.96	-0.01	-0.72	4
(GrMn vs. GF)(pea/Oat vs. Pea/Trit)		(4, 11)(6, 13)	0.69	-1.58**	0.11	1

*, ** indicate differences are significant at the 0.2, 0.1evels of significance.

[1]Target planting densities: Oat 1 = 50 plants m^{-2}, Oat 2 = 100 plants m^{-2}, Oat 3 = 150 plants m^{-2}

[2]Light fraction organic matter

Table 13. Available N and P supply for fall soils sampled at Vonda in 2005. Samples (0 to 15cm) were collected in the fall following the wheat crop harvest. The green manure and forage treatments were grown the previous year (2004).

Management System	Treatment	Trt No.	N supply rate ($\mu g\ NO_3\ cm^2 d^{-1}$)	Avail. N[2] ($\mu g\ NO_3\ g^1$ soil)	P supply rate[3] ($\mu g\ cm^2\ d^{-1}$)	P supply rate [4] ($\mu g\ cm^2\ 7\ d^{-1}$)	Avail. P[2] ($\mu g PO_4\ g^1$ soil)
Green Manure	Feedpea	1	3.09	10.14	0.37	0.15	2.24
	Feedpea/Oat1[1]	2	2.59	8.38	0.27	0.10	1.45
	Feepea/Oat2[1]	3	2.29	9.54	0.30	0.11	1.71
	Feedpea/Oat3[1]	4	3.00	8.26	0.24	0.09	1.31
	Oat	5	2.67	9.29	0.27	0.10	1.50
	Feedpea/Trit.	6	3.13	9.25	0.26	0.09	1.35
	Triticale	7	3.41	10.31	0.35	0.13	1.85
Forage	Feedpea	8	2.16	8.88	0.24	0.09	1.26
	Feedpea/Oat1[1]	9	2.34	9.50	0.25	0.09	1.42
	Feepea/Oat2[1]	10	2.17	10.22	0.31	0.13	1.88
	Feedpea/Oat3[1]	11	1.11	9.76	0.25	0.10	1.40
	Oat	12	2.21	8.81	0.29	0.10	1.59
	Feedpea/Trit.	13	3.57	8.82	0.22	0.07	1.28
	Triticale	14	2.47	9.71	0.33	0.12	1.89
Controls	Fallow-wheat	15	2.09	8.45	0.31	0.12	1.88
	Wheat-wheat	16	1.58	9.27	0.36	0.15	2.14
Lsd (0.05)			3.43	2.38	0.19	0.11	1.34
Lsd (0.10)			2.63	1.82	0.14	0.08	1.03
Contrasts		**Trt compared**	----------	*Difference Between Means*	----------		
fallow vs. (GrMn+GF)		15- (1:14)	-7.02	-12.60*	0.34	0.20	4.24
wheat vs. (GrMn+GF)		16 - (1:14)	-14.04	-1.11	1.07*	0.61*	7.82*
GrMn vs. GF		(1:7)-(8:14)	4.15	-0.53	0.19	0.08	0.69
Oat vs. Triticale		5,12 - 7,14	-1.00	-1.92*	-0.12	-0.05	-065
Pea/Oat vs. Pea/Trit		4, 11-6, 13	-2.59*	-0.06	0.02	0.02	0.07
(GrMn vs. GF)(Oat vs. Trit.)		(5,12)(7,14)	-0.49	-0.12	-0.05	-0.01	-004
(GrMn vs. GF)(pea/Oat vs. Pea/Trit)		(4, 11)(6, 13)	2.32*	-1.93*	-0.06	-0.03	-0.17

*, **, *** indicate differences are significant at the 0.2, 0.1, and 0.05 levels of significance respectively.
[1] Target planting densities: Oat 1 = 50 plants m^{-2}, Oat 2 = 100 plants m^{-2}, Oat 3 = 150 plants m^{-2}
[2]Immediately available - Extracted using anion exchange membranes incubated for 2 hours
[3]Short term supply rate - Extracted using anion exchange membranes incubated for 24 hours
[4]Long- term - Extracted using anion exchange membranes incubated for 7 days

Table 14. Soil microbial analyses for fall soils sampled at Vonda in 2005. Samples (0 to 15cm) were collected in the fall after the wheat crop was harvested. The green manure and forage treatments were grown the previous year (2004).

Management System	Treatment	Trt No.	SMB[2]-C ($\mu g\ g^{-1}$ soil)	SMB-N ($\mu g\ NH_4\ g^{-1}$ soil)	SMB-P ($\mu g\ PO_4\ g^{-1}$ soil)	Deh. Act.[3] (g TPF g soil d^{-1})	MMPot[4]
Green Manure	Feedpea	1	769.3	72.21	13.51	94.27	12.72
	Feedpea/Oat1[1]	2	785.3	74.55	14.04	95.19	10.12
	Feepea/Oat2[1]	3	670.4	64.93	13.11	100.01	13.17
	Feedpea/Oat3[1]	4	755.4	68.40	13.64	95.88	10.45
	Oat	5	686.2	70.57	13.12	92.94	10.70
	Feedpea/Trit.	6	735.1	72.47	13.72	93.14	11.29
	Triticale	7	720.7	73.52	14.42	96.37	11.67
Forage	Feedpea	8	762.4	77.26	14.21	98.63	10.98
	Feedpea/Oat1[1]	9	677.1	75.36	12.70	90.82	9.38
	Feepea/Oat2[1]	10	669.4	62.11	13.39	101.91	12.94
	Feedpea/Oat3[1]	11	653.3	63.58	12.70	102.74	12.82
	Oat	12	721.9	66.94	12.84	92.86	13.31
	Feedpea/Trit.	13	715.6	71.89	14.57	98.57	10.30
	Triticale	14	687.5	67.07	13.13	98.25	13.64
Controls	Fallow-wheat	15	643.1	56.48	10.50	92.10	10.92
	Wheat-wheat	16	702.0	74.44	12.95	96.28	12.73
Lsd (0.05)			492.9	31.39	5.29	28.32	8.77
Lsd (0.10)			378.5	24.11	4.06	21.75	6.74
Contrasts		**Trt compared**	--------------------------------------	*Difference Between Means*		--------------------------------------	
fallow vs. (GrMn+GF)		15- (1:14)	-100.7	-190.20*	-42.07***	-62.33	-10.55
wheat vs. (GrMn+GF)		16 - (1:14)	-18.1	61.31	-7.83	-3.69	14.67
GrMn vs. GF		(1:7)-(8:14)	23.5	12.43	2.01	-15.97	-3.24
Oat vs. Triticale		5,12 - 7,14	-0.00	-3.08	-1.60	-8.83	-1.30
Pea/Oat vs. Pea/Trit		4, 11-6, 13	-4.2	-12.38	-1.95	6.91	1.67
(GrMn vs. GF)(Oat vs. Trit.)		(5,12)(7,14)	-6.9	-2.82	-1.02	1.96	-0.63
(GrMn vs. GF)(pea/Oat vs. Pea/Trit)		(4, 11)(6, 13)	8.3	4.23	1.79	-1.44	-3.36

[1]Target planting densities: Oat 1 = 50 plants m^{-2}, Oat 2 = 100 plants m^{-2}, Oat 3 = 150 plants m^{-2}
[2]SMB-Soil Microbial Biomass
[3] Dehydrogenase activity
[4]MMPot-Microbial Metabolic Potential

Table 15. Soil chemical analyses for fall soils sampled at Delisle in 2006. Samples (0 to 15cm depth) were collected in the fall after the wheat crop harvest. The green manure and forage treatments were grown the previous year (2005)

Management System	Treatment	Trt No.	Soil H_2O (%)	Inorg. N ($\mu g\ g^{-1}$)	LFOM[1] (mg)	LFOM- C (%)	Extractable P ($\mu g\ PO_4\ g^{-1}$)
Green Manure	Feedpea	1	8.40	9.45	103	19.76	13.76
	Feedpea/Oat1[2]	2	8.22	8.85	113	20.12	12.80
	Feepea/Oat2[2]	3	8.17	9.30	108	20.06	12.20
	Feedpea/Oat3[2]	4	8.18	6.55	135	20.09	12.60
	Oat	5	7.90	8.00	111	19.12	13.30
	Feedpea/Trit.	6	8.86	10.65	102	20.84	13.06
	Triticale	7	7.73	7.15	114	18.56	11.84
Forage	Feedpea	8	7.46	5.35	149	20.23	11.42
	Feedpea/Oat1[2]	9	9.95	6.80	149	21.71	10.63
	Feepea/Oat2[2]	10	7.91	4.90	164	21.27	12.07
	Feedpea/Oat3[2]	11	8.08	4.71	158	20.54	13.53
	Oat	12	7.19	4.55	161	20.66	11.28
	Feedpea/Trit.	13	7.21	3.70	156	19.31	11.01
	Triticale	14	7.66	4.10	160	20.10	13.38
Controls	Fallow-wheat	15	9.89	7.55	123	19.82	14.85
	Wheat-wheat	16	8.94	4.80	177	22.49	13.05
Lsd (0.05)			3.07	7.80	8.97	3.35	6.63
Lsd (0.10)			2.35	5.99	6.89	2.57	5.09
Contrasts		**Trt compared**	------------------------------------	*Difference Between Means*	--------------------------------------		
fallow vs. (GrMn+GF)		15- (1:14)	25.47***	11.65	-16.58	-4.93	34.97*
wheat vs. (GrMn+GF)		16 - (1:14)	12.26	-26.86	59.34**	32.49***	9.81
GrMn vs. GF		(1:7)-(8:14)	2.00	25.85***	-31.13***	-5.28**	6.23
Oat vs. Triticale		5,12 - 7,14	-0.29	1.30	-0.18	1.12	-0.63
Pea/Oat vs. Pea/Trit		4, 11-6, 13	0.19	-3.10	3.57	0.48	2.05
(GrMn vs. GF)(Oat vs. Trit.)		(5,12)(7,14)	0.63	0.40	-0.40	-0.00	3.56
(GrMn vs. GF)(pea/Oat vs. Pea/Trit)		(4, 11)(6, 13)	-1.55	-5.10	3.11	-1.20	-2.98

*, **, *** indicate differences are significant at the 0.2, 0.1, and 0.05 levels of significance.

[1]Light fraction organic matter

[2]Target planting densities: Oat 1 = 50 plants m^{-2}, Oat 2 = 100 plants m^{-2}, Oat 3 = 150 plants m^{-2}

Table16. Available N and P supply for fall soils sampled at Delisle in 2006. Samples (0 to 15cm) were collected in the fall after the wheat crop harvest. The green manure and forage treatments were grown the previous year (2005).

Management System	Treatment	Trt No.	N supply rate[4] ($\mu g\ NO_3\ cm^2\ 7\ d^{-1}$)	Avail N[2] ($\mu g\ NO_3\ g^{-1}$ soil)	P supply rate [3] ($\mu g\ PO_4\ cm^2 d^{-1}$)	P supply rate[4] ($\mu g\ PO_4\ cm^2\ 7\ d^{-1}$)	Avail. P[2] ($\mu g\ PO_4\ g^{-1}$ soil)
Green Manure	Feedpea	1	0.95	7.37	0.92	0.40	6.83
	Feedpea/Oat1[1]	2	1.67	7.82	0.85	0.31	5.98
	Feepea/Oat2[1]	3	0.89	6.89	0.86	0.34	5.89
	Feedpea/Oat3[1]	4	1.03	5.46	0.88	0.36	5.90
	Oat	5	1.22	7.43	0.79	0.37	6.26
	Feedpea/Trit.	6	1.45	8.93	0.81	0.35	5.72
	Triticale	7	0.49	7.28	0.81	0.36	5.48
Forage	Feedpea	8	0.72	5.05	0.72	0.31	5.33
	Feedpea/Oat1[1]	9	1.05	6.32	0.68	0.28	4.71
	Feepea/Oat2[1]	10	0.63	4.56	0.88	0.37	5.36
	Feedpea/Oat3[1]	11	0.61	6.00	0.99	0.44	6.88
	Oat	12	0.32	3.68	0.82	0.33	5.29
	Feedpea/Trit.	13	0.58	3.94	0.74	0.33	5.06
	Triticale	14	1.10	4.08	0.77	0.38	6.34
Controls	Fallow-wheat	15	1.60	7.52	0.89	0.41	6.98
	Wheat-wheat	16	0.39	4.78	0.79	0.36	6.36
Lsd (0.05)			5.29	1.56	0.66	0.26	3.76
Lsd (0.10)			4.06	1.20	0.12	0.20	2.89
Contrasts		**Trt compared**	-------------------------	-------------------------	*Difference Between Means*	-------------------------	-------------------------
fallow vs. (GrMn+GF)		15- (1:14)	20.44	9.64**	0.86	0.88	16.63
wheat vs. (GrMn+GF)		16 - (1:14)	-17.87	-7.25	-0.47	0.18	7.97
GrMn vs. GF		(1:7)-(8:14)	17.56***	2.70**	0.32	0.04	3.09
Oat vs. Triticale		5,12 - 7,14	-0.25	-0.04	0.03	-0.05	-0.26
Pea/Oat vs. Pea/Trit		4, 11-6, 13	-1.43	-0.39	0.31	0.12	2.00
(GrMn vs. GF)(Oat vs. Trit.)		(5,12)(7,14)	0.54	1.51**	-0.07	0.06	1.84
(GrMn vs. GF)(pea/Oat vs. Pea/Trit)		(4, 11)(6, 13)	-5.54***	-0.44	-0.18	-0.10	-1.63

*, **, *** indicate differences are significant at the 0.2, 0.1, and 0.05 levels of significance respectively.

[1] Target planting densities: Oat 1 = 50 plants m^{-2}, Oat 2 = 100 plants m^{-2}, Oat 3 = 150 plants m^{-2}

[2]Immediately available - Extracted using anion exchange membranes incubated for 2 hours

[3]Short term supply rate - Extracted using anion exchange membranes incubated for 24 hours

[4]Long- term - Extracted using anion exchange membranes incubated for 7 days

Table 17. Soil microbial analyses for fall soils sampled at Delisle in 2006. Samples (0 to 15cm) were collected in the fall after the wheat crop was harvested. The green manure and forage treatments were grown the previous year (2005).

Management System	**Treatment**	**Trt No.**	**SMB[2]-C ($\mu g\ g^{-1}$ soil)**	**SMB-N ($\mu g\ NH_4\ g^{-1}$ soil)**	**SMB-P ($\mu g\ PO_4\ g^{-1}$ soil)**	**Deh. Act.[3] (g TPF g soil d^{-1})**	**MMPot[4]**
Green Manure	Feedpea	1	300.14	2.46	8.43	35.73	0.61
	Feedpea/Oat1[1]	2	300.15	2.54	8.39	52.33	0.86
	Feepea/Oat2[1]	3	299.67	2.52	8.54	58.40	1.01
	Feedpea/Oat3[1]	4	303.67	2.58	8.36	49.89	0.83
	Oat	5	218.32	2.31	10.44	58.74	0.97
	Feedpea/Trit.	6	312.46	2.38	8.77	59.51	1.03
	Triticale	7	206.07	1.87	7.65	79.73	1.56
Forage	Feedpea	8	189.84	1.65	8.15	61.87	1.30
	Feedpea/Oat1[1]	9	372.20	3.00	9.37	61.80	1.09
	Feepea/Oat2[1]	10	313.63	2.29	10.54	62.18	1.15
	Feedpea/Oat3[1]	11	242.50	2.07	9.06	56.68	1.07
	Oat	12	255.19	1.78	7.28	62.87	1.19
	Feedpea/Trit.	13	232.16	1.07	8.65	60.12	1.11
	Triticale	14	305.91	2.24	9.72	59.09	1.06
Controls	Fallow-wheat	15	241.37	2.29	9.05	32.57	0.60
	Wheat-wheat	16	375.05	2.30	10.68	51.65	0.95
Lsd (0.05)			211.21	1.83	4.67	21.66	0.51
Lsd (0.10)			162.21	1.41	3.59	16.63	0.39
Contrasts		**Trt compared**	------------------------------------- *Difference Between Means* -----------------------------				
fallow vs. (GrMn+GF)		15- (1:14)	-472.8	1.27	3.30	-363.0***	-6.49***
wheat vs. (GrMn+GF)		16 - (1:14)	1398.8**	1.55	26.12*	-95.9	-1.53
GrMn vs. GF		(1:7)-(8:14)	29.1	2.55*	-2.18	-30.3*	-1.08***
Oat vs. Triticale		5,12 - 7,14	-38.5	-0.03	0.34	-17.2*	-0.46**
Pea/Oat vs. Pea/Trit		4, 11-6, 13	1.6	1.19	0.00	-13.1	-0.25
(GrMn vs. GF)(Oat vs. Trit.)		(5,12)(7,14)	62.9	0.89	5.22***	-24.8***	-0.72***
(GrMn vs. GF)(pea/Oat vs. Pea/Trit)		(4, 11)(6, 13)	-19.1	-0.80	-0.82	-6.2	-0.17

*, **, *** indicate differences are significant at the 0.2, 0.1, and 0.05 levels of significance respectively.
[1] Target planting densities: Oat 1 = 50 plants m^{-2}, Oat 2 = 100 plants m^{-2}, Oat 3 = 150 plants m^{-2}
[2]SMB-Soil Microbial Biomass
[3] Dehydrogenase activity
[4]MMPot-Microbial Metabolic Potential

Recommendations and Conclusions:

The overall objective of this study was to evaluate feedpea, oat and triticale in monoculture and intercropped together, as green manures and as green forages under organic management. Growing crops with the intention of ploughing them into the soil for supplying nutrients to a subsequent crop is an integral part of sustainable organic management. However, the green manure year represents a year where the farmer does not receive any direct economic benefit from this land. This study was initiated, in part, to determine if a green forage crop might enable the farmer to gain some economic benefit without compromising the fertility of the soil.

The green forage crops were harvested in the early grain filling stage, approximately 4 to 6 weeks before the grain would typically be harvested from a mature crop. Despite this early harvest, all of the green forage treatments extracted considerable amounts of nutrients (N and P) from the soil. The comparable green manure treatments were ploughed under approximately four weeks before the green forages were harvested. During this four week period, the green forages accumulated more than twice as much N and P in their biomass, compared to the green manures. Because the forages were harvested, this represents a net nutrient removal from the system. Without some means of returning these nutrients to the soil, this practice would not be sustainable.

Of the treatments tested, feedpea was among the most productive, and supplied the most N through biological N fixation of all of the treatments. It was hypothesized that intercropping a cereal with the feedpea could stimulate N fixation by creating a low soil N environment conducive to fixation. Results from this study indicate however, that intercropping feedpea with a cereal (oat or triticale) decreased the efficiency with which the feedpea acquired N. It appears that in addition to feedpea fixing N, it also is efficient at extracting inorganic N from the soil. The intercropped cereal did not extract inorganic N from the soil to the point that the low inorganic N stimulated the feedpea to fix N to the degree that there was a net increase in the accumulation of N. Instead, competition from the cereal appeared to either reduce N uptake, or depress N fixation by the pea such that the total N accumulated was reduced in the intercropped system. All densities of oat intercropped with the feedpea resulted in reduced total N accumulation.

There was little difference among the soil chemical and microbiological parameters associated with green manuring the crops versus green forage harvesting. There were some differences among individual treatments which were probably related to the C:N ratios of the residues and therefore the susceptibility of these plant materials to decomposition and nutrient mineralization.

Wheat was grown as the test crop in the year following the different green manure/green forage treatments. In all cases, the feedpea and fallow controls provided the most N and P for uptake by the wheat. Mineralization of inherent organic matter in the fallow year was sufficient to achieve near optimal yields for the conditions at the sites. However, over the long-term, soils under organic management will lose organic matter and the soil will not be able to continually supply nutrients. Not surprisingly, the feedpea green manure supplied the most N for uptake by the wheat crop. Additionally, feedpea was the most efficient at extracting P from the soil. Whether this was due to more efficient extraction of P by the root system or mycorrhizal associations or the P-solubilizing inoculant used in this study was not determined.

At the Vonda site, wheat yields were consistently 30 to 40 % higher on the green manures as compared to the green forage treatments. At the Delisle site, wheat yields were not always higher on the green manure treatments as compared to the green forage treatments. This reflects the inherently higher soil fertility at the Delisle site. Despite the inconsistent yield response at Delisle, nutrient uptake by the wheat crops was consistently higher from the green manure treatments.

In short, green forage is not a sustainable alternative to green manuring. Of the crops tested, feedpea grown in monoculture was clearly superior to all other treatments.

f) Acknowledgements:

Saskatchewan Agriculture and Food has been acknowledged as the funding agency supporting this work at all of the conferences, workshops, field days and tours that this work has been presented at.

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h) Appendices: none

i) Administrative

Presentations at conferences, workshops and field days:

G. Marufu, F. Walley and J.D. Knight. 2007. Productivity and N-Fixation of legume-Cereal Intercrops and their Monocrop Counterparts. Soil and Crops Workshop, Saskatoon, SK. March 1-2, 2007.

G. Marufu, F. Walley and J.D. Knight. 2007. Productivity of Green Manure and Green Feed Forage Options in organic Cropping Systems: Effects on Subsequent Crops. Pulse Days 2007. Saskatoon, SK. January 8-9, 2007.

G. Marufu, F.L. Walley and J.D. Knight. 2006. Productivity of Organic Legume-Cereal Intercrops Managed as Either Green Manure or Green Feed Forage. Canadian Society of Soil Science Annual Meeting, May 14-17, Banff, AB.

G. Marufu, F.L. Walley and J.D. Knight. 2006. Productivity of Green Manure and Green Feed Forage Options in organic Cropping Systems: Effects on Subsequent Crops. Organic Connections Conference, Nov. 12-14, Saskatoon, SK.

G. Marufu. 2006. Response of subsequent wheat crop to different green manure and green feed forage options in organic cropping systems. Chapter 5 Organic Field Day. Delisle, SK. July 10, 2006.

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Name	Position	Time Commitment
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Expense Statement: To follow from Financial Services, University of Saskatchewan.