Project Title: Transition and sustainability strategies for organic farms

NSERC Strategic Project Grant Final Report

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Table of Contents

1

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2 Description of Progress and Significance of Results

2.1 Objectives 1 and 2

Integration of forage and livestock manure into farming systems has increasingly being practiced on organic farms to relieve nutrient management pressure. A potato rotation experiment was established on a sandy-loam soil (Orthic Humoferric Podzol) to assess forage and soil amendment effects on soil N, P, and K availability. Forage levels included 0-, 1-, and 2-year forages in three different 4-year crop rotations: wheat (w)/soybean (s)/barley (b)/potato (p), w/b/forage (f)/p, and w/f/f/p, respectively. The forage crops used in the experiment were a mixture of red clover and timothy. Soil amendments included composted poultry manure (M), composted beef manure (R), and alfalfa meal (S), pertaining to nutrient sources from monogastric, ruminant, and stockless farming systems, respectively. Three soil amendments were nested under each forage level. In the potato year (year 4), the original plots were split into two parts: amended and unamended subplots. No soil amendment was applied in the unamended subplots. The amended subplots received soil amendments as per soil test recommendations, and soil amendment application rates were adjusted to equalize soil extractable N levels based on assumed N availability.

2.2 Soil Nitrogen, Phosphorus, and Potassium Availability as Affected by Organic Potato Rotations

Lead Participants: R. Martin, K. Liu, D. Patriquin, A. Georgallas, A. Hammermeister, P. Warman, J. Hoyle, T. Astatkie, M. Entz, J. Clapperton

Application of soil amendments to potatoes significantly increased soil N_{tot}, extractable P_2O_5 and K_2O, but did not significantly affect soil extractable N and soil N supply rates compared with the residual effects of soil amendments. Soil extractable N and soil N supply rates determined in the potato year were significantly higher in the 1- and 2- year forage rotations than in the 0-year forage rotations. This high soil mineral N in the 1- and 2-year forage rotations was a result of forage N benefits and N carryover from extra compost N application in the 1- and 2-year forage rotations, and was related to the high soil N potential mineralization rates at the end of year 3. Nitrogen availability was similar to assumed N availability in the alfalfa meal, but was far lower than assumed N availability in two composts. The alfalfa meal had a quicker N release compared with two composted manures. Soil mineral N was significantly affected by both forages and soil amendments, with the highest soil N supply rates in alfalfa meal amended 1-year forage rotations and the highest soil extractable N in alfalfa meal amended 2-year forage rotations. Soil P_2O_5 and K_2O were not different among forage levels, but were significantly affected by soil amendment rates and types. Across the first cycle of 4-year rotations, forages and soil amendments increased soil N_{tot}, extractable P_2O_5 and K_2O, and soil extractable N was decreased in the first 2 years because of high background soil N, and tended to reach an equilibrium state in the last 2 years. In the cropping management under which soil amendment application rates were adjusted to equalize soil extractable N with assumed N availability, the combination of forages with composted beef manure is recommended in terms of soil N, P, and K management.

2.3 Plant Nitrogen, Phosphorus and Potassium Uptake and Tuber Yield as Affected by Organic Potato Rotations.

Lead Participants: K. Liu, R. Martin, D. Patriquin, A. Georgallas, A. Hammermeister, P. Warman, J. Hoyle, T. Astatkie, M. Entz, J. Clapperton

Nutrient management is a challenge for organic potato production. A potato rotation experiment was established to assess the effects of forage frequency and soil amendment under assumptions of isonitrogeneity on potato tuber yield and plant nutrient uptake. Application of soil amendments to potatoes significantly increased potato marketable tuber yield and plant nutrient uptake compared with the residual effects of soil amendments. Potato marketable tuber yield, plant biomass C, and plant P and K uptake were significantly affected by soil amendment and forage levels, but plant N uptake was not significantly different among treatments in the nutrient management regime under which soil amendment application rates were adjusted to equalize soil available N with assumed N availability. The highest potato tuber yield and the highest nutrient uptake were in R treatments among the three soil amendments because of high application rates. Differences in potato tuber yield and nutrient uptake among soil amendments were mainly in the 2-year forage rotation. This is mainly due to the substantial difference in cumulative soil amendment applications. Forage detrimental effects such as wireworm and nematode infestations resulted in significantly lower potato marketable tuber yield, plant biomass C, plant P and K uptake in the 1- and 2-year forage rotations than in the 0-1yr forage rotations in amended subplots. The balances in N, P, and K were positive in all treatment combinations except the K balance in the M amended 2-year forage rotations. The results indicated that forages had some detrimental effects on potatoes when used as a preceding crop in the first cycle of rotations established after a long-term pasture was broken, and that the R treatments had the best potato performance among M, R, and S treatments.

2.4 Economics of Introducing Forages and Livestock into Alternative Crop Rotation Systems During the Transition to Organic Agriculture.

Lead Participants: A. Riofrio, E. Yiridoe, J. Henning, R. Martin, K. Liu, A. Hammermeister, P. Warman, T. Astatkie

The economic feasibility of alternative crop rotations, and to determine the economic implications of including forages and livestock during the transition to organic agriculture was investigated. The rotations were distinguished by: i) frequency of forages in a rotation, ii) source of crop nutrients, and iii) type of farming system. The economic analyses included enterprise budgeting, statistical analysis, and multi-period linear programming.

Wheat and potato yields tended to be higher under ruminant compost. In addition, regardless of the type of soil amendment, the highest forage yield was found in the rotation with two consecutive years of forage (i.e., WF<u>F</u>P).

Fixed costs varied by rotation, primarily because the machinery complement was different among rotations. In general, higher fixed costs were found in forage-based crop rotations, and rotations involving compost applications. Variable costs were relatively high and varied substantially among treatments. The high variable costs were primarily due to the amount of soil amendment required to meet soil test recommendations, and the associated (soil amendment) costs. In general, variable costs in the core plots were lower under monogastric systems and with two years of forage in the rotation.

Net returns were greatly influenced by nutrient supply costs. On average, most crops generated losses during the transition period. However, certified organic potatoes with a price premium of 87% above the conventional price, generated positive net returns in the fourth year. In general, crop net returns tended to be higher in forage-based crop rotations and in livestock systems, compared to rotations with no forage, and in the stockless system. In particular, rotations with two years of forage, and rotations under monogastric system yielded higher net returns. The highest wheat net returns were found in the WFFP rotation under the monogastric system. By comparison, the highest forage net returns from 2003 to 2004 were found for the stockless system, while the highest barley net returns were found in the WSBP rotation under monogastric compost. In 2005, the highest potato net returns were generated from the ruminant system.

Results of the statistical analysis of the Truro experiment indicate that ruminant compost can provide additional economic benefits to a farming operation during the transition to organic agriculture, since yields tend to be higher. In addition, forage-based crop rotations may be needed to build soil organic matter. Including forages and livestock with a cash crop rotation system can provide economic benefits to ease the financial difficulties during the transition to organic agriculture. Based on results from the study, the most important economic implication during the transition to organic agriculture related to substituting organic soil amendments for synthetic fertilizers. Production costs associated with maintaining soil fertility can be high, especially if soil amendments are applied to meet standard soil nutrient recommendations. However, once the system is implemented, the results of this study support the view that organic farming can be profitable. However, organic farming could potentially generate (positive) externalities that may not have a direct monetary value, such as human health, better tasting food, animal welfare, and biodiversity and environmental stewardship. In addition, as in conventional agriculture, the success of organic farming can be site specific, and depending management skills and farmer's experience, and history of the farm fields.

<u>Objective 3:</u>

2.5 <u>Agronomic benefits of alfalfa mulch applied to organically managed spring wheat</u>

Lead Participants: R. Martin, M. Entz, M. Wiens, A. Hammermeister

Field experiments were established at two locations in Manitoba in 2002 and 2003 to determine N contribution, moisture conservation, and weed suppression by alfalfa mulch applied to spring wheat (*Triticum aestivum* L). Mulch treatments included mulch rate (amount harvested from an area 0.5□, 1□and 2□the wheat plot area), and mulch application timing (at wheat emergence or at three-leaf stage). Positive relationships were observed between mulch rate and wheat N uptake, grain yield, and grain protein concentration. At Winnipeg, the 2□mulch rates (3.9 to 5.2 t ha–1) produced grain yields equivalent to where 20 and 60 kg ha–1 of ammonium nitrate-N was applied in 2002 and 2003, respectively. Where mulch and ammonium nitrate produced equivalent grain yield, grain protein in mulch treatments was often higher than where chemical fertilizer was used. N uptake was also observed in the following oat (*Avena sativa* L.) crop. The highest mulch rate (2□) produced higher N uptake and grain yield of second-year oat compared with ammonium nitrate treatments. N use efficiency of mulch-supplied N by two crops over 2 yr [calculated as (treatment N uptake – control N uptake)/total N added] was between 11 and 68%. Mulch usually suppressed annual weeds, with greater suppression with late- than early-applied mulch. Increased soil moisture conservation was observed with high mulch rates (≥4.3 t ha–1) at three sites. Alfalfa mulch holds promise for low-input cropping systems when used on wheat at the 2□rates.

In 2002 in NS, all rates of mulch application reduced yields in comparison to a control where no mulch was applied. High application rates either suppressed crop establishment or smothered the crop. In 2003, we adjusted our mulch application rates, and although high application rates still suppressed yields, there was a yield benefit from several treatments. A late application of chopped mulch at 1 t ha^{-1} gave the highest yield benefit, with a gross return of roughly \$80 ha^{-1} more than the control. An early application of 2 t ha^{-1} also produced higher yields, with a gross return of roughly \$17 ha^{-1}. An application rate of 4 t ha^{-1} proved to be excessive, resulting in low yields and, surprisingly, greater weed problems. It appears that a late application of chopped mulch at 1 t ha^{-1} would be the most economical, as it has higher returns, lower application costs, and lower requirements for forage land area.

2.6 Supporting Organic Transition Projects

The following projects were initiated to support the main objectives and address major transition issues that have been identified as they relate to: nutrient supply from amendments, weed and insect control, and soil quality and susceptibility to erosion.

2.7 Impact of Organic Production and Reduced Chemical Inputs on Soil Nutrient Depletion and the Functional and Nutritional Quality of Crops

Lead Participants: C. Grant, K. Slawinski,

A field study was initiated in 2001 on a Newdale Clay Loam soil, located on the Brandon Research Centre Philips Farm. Two additional sites, near Lacombe and Beaverlodge, Alberta, were initiated in 2002. This study was designed to evaluate the impact of several cropping systems, ranging from organic, through pesticide-free production to conventional management, on soil quality, cost of production, agronomics and final crop quality. Each production system was evaluated in a fully-phased 4-year rotation (Table 1). The study was continued until 2005, but was modified in 2006 to evaluate organic, inorganic and integrated nutrient management systems. From 2001 to 2005, crops were evaluated for yield, nutrient uptake and crop quality parameters. Soil samples were taken to evaluate nutrient dynamics over the growing season.

Table A: Cropping systems and crop rotations used in the experiment.

	A. Organic	B. Organic-Compost	C. Continuous PFP – Chemical fertilizers but no pesticides	D. PFP[1]	E. Integrated Management
Year 1	Field pea	Field Pea	Field pea	Field pea	Field pea
Year 2	durum u/s sweet clover	durum u/s sweet clover	durum u/s sweet clover	durum	durum
Year 3	sweet clover	sweet clover	sweet clover	flax	Flax
Year 4	oat	oat	oat	oat	Oat

[1]PFP = Pesticide-Free Production: No pesticides are applied to the growing target crop and no residual pesticides may be used, but pesticides may be used before and after crop growth begins and in other crops in the rotation. Durum wheat and oats are the target PFP crops.

Weed competition was the major limiting factor in the study, with extremely poor crop yields occurring in the organic systems due to weed competition in wet years when the physical control unamended organic system, while P supply was maintained in the organic system that received compost application. Nitrogen deficiency was also a major limitation for production of the non-legume crops in the organic systems. Detailed measurements of crop N uptake over the growing season were taken. Several measurements of N release over the growing season from the soil were used to evaluate seasonal N supply and its correlation with periods of peek crop demand. Overall, nitrogen dynamics over the growing season indicated a reduction in available N under the organic production system, even when compost was applied. Protein content of crops tended to be reduced in the organic production systems, although the amino acid profiles were generally not affected by management. Generally, the effects of management system on crop quality were minor.

2.8 Nutrient status of organic dairy farms in Ontario

Lead participants: C. J. Roberts, D. H. Lynch, and R. P. Voroney

The sustainability of organic dairying in Canada, with respect to farm nutrient status, remains unexamined. To assess the relationship between farm management and nutrient status, we documented farm management practices and productivity, whole farm nutrient (NPK) budgets (inputs-outputs) and soil (0-15cm) fertility status on 15 long-term Ontario organic dairy farms over two years (2003 to 2005). Farm size, stocking rate and herd productivity averaged 110 ha, 1.00 livestock units ha^{-1} and 6526 kg milk cow^{-1} yr^{-1}, respectively. Annual farm nutrient surpluses of 75 (N), 1 (P) and 11 (K) kg ha^{-1} yr^{-1}, were low relative to surpluses reported for confinement-based dairy systems. Nutrient budget results were supported by soil fertility data. Soil test P levels were low (<10 mg kg^{-1}) on approximately 50% of farms, while exchangeable K levels were moderate to high (76-160 mg/kg) on all farms. A subset of farms (n=4) adopting a 'self-sufficient' approach to feed and importing little P (1.37 to 1.90 kg P ha^{-1} yr^{-1}) had negative farm P surpluses (-1.54 avg., range -2.50 to 0.06 P ha^{-1} yr^{-1}) . Combining an integrated approach to farm nutrient management with a flexible approach to feed imports is critical for the continued sustainability of organic dairying systems.

2.9 Organic Crop Management Decreases Labile P, Promotes Mycorrhizal Colonization, and Increases Spore Populations.

Lead Participants: M. Tenuta, M. Entz, C. Welsh

Obj.: To study the effect of long-term organic rotations on soil labile P and mycorrhizal colonization relative to conventional systems.

Arbuscular mycorrhizal fungi (AMF) are one of the most important soil organisms in relation to plant nutrition, particularly phosphorus (P). With interest in lowering soil P levels, promoting the activity of mycorrhizal fungi may be critical to maintaining crop yields. This study compares organic and conventional practices and different crop rotations to determine the extent of their impact on AMF colonization. The research was carried out at the 14 year study at Glenlea, in Southern Manitoba. This site consists of 3 different 4 year rotations under organic and conventional management: Wheat – Alfalfa –Alfalfa – Flax with and without animal manure, Wheat – Pea – Wheat – Flax, and a restored prairie. The organic rotations had lower levels of labile P fractions than conventional and the native prairie grass had P levels similar to conventional systems. The annual rotation had higher labile P than the alfalfa rotations (P = 0.05). AMF colonization levels as either hyphae alone or arbuscules were significantly higher (P =0.05) in organic than conventional systems; however crop rotations did not significantly differ in colonization. The same was true for spore populations (P = 0.05). Organic management therefore has a greater impact on increasing AMF colonization than differing crop rotations.

2.10 <u>Nutrient supply rates from organic amendments</u>

Lead Participants: A. Hammermeister, P. Warman, T. Astatkie, E. Jeliazkova, R. Martin, H. Yu
Obj.: To compare the amount and timing of release of several nutrients from the organic amendments, alfalfa meal, feather meal, earthworm castings and poultry manure compost and to assess yields of lettuce and orchard grass planted one week after amendment application, in a growth room.

Amendments were applied at rates to deliver equal amounts of total, rather than plant available, nitrogen. Feather meal and poultry manure compost initially either stunted the plants or killed them, especially when applied to lettuce at higher rates. Allowing more time between amendment application and planting will likely prevent this problem. Although the lettuce plants never fully recovered, the orchard grass was more tolerant and also had more time to recover. The earthworm castings gave the lettuce and orchard grass a good boost at the start of the experiment and also gave the highest lettuce yields. In the longer running orchard grass experiment, however, the early stimulation was not sustained, and the poultry manure and feather meal produced higher yields. The Plant Root Simulator probe (PRS™; http://www.westernag.ca) showed that the kinds and amount of N initially available to the crop varies with the amendments. The amendments also supplied varying quantities of other nutrients such as P, K, and S. It is therefore likely that blending different amendments will be the best approach to managing crop nutrition.

2.11 <u>Comparing four organic amendments with chemical NPK fertilizer in strawberry and blueberry crops</u>

Lead Participants: P. Warman, S. Shanmugam
Obj.: To compare four organic amendments a) alfalfa meal + rock phosphate + wood ash, b) Lunenburg municipal solid waste (MSW), c) compost; yard waste, manure, and food waste compost (YMFC), and d) ruminant compost) with chemical NPK fertilizer in strawberry and blueberry crops.

In 2002, the ruminant compost treatment produced higher levels of extractable K in the soil and also produced higher levels of available K in the tissue. The MSW compost application produced the highest level of extractable Na in all cultivars, and the chemical fertilizer treatment gave higher levels of extractable soil sulphur in both strawberries and blueberries. In 2003, there was no significant difference between the treatments with respect to the yield of strawberries. The half-high blueberries did not produce a consistent yield and there was non-uniform ripening of fruits.

2.12 <u>Efficacy of five companion plants and three plant-derived sprays as alternative controls for the Colorado potato beetle (CPB)</u>

Lead Participants: P. Warman, T. Moreau, J. Hoyle
Obj.: To investigate the efficacy of five companion plants and three plant-derived sprays as alternative controls for the Colorado potato beetle (CPB) given that decades of pesticide use have resulted in highly publicized problems with insect resistance, environmental pollution and human toxicity.

Results from two years of trials, demonstrated that the greatest CPB control was obtained from those plots treated with Neemix 4.5Ò. The sprays, Hot Pepper Waxä and Garlic BarrierÒ showed no insecticidal action on populations of Colorado potato beetles. Trials with the companion plants demonstrated that no CPB control was obtained; in fact, there was some indication that the presence of companion plants may have actually increased the beetle population. There was a strong variety effect demonstrated for both the field and laboratory research. Fundy potatoes experienced greater insect densities and damage than Superior potatoes.

In a related experiment at NSAC, NOVODOR® at the first and second larval stages controlled CPB with 86% effectiveness. When averaged across driving speeds, the open flame equipment performed better than the hot steam or pneumatic equipment, with 56% control for the first and second stage larvae, and 45-50% control for the third and fourth stage larvae and the adult. However, at a driving speed of 1.0 km/h hot steam gave good control of this pest (63% for the first and second stage larvae and 52-54% for the third and fourth stage larvae and the adults). The pneumatic collector worked better on the third and fourth stage larvae than on the first and second stage larvae or the adults. The lowest control rate (7%) was obtained with pneumatic collection of the adult beetles.

2.13 Evaluation of thermal, pneumatic and biological methods for controlling Colorado potato beetles (*Leptinotarsa decemlineata* Say)

Lead Participants: N. Rifai, M. Lacko-Bartosova

Obj.: The efficacy of four different methods (hot water steam, open flame, pneumatic collector, bio-insecticide NOVODOR) in controlling Colorado potato beetles (CPB) in potatoes were compared under field conditions.

Hot water steam was tested at 1.0, 1.5, 2.5 and 3.5km/hdriving speeds, while open flame and pneumatic collector were tested at the latter three speeds. All methods were tried on CPB at L1-2 (first and second instar larvae), L3-4 (third and fourth instar larvae), and Adult life stages. The results suggest that the best time to control CPB is at L1-2 stage using bio-insecticide that gave 86% effectiveness. When averaged across the driving speeds, open flame performed better than hot water steam and pneumatic collector with 56% efficacy on L1-2, and 45-50% on L3-4 and Adult life stages. Pneumatic collector worked relatively better on L3-4 than on L1-2 and Adult life stages. Hotwater steam gave excellent efficacy (63% on L1-2, 52-54% on L3-4 and Adult) at 1.0 km/h speed. The worst efficacy (7%) was obtained from pneumatic collector on Adult beetles. This research, which benefits mainly organic (ecological) crop production, demonstrated the potential of alternative non-chemical CPB control methods, and identified the optimum life stage and driving speed for best results.

2.14 Can intercropping result in more stable crop yields under organic management?

Lead Participants: M. Entz, J. Pridham

Obj.: The usual practice of seeding a single variety in a field was compared to using mixtures of varieties of wheat, mixtures of cereal crops and mixtures of cereals with other types of crops.

The cultivar mixture trial implemented 4 varieties of wheat in various mixtures: **AC Barrie** and **5602HR** are modern cultivars of Canada Western Red spring wheat; **Red Fife** and **Marquis** are heritage varieties that are no longer registered with the Canadian Grain Commission. Treatments in this experiment included each variety grown alone, all possible combinations of two and three varieties together as well as all four varieties together. Varieties were mixed together to obtain equal proportions of each variety in the mix, with a total seed population of 300 viable seeds per square metre.

Of the four varieties tested, AC Barrie and Marquis were found to be most susceptible to disease (rusts, tan spot), while Red Fife had the lowest disease incidence. Red Fife's resistance to disease was attributed to its slower development (later heading). It was interesting to observe that the mixtures including Red Fife also had low disease levels, even when other varieties in the mix were highly susceptible to disease. The modern cultivar 5602HR had good resistance to rust but was susceptible to tan spot.

In general, wheat grain yield did not vary greatly between treatments. Heritage varieties had comparable grain yields to the modern varieties, suggesting that under organic management, heritage varieties (specifically Red Fife) are competitive enough to produce yields similar to modern varieties that are bred for a high harvest index. The modern variety 5602HR also performed well in general in this experiment, and out-performed other varieties and mixtures at Carman in 2005 where plots were flooded due to excess rainfall.

Variety mixtures generally outyielded AC Barrie and Marquis grown as monocrops and were comparable to Red Fife and 5602HR. As AC Barrie and Marquis suffered high disease incidence, it is not surprising that their yield was reduced.

Overall, it was found that mixtures can produce higher yields, can increase profitability and allow for a more stable yield. Wheat cultivar mixtures provided yield stability and resulted in lower disease levels than some varieties of monocropped wheat in this experiment.

2.15 Wheat crop competitiveness with weeds under crop yield under different seeding rates

Lead Participants: A. Hammermeister, R. Beavers, R. Martin

Obj.: To determine whether increased seeding rates for spring wheat can be used to enhance weed control in organic systems without affecting crop yield and quality.

Seeding rates in organic systems should balance a crop’s competitive ability while maintaining grain yield and quality. A 2-yr study assessed the response of spring wheat (*Triticum aestivum* L.) to variable seeding rates (1X conventional, 1.25X, 1.5X and 2X) in a plot experiment in Nova Scotia and on organic farms across Canada. The plot experiment was a replicated design with two factors: seeding rate and fertility. On each farm, the single factor of seeding rate was replicated once. Wheat yield was highest at the 2X seeding rate in 2003, but average crop emergence across all treatments was only 56%. In 2004, crop emergence was 76% and the 1.25X, 1.5X and 2X seeding rates had greater yield than the 1X rate. Seeding rate affected plant and head density, but no differences were observed among rates for kernels per head or thousand kernel weight. Grain protein content was similar among seeding rates and was positively affected by the fertility treatment. On farms, a 1.25X seeding rate was sufficient to maximize yield when averaged across all sites. Increasing seeding rate by at least 1.25X the conventionally recommended rate appears to be an appropriate management practice for organic production.

2.16 Weed control efficiency and energy inputs for hot steam, open flame, and infrared thermal units.

Lead Participants: N. Rifai, M. Lacko-Bartosova

Obj.: To evaluate the percentage of weeds killed and the energy inputs for hot steam, open flame, and infrared thermal units.

Hot steam was the least effective in controlling weeds, with only 0 to 48% kill at driving speeds of 1.5, 2.5, and 3.5 km/h. The infrared unit, when operated at speeds of 1.5 and 2.5 km/h, killed 100% of all weed species in a growth stage of <6 true leaves. When operated at these speeds the flame weeder also killed 100% of young redroot pigweed, common lamb's-quarters, and redleg, but not white mustard. The infrared unit used over four times more fuel than the hot steam and open flame units, which used similar amounts of fuel. All units had the best energy efficiency at a driving speed of 2.5 km/h speed. In a related experiment at NSAC, at a groundspeed of 1.5 km/h the hot water-steam unit had a temperature of only 43.6ºC, whereas the infrared and open flame units developed temperatures of 620.9 and 186.1ºC, respectively. At this groundspeed the infrared unit had a propane consumption of 165.2 kg/ha, compared with 24.5 and 29.8 kg/ha for the hot steam and open flame units, respectively. The hot steam unit was the safest of the thermal units because the flames were contained within the boiler. Also, the hot water would cause minimal damage to the soil and would create minimal risk of fire during operation.

2.17 Soil Erosion Risk and Mitigation through Crop Rotation on Organic and Conventional Cropping Systems.

Lead Participants: J. Froese, A. Nelson, M. Entz

Obj.: To compare cropping practices (including crop rotations and tillage regime) on organic and conventional cropping systems, and examine the effect of crop rotation (annual-, biennial-, or perennial-containing rotations) and management (organic or conventional) on soil properties relating to wind and water erosion risk.

Organic cropping systems are often accused of increasing soil erosion risk through an increased use of tillage for weed control. However, little research has been conducted in Canada regarding soil erosion risk on organic farms. It is known that crop rotations can be used to ameliorate a variety of agronomic problems encountered in cropping systems, including soil erosion. Organic systems, which do not use synthetic pesticides and fertilizers, rely more heavily on crop rotations than conventional systems to solve agronomic problems such as weeds and insects.

A mail-out survey was the source of data on soil conservation, crop rotation and tillage practices from 225 organic and conventional farmers in the study provinces of AB, SK, MB, ON, PEI, NB and NS. When compared to conventional farmers, organic farmers had more perennials and green manures in rotation, but fewer organic farmers had zero tillage practices on their farm. More organic farmers had other soil conservation practices (such as shelterbelts, contour tillage, ridge tillage and the use of composts) on their farm than conventional farmers.

Soil from three long-term rotation studies in the prairies (Lethbridge, AB; Scott, SK and Glenlea, MB) and 25 paired organic and conventional farms (in AB, SK, MB, ON, PEI and NS) was sampled. The effect of management and rotation on dry and wet aggregate stability, as well as percent organic carbon (C) was determined. At the long-term studies, the biennial-containing rotation resulted in the highest wet and dry aggregate stability. Management significantly affected organic C in both the long-term studies and the farm pairs, with the organically managed soils having lower C contents than the conventionally managed soils. Despite the lowered organic C levels in the organic systems, aggregate stability remained higher, or equivalent to the conventional systems. This result indicates that aggregate stability in the organic systems is independent of total organic C levels at the current time (however, there are limitations to lowered levels of organic C, and at some point lower C will begin to affect soil properties). The organic soils may be higher in certain C compounds (such as polysaccharides) that stabilize the soil aggregates, but do not alter the total organic C levels.

Few differences in the measured soil properties of the paired organic and conventional farms were found. However, when farms were compared based on having an annual- or perennial-containing rotation, the farms with perennials in rotation were found to have higher wet aggregate stability. Rotation (annual- versus perennial-containing rotations) had a larger effect on wet aggregate stability and percent organic C than management in the farm pairs.

Organic management does not inherently lead to a higher risk of soil erosion than conventional management. While organic systems generally have higher intensities of tillage than conventional systems, organic farms also tend to have more perennials in rotation, which has been shown in this study to lower the risk of soil erosion.

2.18 <u>Scientific And/Or Engineering Significance of Results</u>

Very little research has been conducted in Canada on the role of livestock and forages in organic farming systems, particularly during the organic transition period (the first 3 years of conversion from conventional to organic production). One of the key outcomes of the research related to the importance of management history on soil properties and subsequent farming system treatments that we tested. It is clear that fertility and weed management during organic transition is distinctly different for land that has been in long-term pasture versus coming out of annual crop production. These two starting points need to be studied further and independent strategies need to be developed for each system.

In most conventional agricultural research, nutrients are provided with chemical fertilizers with relatively pure and consistent forms of available nutrients, with predictable availability in the soil. In organic systems these fertilizers are not available so composts and alfalfa meal were used. We attempted to mimic a farmer's practices regarding soil amendment application using simple, scientifically based assumptions about the nutrient availability from organic amendments, and standard soil test recommendations. We essentially tried to establish a condition of isonitrogeneity (equal nitrogen levels) among the three livestock systems tested so that we could evaluate fertility and weed effects and economic outcomes. We soon realized that management of soil fertility using the organic amendments was much more difficult to achieve due to the complex nature of the amendments and their additional effects on non-target soil nutrients, weed seed banks, soil organic matter and soil microorganisms. Amendment trials in the greenhouse demonstrated how nutrient imbalances can limit nitrogen mineralization, and how the form of nitrogen in the amendment may affect crop growth. Isonitrogeneity is difficult to achieve when working with organic amendments. This concept of isonitrogeneity warrants significant further investigation.

The effect of long-term organic management on soil phosphorus levels is a key question relating to the sustainability of organic production. Our results have shown that labile P is lower under organic management than in conventional or in native grassland soils. Low P levels were linked to higher mycorrhizal colonization under organic management. This research has opened a need for a much more detailed evaluation of organic management on soil P levels, and related factors such as nitrogen fixation.

The organic production system has been criticized for its high use of cultivation for weed control and resulting effects on soil organic matter content and erosion susceptibility. Landmark research conducted in part with this NSERC funding has shown that organic management reduces soil organic matter content, however, it does not reduce aggregate size and hence does not increase soil erosion potential relative to conventional management. The inclusion of forages in the crop rotation was the most important factor.

Weeds are cited as the biggest deterrent to farmers considering transition to organic, and are the biggest problems cited by existing organic farmers. In this research we evaluated wheat seeding rates and the resulting crop competitiveness with weeds. This research has definitely illustrated the complex interaction between soil fertility, crop physiology, and weed competitiveness, and has verified the long-standing practice of increasing seeding rates in organic production.

Weed control in potato (and other horticultural) crops can be very challenging. Evaluation of thermal means of controlling weeds provided very useful insights on the efficacy of this equipment and future engineering research.

2.19 Potential Benefits To Canada

The organic sector is one of the fastest growing sectors in agriculture. Organic or its related production practices are repeatedly being cited as examples of sustainable production. This research has contributed significantly to our understanding of just how sustainable organic management is and what sustainability challenges must be addressed in organic production. It has answered, and begun to answer, many key questions regarding the sustainability of the organic production system.

This research has connected and trained many researchers, graduate students, technicians, and professionals. Organic needs researchers and professionals knowledgeable about the organic production, and how to best conduct research in this complex, holistic system. This research has allowed us to establish linkages with many other researchers across Canada, resulting in significantly greater collaboration and interest in organic research, Perhaps one of the most important benefit.

In Canada the organic market is increasing at about 25% per year. There is potential for a 100 billion US$ organic market within the next 10 years, mostly in the USA and Japan. Many farmers will be considering transition to organic production to meet the market and to improve their environmental management and stewardship on farms they intend to pass on to future generations. The premium prices and reduced input costs of organic agriculture offer this opportunity. Canada is perceived as a nation of clean air, water and healthful food. The development of organic agriculture will enhance or at least sustain this perception and actually contribute to improved sustainability of agricultural capacity.

Society is increasingly less tolerant of the environmental impacts of biocides. Organic farming, especially if supported by governments and university research will prove more than capable of feeding the world with food that is not only healthy and abundant but sustainably produced (Clark 2001).

3 Research Team

Details of the contribution of the participants are summarized below, and link with the description of project outcomes described above.

3.1 Principal Investigator

Dr. Ralph C. Martin, Department of Plant and Animal Sciences and Organic Agriculture Centre of Canada (OACC), Nova Scotia Agricultural College (NSAC)
Dr. Martin was the lead responsible for coordinating and administering the project, pulling together

collaborators, supervising graduate students, coordinating meeting, allocating funds, establishing a research team and hiring employees.

3.2 Co-investigators

Dr. Martin Entz, Department of Plant Science, U of M
Dr. Entz was a key researcher identifying the objectives of this proposal and contributing to the experimental design. He has been one of the primary co-investigators in MB, establishing a new rotation study, providing access to the long-term organic-conventional rotational trials at Glenlea, supervising 2 graduate students, attracting collaborators to the project and contributing to 3 graduate student committees on supporting projects.

Dr. Tess Astatkie, Department of Engineering, NSAC
Dr. Astatkie been the lead statistician on projects related to Objectives 1 & 2 and on several of the supporting projects. He also was the instructor for graduate students working out of the NSAC. Dr. Astatkie has co-authored at least 2 of papers published to date from this work, and will be co-author on at least three more papers.

Dr. Cindy Grant, Brandon Research Centre, AAFC and an Adjunct Professor, Department of Soil Science, UofM
Dr. Grant was a lead contributor to establishing organic-conventional amendment trials at Brandon. Aside from contributing to overall project design, she has led establishment of rotational trials at Brandon testing organic and conventional management systems. She supervised 1 M.Sc. student, and a number of technicians through the duration of the project.

Dr. Jeff Hoyle, Department of Environmental Sciences, NSAC
Dr. Hoyle participated in the design and implementation of the rotation study in NS. He also co-supervised one graduate student investigating Colorado potato beetle control, co-supervised one NSERC USRA student, and co-authored at least 1 paper arising from the project.

Dr. Nabil Rifai, Department of Engineering, NSAC
Dr. Rifai was the lead engineer on the project, focusing on equipment that could be used to mechanically control weeds and Colorado potato beetle. His leadership on these projects led to publication of two papers.

Dr. Phil Warman, Department of Environmental Sciences, NSAC
Dr. Warman was the lead soil fertility and compost specialist on the project. He made fundamental contributions to the design of the primary rotation study in this project, co-supervised one graduate student studying Colorado potato beetle control, supervised one graduate student studying compost utilization in organic fruit production, and contributed to the design and analysis of at least one supporting project. Dr. Warman was co-author on at least 2 papers resulting from this work, and is expected to co-author on future papers arising from the work.

Dr. Emmanuel Yiridoe, Department of Business and social Sciences, NSAC
Dr. Yiridoe was the lead economist on this project, contributing to the design of the primary rotation study. He co-supervised one graduate student.

Dr. Alan H. Fredeen, Department of Plant and Animal Sciences, NSAC
Dr. Fredeen was instrumental in the initial design of the project and and ongoing team discussions. Unfortunately, we did not find a suitable graduate student to work on the planned modeling with Dr. Fredeen so this aspect did not proceed.

3.3 Collaborators

Dr. John Henning, Deparment of Economics, McGill U.
In collaboration with Dr. Yiridoe, Dr. Henning co-supervised an MSc student studying the economics of the

primary farming system study in this project.

Dr. Alex Georgallas, Department of Engineering, NSAC
In collaboration with Dr. Martin, Dr. Georgallas was involved in project design and explored opportunities for modelling flow of nutrients and energy in the primary farming system study of this project. He further contributed on a graduate student committee related to this project.

Dr. David Patriquin, Department of Biology, Dalhousie U.
In collaboration with Dr. Martin, Dr. Patriquin co-supervised a PhD student working on the primary farming system study in this project. He contributed significantly to design, data analysis, and writing of the research results. Dr. Patriquin will be co-author on related papers.

Dr. Mario Tenuta, Department of Soil Science, UofM
In collaboration with Dr. Entz, Dr. Tenuta supervised a graduate student studying the effect of long-term organic rotation on soil labile P and mycorrhizal colonization.

Dr. Jane Froese, Department of Plant Science, UofM
In collaboration with Dr. Entz, Dr. Froese supervised a graduate student who studied the effect of tillage in organic and conventional production and its impact on soil organic matter content and erosion potential. This was a key sustainability question for organic.

Dr. Derek Lynch, Plant and Animal Science Department, NSAC
In collaboration with Dr. Martin, Dr. Lynch co-supervised a graduate student studying soil phophorus in organic dairy systems, and co-authored one paper. Dr. Lynch also was a committee member for another graduate student on this project.

Dr. Paul Voroney, Department of Soil Science, UofG
In collaboration with Dr. Martin, Dr. Voroney co-supervised a graduate student studying soil phophorus in organic dairy systems, and co-authored one paper.

Dr. M. Lacko-Bartosova, Department of Sustainable Agriculture and Herbology, Slovak Agricultural University
In collaboration with Drs. Rifai and Astatkie, Dr. Lacko-Bartosova contributed to the design and implementation of mechanical pest control trials.

Dr. Peter Havard, Department of Engineering, NSAC
In collaboration with Drs. Rifai and Astatkie, Dr. Havard contributed to the design and implementation of mechanical pest control trials.

Dr. Brenda Frick, Department of Plant Science, UofS
In collaboration with Dr. Martin, Dr. Frick assisted in the wheat seeding rate project, coordinated participation of farmers and other researchers, and was a committee member for R. Beavers MSc.

3.4 Government Scientists

Dr. Jill Clapperton, AAFC-Lethbridge
In collaboration with Drs. Martin and Entz, Dr. Clapperton contributed significantly to the design and analysis of the soil biological measurements in the primary farming system study, and trained one graduate student in specialized soil microbiological analysis.

3.5 Postdoc

Dr. Andrew Hammermeister, OACC, NSAC
Dr. Hammermeister coordinated the implementation of the primary farming system trial and the mulch trials in NS and MB. He also initiated growth room trials studying the nutrient supplying capacity of different soil amendment, and the wheat seeding rate study which was the largest organic on-farm trial ever conducted.

He co-supervised two MSc students and sat on one graduate student committee. Dr. Hammermeister has authored one paper from this project, and is co-author on one submitted paper and 3 more paper that are in progress. Dr. Hammermeister began as a PostDoc, and later advanced to Research Associate status.

3.6 Graduate Students

Kui Liu – PhD completed, NSAC/Dalhousie University (S: Ralph Martin and David Patriquin)
Roxanne Beavers – MSc completed, NSAC (S: Andrew Hammermeister and Ralph Martin)
Jackie Pridham – MSc in progress, UofM (S: Martin Entz)
Mathew Wiens – MSc completed, UofM (S: Martin Entz)
Catherine Welsh – MSc in progress, UofM (S: Mario Tenuta and Martin Entz)
Alison Nelson – MSc completed, UofM (S: Jane Froese)
Tara Moreau – MSc completed, NSAC (S: Phil Warman and Jeff Hoyle)
Shankar Shanmugam – MSc completed, NSAC (S: Phil Warman)
Karl Slawinski - MSc in progress, UofM (S: Cynthia Grant)
Andres Riofrio – MSc completed, McGill U. (S: John Henning and Emmanuel Yiridoe)
Corey Roberts – MSc in progress, UofG (S: Paul Voroney and Derek Lynch)
P. Otepka – PhD, Slovak Agricultural University (S: M. Lacko-Bartosova and N. Rifai)
Hao Yu – MSc not completed, NSAC (S: Ralph Martin and Andrew Hammermeister)

3.7 Technicians and Summer Students (working in part on this NSERC)

NSAC (S: R. Martin and A. Hammermeister):
Steven Boyce, S. McMillan, S. Urbaniuk, L. Weatherby, P. Schofield, L. Rector, M. Quenum, E. Jeliazkova, J. Nelson, M. Graves, S. Barot-Cortot, S. Beauchet, Krista Kagume, Jeanine Cudmore, Laura Gaulton, Angie Forbes, Gisela Duerr, Eric Embree, Norma MacLellan, OJ Lien, Brent Craig, Caroline Ramsay

NSAC (S: J. Hoyle and A. Hammermeister)
A. Bambrick

UofM (S: M. Entz):
K. Bamford, S. Eidse

UofM (S: C. Grant):
Brian Hadley, Mike Svistovski, Kim Smith, Cheryl Dooley, Ian Murchison Kristie Miller, Jolie Horn, Chrissy Barbeau, Sarah Whetter, Ryan Boyd (+ at least 3 other summer students)

3.8 Others

In addition to the research collaborators listed above, research funded in part by this NSERC Strategic grant has resulted in work on over 60 farms across Canada. Further, we have worked to varying degrees with extension, college and university staff in at least 7 provinces on this or related projects.

4 Training

4.1 List of Trainees

Trainee- Specify type (e.g. M.Sc., Ph.D. etc) (one trainee per line)	(a) Number of calendar years on the project	(b) % of research time spent on this project
K. Liu (PhD)	4.5	100
R. Beavers (MSc)	2.3	100
A. Riofrio (MSc)	2.5	100
T. Moreau (MSc)	2.5	100
S. Shanmugam (MSc)	2.5	25
H. Yu (MSc)	.75	100
M. Wiens (MSc)	2.5	100
J. Pridham (MSc)	2.5	100
C. Welsh (MSc)	2.5	100
A. Nelson (MSc)	2.5	100
K. Slawinski (MSc)	3	80
C. Roberts (MSc)	3	100
P. Otepka (PhD)	2	30
S. MacMillan (Technician)	.5	75
S. Urbaniuk (Technician)	1	10
L. Weatherby (Technician)	.5	25
P. Schofield (Technician)	.5	10
K. Punnett	.5	25
M. Quenum (Technician)	.3	10
K. Bamford (Technician)	4	25?
J. Horn (Technician)	.7	10
S. Boyce (Summer Student)	.3	100
Amanda Bamabrick	.3	50
J. Nelson (Summer Student)	.3	15
M. Graves (Summer Student)	.3	15
S. Barot-Cortot (Summer Student)	.2	10
S. Beauchet (Summer Student)	.2	10
S. Eidse (Summer Student)		75
K. Miller (Summer Student)	1.6	10
C. Barbeau (Summer Student)	.3	10
S. Whetter (Summer Student)	1	10
R. Boyd (Summer Student)	.3	10
K. Kagume (Summer Student)	.2	100

J. Cudmore (Summer Student)	.2	100
L. Gaulton (Summer Student)	.2	100
A. Forbes (Summer Student)	.2	100
E. Embree (Summer Student)	.2	100
N. MacLellan (Summer Student)	.2	100
O.J. Lien (Summer Student)	.2	100
B. Craig (Summer Student)	.2	100
C. Ramsay (Summer Student)	.2	100
R. Nason	.3	25
T. Naugler	.3	25
S. Marguirite	.3	25

4.2 Interaction of highly qualified personnel (HQP) with the partners

X____ HQP presented research results to the partners
x____ HQP discussed the project directly with partners to obtain input
x____ Partners jointly supervised thesis projects of HQP
_____ HQP worked regularly in the partner's facilities
_____ HQP did not interact with the partners
x Other (Specify) HQP conducted trials on organic farms _____

4.3 Employment of HQP involved in the project

Type of HQP	# hired by partner	# of hired by industry	# hired by government labs	# employed in academia (faculty)	# hired by other (specify)	# in academic training
Undergraduate Students	1					17, after work on this project
Master's Students	3	1			2 hired by government 1 farming	7
Doctoral Students	1			1		
Postdoctoral Fellows	1					
Research Associates				1		
Technicians	4	1				4
Other (Specify)						

5 Dissemination of Research Results and knowledge or Technology Transfer

	Number of publications, presentations…		
Status	**Refereed Journal Articles**	**Conference Presentations/ Poster**	**Other (including Technical Reports, Non-Refereed Articles, etc.)**
Accepted/Published	10	19	21
Submitted	2		

5.1 Refereed Journal Articles:

5.1.1 Published

Hammermeister, A. M., Astatkie, T., Jeliazkova, E. A., Warman, P. R. and Martin, R. C. 2006. **Nutrient supply from organic amendments applied to unvegetated soil, lettuce and orchardgrass**. Can. J. Soil Sci. 86: 21–33.

Wiens, M. J., Entz, M. H., Martin, R. C. and Hammermeister, A. M. 2006. **Agronomic benefits of alfalfa mulch applied to organically managed spring wheat**. Can. J. Plant Sci. 86: 121–131.

Moreau, T.L. Warman, P.R., and Hoyle, J. 2006. **An evaluation of companion planting and botanical extracts as alternative pest controls for the Colorado potato beetle**. Biol. Agric. Hort. 23:351-370.

Rifai, M. N., T. Astatkie, M. Lacko-Bartošová, and P. Otepka . 2004. **Evaluation of thermal, pneumatic, and biological methods for controlling Colorado Potato Beetle (Leptinotarsa Decemlineata Say)**. *Potato Research*. 47: 1-9.

Rifai, N. M. - Miller, J. - Gadus, J. - Otepka, P. - Kosik, L.: **Comparison of infrared, flame and steam units for their use in plant protection**. Research in Agricultural Engineering 49 (2): 65-73

Rifai, N. M. - Otepka, P. - Kosik, L. - Gadus, J.: **Zariadenia pre termicku regulaciu zaburinenosti a hodnotenie ich ucinnosti**. In: Nove trendy v konstruovani a v tvorbe technickej dokumentacie 2003 (Zbornik s medzinarodej vedeckej konferencie pocas konania 10. Medzinarodneho strojarskeho veltrhu v Nitre). Nitra, 29. maj 2003. s. 97-102.

Rifai, N. M. - Lacko-Bartosova, M. - Otepka, P. - Kosik, L.: **Hodnotenie ucinnosti termickych metod na regulaciu vybranych druhov burin.** In: Aktualne problemy riesene v agrokomplexe (Zbornik s medzinarodneho vedeckeho seminara). Nitra: VES SPU, 15. November 2002. s. 162-165.

Rifai, N. M. - Otepka, P. - Kosik, L. - Gadus, J.: **Zariadenia pre termicku regulaciu zaburinenosti a hodnotenie ich ucinnosti**. In: Moderna mechanizacia v polnohospodarstve 2003, 5 (3): 22-24.

Rifai, N. M. - Gadus, J. - Kosik, L. - Otepka, P.: **Testovanie vyvijaca infracerveneho ziarenia. In: Moderna mechanizacia v polnohospodarstve** 2003, 5 (1).

5.1.2 Accepted

Astatkie, T., M.N. Rifai, P. Havard, J. Adsett, M. Lacko-Bartosova & P. Otepka. 2006. **Effectiveness of hot water, infrared and open flame thermal units for controlling weeds**. Biological Agriculture & Horticulture. Accepted for publication.

5.1.3 Submitted

Beavers, R.L., Hammermeister, A.M., Frick, B. and Martin R.C. Submitted in 2006. **Spring wheat yield response to variable seeding rates in organic farming systems**. Can J. Plant Sci. Submitted.

Roberts C.J., Lynch, D. H., and Voroney, R.P. Submitted in 2006. **Farm nutrient status in relation to farm management and productivity across fifteen organic dairy farms in Ontario.** Can J. Soil Sci. Submitted.

At least 4 papers known to be in progress for submission, and 3 others expected.

5.2 Conference Presentation/Poster:

5.2.1 Presentations:

Pridham, J.C. and Martin Entz. **Effect of Intercropping and Cultivar Mixtures on Organic Wheat Production.** Presented at the ASA-CSSA-SSSA International Annual Meetings (November 6-10, 2005), Salt Lake City, UT.

Hammermeister, A.M., P. Warman, M. Entz, K. Liu, R. Martin. 2003. **Transition and Sustainability Strategies for Organic Farms.** Atlantic Canadian Organic Regional Network Conference, Halifax, NS.

Hammermeister, A.M. 2004. **Farming Systems And Soil Fertility Research.** Atlantic Canadian Organic Regional Network Conference, Charlottetown, PE.

R. Beavers, A. Hammermeister, B. Frick, D. H. Lynch, and R. C. Martin. 2006. **Increasing seeding rate in organic production: Effects on weed competition, crop yield and quality.** Canadian Society of Agronomy Atlantic Regional Conference, Charlottetown. PE.

R. Beavers and A. Hammermeister. 2006. **Seeding Rate Experiments across Canada: the wheat-weed dynamic.** Guelph Organic Conference, Guelph, ON.Beavers, R. and A.M. Hammermeister. 2005. Seeding Rate Experiments – Nova Scotia and Canada wide results. Atlantic Canadian Organic Regional Network Conference, Fredericton, NB.

Kui Liu, Andrew M. Hammermeister, Phil R.Warman, Martin H. Entz, Ralph C. Martin. 2006 **Nitrogen responses to amendments and crop rotations varying in proportions of forages in the first three years of four-year crop rotations.** Canadian Society of Soil Science Conference. Halifax, NS.

Hammermeister, A.M. 2004. **NSERC Strategic Grant: Transition and Sustainability Strategies For Organic Farms.** Nova Scotia Agricultural College Seminar Series. Truro, NS.Riofrio, A. 2005. The Economics of the Transition to Organic Agriculture. Seminar presentation, Department of Agricultural Economics, McGill University. January 2005.

Riofrio, A., E.K. Yiridoe, J. Henning, A. Hammermeister, and R.C. Martin**.** 2006. **Economic analysis of crop rotation systems during the transition to organic agriculture.** Selected paper presented at the joint Canadian Economics Association and Canadian Agricultural Economics Society Conference. May 25-28. Montreal, Quebec.

Lynch, D.H., Roberts, C., and Voroney, R.P. 2006. **Sustainability of organic dairying in Canada.** pp 454-455 in 'Organic Farming and European Rural Development'. Proceedings of the European Joint Organic Congress, May 30th-31st, Odense, Denmark.

Slawinski, K, **Grant, C.A.,** Flaten, D. N., Entz, M. H., Crow. G. 2004. **Nitrogen Release from Composted Beef Manure in Wheat Production**. American Society of Agronomy Annual Meeting. Seattle Washington, November 1 to 5. 2004. Abstract of oral paper. 1 pp.

Grant, C. A., Slawinski, K., Buckley, K and Irvine, B. 2005. **Manures and Inorganic Fertilizers, Matching Supply and Demand.** Presentation to Manitoba North Dakota Zero Tillage Farmers Association. Annual Meeting. Brandon. Feb. 2. 2005.

5.2.2 Posters:

Liu, K., A.M. Hammermeister, P.R. Warman, R.C. Martin. 2004. **Effects of soil amendments and crop rotations on plant nitrogen uptake and soil nitrate supply during organic transition.** Can. Soc. Agron. Atlantic Region Workshop. Charlottetown, PE.

Liu, K., A.M. Hammermeister, P. R. Warman, M. H. Entz, Ralph C. Martin. 2005. **Potato Tuber Yield as Affected by Organic Farming Systems Integrating Soil Amendments and Forage-based Crop Rotations in the First Four-year Cycle**. AIC Conference, Quebec City, QC.

Liu, K., **A.M. Hammermeister, P**.R. Warman, M.H. Entz, R.C. Martin. 2004. **Effects of soil amendments and crop rotations on plant nitrogen uptake and soil nitrate supply during organic transition**. Guelph Organic Conference, Guelph.

Hammermeister, A.M., Astatkie, P.R. Warman, E.A. Jeliazkova and R.C. Martin. **Nutrient Supplying Potential Amendments for Organic Production.** American Society of Agronomy Conference. 2004. Seattle, WA.

Hammermeister, T. Astatkie, P.R. Warman, E.A. Jeliazkova and R.C. Martin. **Nutrient Supplying**

Potential Amendments for Organic Production. Organic Connections Conference. 2004. Saskatoon, SK.

Liu, K., A.M. Hammermeister, T. Astatkie, P.R. Warman, E. Jeliazkova and R.C. Martin. 2004. **Nutrient Supply From Organic Amendments. Guelph Organic Conference**. Guelph, ON.

Beavers, R.L., A.M. Hammermeister, R.C. Martin. 2004. **Effect of variable seeding rates on weed-wheat competition, wheat yield and grain quality at different fertility levels.** Organic Connections Conference. 2004. Saskatoon, SK.

Roberts, C., Lynch, D.H., and Voroney, R. P. 2004. **Soil test phosphorus and nutrient budgets for 15 organic dairy farms in Ontario.** Poster. Organic Connections Conference, Saskatoon, Sk.

5.3 Other (Including Technical Reports, Non-Refereed Articles, etc.):

5.3.1 Theses

Riofrio, A. 2006. Economics of Introducing Forage and Livestock into Alternative Crop Rotation Systems During the Transition to Organic Agriculture. M.Sc. Thesis, McGill University, QC.

Beavers. R.L. 2005. Wheat-weed interactions at variable seeding rates in organic farming systems. M.Sc. Thesis, Nova Scotia Agricultural College and Dalhousie University, NS.

Liu, K. 2006. Soil and plant responses in the first cycle of four-year organic potato rotations. Ph.D. Dissertation. Dalhousie University, NS.

Moreau, T. An evaluation of alternative pest controls for the Colorado potato beetle, *Leptinotarsa decemlineata* (Say) on organic potatoes. M.Sc. Thesis, Nova Scotia Agricultural College and Dalhousie University, NS.

Ganapathi Shanmugam, S. 2005. Soil and plant response of organic amendments on strawberry and half-high blueberry cultivars. M.Sc. Thesis, Nova Scotia Agricultural College and Dalhousie University, NS.

Nelson, A.G. 2005. Soil Erosion Risk and Mitigation through Crop Rotation on Organic and Conventional Cropping Systems. M.Sc. Thesis, University of Manitoba, MB.

Wiens, M. 2004. Nitrogen, weed control, and moisture conservation benefits of alfalfa mulch applied to organically grown spring wheat. M.Sc. Thesis, University of Manitoba, MB.

5.3.2 Newspaper

Beavers, R. and Frick, B. 2006. Large On-Farm Study Confirms Organic Recommendation. Western Producer

Frick, B. 2004. Are higher seeding rates warranted? Western Producer

Liu, K., A. Hammermeister and F. Willick. 2006. Are Livestock And Forages Needed On Organic Farms? Farm Focus.

Hammermeister, A.M. 2005. Nutrient supply from organic amendments. Farm Focus

5.3.3 Technical Bulletins and Reports

Grant, C.A. Irvine, R.B. Derksen, D.A. McLaren, D.L. Buckley, K. Montreal, M. Moulin, A. Mohr, R., House, Jim Marchylo, Brian, and Ames, Nancy. 2002. **Impact of Organic Production and Reduced Chemical Inputs on Soil Nutrient Depletion and the Functional and Nutritional Quality of Crops.** Report to Manitoba Pulse Growers and Agrium, December 21, 2001. 6 pp

Grant, C.A. Irvine, R.B. Derksen, D.A. McLaren,D.L. Buckley, K. Montreal, M. Moulin, A. Mohr, R., House, Jim Marchylo, Brian, and Ames, Nancy. 2003. **Impact of Organic Production and Reduced Chemical Inputs on Soil Nutrient Depletion and the Functional and Nutritional Quality of Crops.** Report to Manitoba Pulse Growers and Agrium. January 6, 2003. 19 pp.

Grant, C.A. Irvine, R.B. Derksen, D.A. McLaren, D.L. Buckley, K. Montreal, M. Moulin, A. Mohr, R., House, Jim Marchylo, Brian, and Ames, Nancy. 2004. **Impact of Organic Production and Reduced Chemical Inputs on Soil Nutrient Depletion and the Functional and Nutritional Quality of Crops.** Report to Manitoba Pulse Growers and Agrium. May 11, 2004 19 pp.

Grant, C.A.,Irvine, R. B., Derksen, D. A., McLaren, D. L., Buckley, K, Monreal, M., Mohr, R., House, Jim, Marchylo, Brian, Ames, Nancy. 2002. **Impact of Organic production and reduced chemical inputs on soil nutrient depletion and the functional and nutritional quality of crops.** The Pulse Beat. Issue # 35, Winter 2001/02. Pp. 18-23.

Grant, C.A.,Irvine, R. B., Derksen, D. A., McLaren, D. L., Buckley, K, Monreal, M., Mohr, R., House, Jim, Marchylo, Brian, Ames, Nancy. 2003. **Impact of Organic production and reduced chemical inputs.** The Pulse Beat. Issue # 38, Winter 2002/03. Pp. 19-21.

Grant, C., Slawinski, K., Irvine, B., Derksen, D., McLaren, D., Buckley, K., Monreal, M., Moulin, A., Mohr, R., Ames, N., Marchylo, B., and House, J. 2003. **Impact of Organic Production and Reduced Chemical Inputs on Soil Nutrient Depletion and the Functional and Nutritional Quality of Crops.** Land Resource Management Research, Research Highlights, Brandon Research Centre, 24-27.

Liu, K., A.M. Hammermeister, R. Martin and R. Beavers. 2006 **Are livestock and forages needed on organic farms?** Organic Agriculture Centre of Canada, Nova Scotia Agricultural College, Truro,

NS. E2006-03.
Beavers, R.L. and A.M. Hammermeister. 2006. **Seeding rate for weed control in spring wheat.** Organic Agriculture Centre of Canada, Nova Scotia Agricultural College, Truro, NS. E2006-08.
Nelson, A. and R. Beavers. 2006. **Lowering soil erosion risk in organic cropping systems.** Organic Agriculture Centre of Canada, Nova Scotia Agricultural College, Truro, NS. Final Research Report. E2006-09.
Roberts, C., D. Lynch, P. Voroney and R. Beavers. 2006. **Soil fertility and nutrient budgets on organic dairy farms.** Organic Agriculture Centre of Canada, Nova Scotia Agricultural College, Truro, NS. Interim Research Report E2006-12

6 Impact on Researcher

6.1 Impact of project on teaching

____	Creation of new courses
X	New content for existing courses
X	Use of real world examples
X	Guest lectures from partners
____	New equipment/Material
____	Other (Specify:): ________________

6.2 Impact on research program

X	Influence the direction to more industrial relevant topics
X	Opened up new opportunities for research beyond the original objectives
____	Other (Specify): ________________