Evaluation of organic cropping systems for profit and sustainability in a Maritime climate: exploring new technologies in nutrient management, and weed, pest, and pathogen control.

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SUMMARY

An organic rotational experiment was initiated in the spring of 2013 in the newly certified organic block at the Harrington Research Farm of Agriculture and Agri-Food's Charlottetown Research and Development Centre. The trial consisted of eight rotations (two from each of four proponents (PEI Certified Organic Producers Coop, Dairy Farmers of PEI, Red Soil Organics and the PEI Elevator Corporation)) laid out in a Randomized Complete Block Design with each block consisting of a phase of a four year rotation (staggered start approach). Various crop and soil parameters were measured during and at the end of this trial.

Among the plow-down crops studied, sorghum sudangrass produced the greatest biomass and generally returned the greatest amounts of carbon and nutrients to the soil. However, the higher returns of carbon did not translate into higher organic matter levels due in part to the effect carrot management may have on organic matter oxidation. Although there was no apparent benefit of the sorghum sudangrass on soil organic matter, it is thought that the roots of this crop were beneficial in lowering the resistance to penetration on the plots it was sown.

Sorghum sudangrass, unlike legumes like red clover and alfalfa, generally requires nitrogen inputs in order to produce substantial biomass. These inputs may come in the form of Nutri-wave (pelletilized chicken manure), other manures or composts. In many organic systems, there is a requirement for a plow-down legume to aid in the provision of N to succeeding crops. Under the conditions of this trial, it was apparent that the red clover was of greater benefit than oats/peas and vetch in terms of nitrogen fixing capacity.

Among the various cash crops, carrots gave by far the greatest gross returns. Thus, it is not surprising that the two Red Soil rotations, which had carrots, had the highest gross returns. The actual profitability of the various rotations will be determined when a full economic analysis is completed.

Issues were encountered with the potato crop; flea beetle and wireworm damage occurred. Wireworm control measures are to be incorporated into the crop rotations which include potatoes. It should be noted, that the greatest wireworm damage occurred in 2015, where there was a substantial delay in planting further complicated by drought during the summer. These factors delayed harvest, relative to other years, resulting in significant wireworm damage. With the flea beetles a partial solution was found. Pyganic organic insecticide, evaluated in a related ancillary trial, did not eradicate the beetles but appeared to keep them from decimating the crop. It is noteworthy that some lines in an adjacent potato evaluation project, under organic conditions run by David Main, appeared not to be as susceptible to flea beetle damage as Red Norlands, the potatoes grown in this trial.

Issues were also encountered when no-till seeding soybeans into a rolled fall rye crop in 2015. The delayed spring, eluded to above, resulted in delayed flowing of the rye, the optimum time to roll the rye, which in turn delayed seeding of the soybeans resulting in a short growing season for the soybeans which severely affected yields.

Although not always significant, generally differentiation among the rotations increased with time for many of the parameters measured in routine soil fertility tests. It is reasonable to assume that this differentiation will become more pronounced the longer that the trial runs. Thus, with some afore mentioned tweaks, greater knowledge will be gained the longer that this trial runs. It should also be noted that high soil P_2O_5 concentrations were found at the onset of this trial; related to previous fertilizer inputs and management. The ratios of P/Al were above 14 in many of the plots. This is the predicted thresholds where P may move down the soil profile. This can be verified by measure P_2O_5 concentrations further down the profile. Further, high concentrations of P can be antagonistic to the uptake of various micro-nutrients; this can be determined through greater foliar analysis.

Many of the soil physical and biological parameters studied from the various rotations were only significant when compared to time zero areas which had received no traffic or amendments.

INTRODUCTION

Good crop rotations are the basis for organic agriculture. Properly planned and implemented cropping systems carried out over longer periods of time, serve to build soil fertility and health, increase agro-biodiversity, break pest and disease cycles, and improve economic resiliency. Poor crop rotations can have the inverse effect. Unlike conventional producers, organic farmers do not have quick fixes like synthetic fertilizers and pesticides, and require intelligent cropping systems to build resiliency into their production systems.

Nitrogen and phosphorus are two essential plants nutrients which tend to be most limiting in organic systems. Nitrogen is generally supplied through the incorporation of green manure crops or through the application of other organic amendments such as raw or composted livestock manures. Phosphorous is conventionally applied in the form of rock phosphate or through translocation by deep rooted crops which mine P from soil depths to be utilized by subsequent shallow rooted crops. Generally, soil organic matter status tends to be higher under organic than conventional cropping systems (Gomiero et al. 2011). Clark et al. (1998) found that after eight years of management under organic cropping systems that soil N, C, P and K had increased when compared to the equivalent conventional two-year rotation. However, it may not necessarily be the type and length of rotation that has the biggest impact on soil nutrient and carbon pools, but rather the nutrient flows within the cropping system. Recently, Bell et al. (2012) looked at conventionally versus organically managed cropping systems in Manitoba reported a higher level of soil organic matter under conventional rather than organic cropping systems. Lower soil organic matter was attributed to lower inputs of carbon, while in the latter case it was attributed to lower inputs of nutrients; especially during non-potato years of the rotation. Campbell and Zentner (1993) and Gregorich et al. (1995) reached similar conclusions regarding the role of nutrients in organic matter accumulation. As recently as 2012, Lynch et al. (2012) indicated that synchronizing N supply to crop demand remains a challenge. This highlights the need for a system to effectively track soil nutrient status both during the growing season (based on crop demand), and pre- and post- growing season to determine if excess nutrients are being leached into the environment. Nutrients interact with the physical and biological properties of soils. Soil aeration status governs microbial breakdown of crop residues, organic amendments and soil organic matter. Incorporation of organic amendments and plant residues through tillage is one of the primary means of feeding the crop. Factors like cropping system duration, number of tillage operations and type and amount of fertility inputs have been shown to influence soil organic matter status (Karlen et al. 1994). Frequent tillage decreases soil organic matter content (Jarecki and Lal 2003) and trafficability (Flowers and Lal 1998). Trafficability is largely governed by the mechanical state of the soil and its susceptibility to damage during machinery operations. It can be measured using two components - vertical (penetrometer (Earl 1997; Rodd et al. 1999)) and horizontal (torvane (Błażejczak et al. 2006)). Trafficability issues are compounded by high soil moisture conditions (Schulte et al. 2012), especially during the harvest of late season crops. Crop residues, such as fall rye, may increase trafficability during harvest in the fall. Researchers at CLRC have been evaluating the influence of overseeding and underseeding of soybeans and canola as ways to increase ground cover in the fall thereby improving trafficability. Rolling and crimping fall rye as part of a weed management strategy for soybeans may also increase trafficability.

The maintenance or improvement of soil organic matter content and aggregate stability, are indicators of good rotation systems (Wander et al. 1994). Poeplau and Don (2013) reported that particulate organic carbon was the most sensitive carbon related parameter to land use change.

Where most of the nutrients supplied to plants grown under organic management are supplied from organic, plant unavailable sources, efforts are needed to develop the soil community to encourage nitrogen mineralization and turnover. The makeup of the soil community can be an indicator of the nature of the organic matter decomposition pathway (Wardle et al. 2004; Ward et al. 2010; Nielsen et al. 2011). If a system is largely dominated by a fungal decomposition pathway, nutrients are derived from recalcitrant litter and the system may be considered to be relatively static; however, a bacterial decomposition pathway indicates nutrients are derived from labile sources, and this system is marked by an unevenness of soil function and reduced efficiencies nutrient turnover and utilization (Wardle et al. 2004). Several tools have emerged recently to measure the effects of soil biodiversity on agro-ecosystem function. The analysis of phospholipid fatty acid (PLFA) profiles in soil samples has been shown to be a reliable and efficient way to measure the makeup of the functional soil community at a given point in time (Bardgett et al. 1993; Frostegård et al. 1993; Frostegård and Bååth 1996; Frostegård et al. 2011). Where different crop species have different soil communities associated with their root systems, the diversity and function of the soil community is drastically affected by crop plant identification.

Weeds are generally of greater concern in organic than in conventional systems because organic producers have less options available to them (Forcella 2013). Work done at the CLRC by Main *et al.* (in preparation) have evaluated various organic weed control options including flaming, clove oil (Matran^R), and citrus oil (Native's Avenger^R) for weed control in carrot production. Further, work by Henry at CLRC has shown dramatic allelopathic effect of ryegrass not only on some weeds but also on some following crops such as cereals; similar results were found by Forcella. Einhellig and Leather (1988) noted that strategies for utilizing allelopathy as an aid in crop production include avoidance and application. They noted that varieties of grain and forage sorghums, sunflower, oats, wheat etc. may provide weed control while in other instances they may stimulate the succeeding crop.

Wireworms are a major pest emerging in the Maritimes. Various crop species such as brown mustards, and buckwheat, and have found to have chemicals, such as isothiocyanates in brown mustard, which reduce wireworm damage to the crop (Noronha 2010). At CLRC, Noronha has been working on determining which crops/control strategies are needed for wireworm mitigation. Since wireworms are such a potential major devastating pest, crops which have wireworm control properties are included in the rotations so that we can evaluate their agronomic properties (potential allelopathic influences and nutrient contributions).

Diseases can be a problem in organic rotation systems. At CLRC Peters *et al.* (2003) found that lobster waste was a useful amendment and compared favourably to synthetic fertilizers. As well, lobster wastes used as soil amendments clearly altered soil and tuber microbial populations in favor of those that were both chitinolytic and antagonistic to soil-borne potato pathogens. Evidence was also obtained for disease reduction in the field and in storage. Diseases will be monitored in the rotations and strategies to reduce incidences proposed (Researcher Peters). It should also be noted that as one of the cornerstones at CLRC, researchers (Kirby and McCallum) are bioprospecting for biopesticides.

Economic analysis will be performed on the various rotations. Potatoes are the most important vegetable crop produced in Canada with farm cash receipts totalling almost one billion dollars in 2010 (Statistics Canada, 2011). Potato production relies heavily on inputs such as fertilizers, pesticides, fuel, and machinery and equipment. Organic potato cropping systems can minimize environmental impacts and maximize economic benefits by relying less on fertilizer and chemical application. Few studies are available in Canada to examine economics of organic potato production under different crop rotation systems. This experimental study provides opportunity to assess economic sustainability of organic production under different scenarios and crop rotation systems.

Objectives

A number of objectives were part of this research trial: Foremost was the evaluation of the rate and timing of nutrient application and nutrient availability as a function of using green manures, cover crops and other organically-derived fertility sources on crop production; The second objective was to determine the influence cropping systems on soil physical and biological properties; The third was to evaluate alternative methods of weed, disease and pest control under organic systems; and The final objective was economic valuation of individual cropping systems.

MATERIALS AND METHODS

Weather

Air temperature and precipitation data were collected at the Environment Canada's weather station at the Harrington Research Farm for the 2013, 2014, 2015 and 2016 growing seasons (April 1st to October 31st). Air temperature data was used to calculate growing degree days; 5 C threshold. The growing degree day data was obtained from the AgWeather Atlantic (AgWeather Atlantic 2017). If data was missing, data from the next closest weather station (Charlottetown Airport) was used.

Crop Establishment

This trial was established in the spring of 2013 after a series of consultations with various groups interested in organic production systems. Researchers at the Charlottetown Research and Development Centre met with each of the four proponents: Red Soil Organics (RSOrganic), Dairy Farmers of PEI (Dairy), the PEI Grain Elevator Corporation (Elev) and PEI Certified Organic Producer Coop (PEIOrgan) and helped develop two rotations based of their interest. The trial was established in what was to become a certified 25 acre organic block at the back of the Harrington Research Farm (Figure 1). In the various rotations there were cash crops, soil building crops, cover crops and crops for disease and weed suppression. A schematic diagram of the rotations and the role of the crops within the various rotations is contained in Figure 2. This land had originally been into a red clover grass sod.

The crops grown and their variety in each year are included in Table 1. The type and rate of application of the various inputs are shown in Appendix A. The amount of carbon, nitrogen, phosphorus and potassium applied in each of the block for each rotation was determined at the PEI Analytical Laboratories (Standards Council of Canada. 2017) and is presented in Appendix B. The amount of carbon, nitrogen, phosphorus and potassium applied with the amendments in the spring, fall as well as the total amount applied in the growing season were analysed statistically with Genstat.

Seeding date and management of the various crops for the various years are shown in Appendix C. The crops were seeded at their respective recommended rates.

Crop Yields

Crop yields were taken each year and the dry matter content determined by weighing a subsample, drying the subsample at 70C for 48 hours and then reweighing the subsample. In some instances, the whole sample was weighed thus negating the need for dry matter determination. The method of determining yield depended on the crop. For crops which were broadcast sown or which had prone growth habits like red clover, oats/peas and vetch etc., a meter square area was harvested, while crops which had more upright growth habits or those seeded in beds (carrots and potatoes), a specific length of row was harvested. Cereals and pulse crops were harvested with a plot combine. In all latter cases, yield per hectare was computed from the amount of plant material divided by the product of length of the row harvested times the width of the area harvested.

Cover crop yields

Cover or plow-down crops were harvested in the summer of each year. Since comparison of the raw yields among the various crops is not entirely valid, the amount of carbon, nitrogen, phosphorus and potassium returned to the soil by the various crops was computed by multiplying the concentration of the element by the dry matter yield. Dry matter yield is a greater driving force than concentration in the determination of the amount of nutrient taken up by the plant. Further, the variation in the concentration of the nutrient is not great within a species. If the concentration of the nutrient was unavailable, the average concentration for that nutrient/species combination was used (Rodd et al., 2016; Sarma et al. 2013; Mills and Jones 1996).

Statistical Analysis

A stagger start statistical technique, where all phases of the crop rotation are in the trial were in the field in each year was used. This captures the variations in weather, pest and weed pressure on the crops grown.

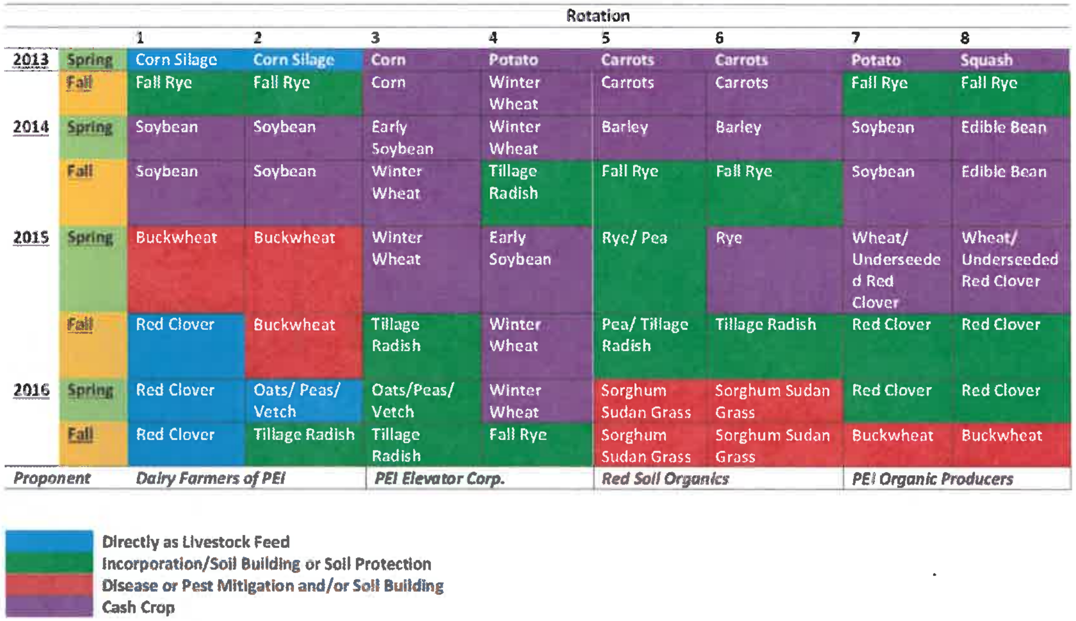
The data was analyzed statistically using the Genstat 18 (VSN International 2015). If the data set was unique it was subjected normal analysis of variance (ANOVA). If the data set varied temporally and spatially it was subjected to repeated measures analysis in Genstat 18 (VSN International 2015). With repeated measures analysis, the overall effect of all the samplings is evaluated with the slopes of each rotation being evaluated for being either linear or quadratic. However, this evaluation is hierarchical in that if the effect of rotation is not significant then we can only indicate trends. Similarly, various contrasts were also evaluated. Although these contrasts were developed prior to evaluation of the data set and some schools of thought indicate that these contrasts if significant are valid. We however, have chosen to take a hierarchical approach where overall effect of the rotations needs to be significant prior to evaluating specific contrasts for significance. However, if the reader disagrees with this approach, the level of significance of the contrasts is presented for their information. The contrasts evaluated are between the two rotations proposed by each proponent, Intensive vs Non (our definition of this includes those rotations which include potatoes and carrots ie. where maximum soil disturbance occurs) and Buckwheat vs Rest (ie. rotations which contain buckwheat vs those that do not). The Dairy Farmers of PEI (Dairy) contrast looks mainly at the inclusion of tillage radish and oats, peas and vetch in the rotation vs red clover (Fig. 2). The major difference between the two PEI Elevator Corporation (Elevator) rotations is corn vs potatoes. However, though most of the subsequent crops are similar, when they occur in the rotations may be different. For the Red Soil Organic (RSOrganic) seeding of peas into fall rye vs harvesting the fall rye as grain was evaluated. For the PEI Certified Organic Producers Coop the two main differences evaluated were potato vs squash and soybean vs edible bean.

For statistical purposes significance is considered when p=0.05 or less, however, in this report when we talk about some trends that may be "approaching significance" we will use the criteria less than p=0.10 and indicate the p value for reader knowledge.

Table 1. The various crops used in the rotation

		2013-2016	
Cash Crops	***Legumes***	Soybean	DH 863
		Early Soybean	Tundra
		Black Beans	Common
		Field Peas	Golden
	Non-Legumes	Carrots	Neptune
		Potatoes	Red Norland
		Grain Corn	Pioneer 8210
		Spring Wheat	Acadia
		Winter Wheat	Sampson
		Fall Rye	Common
		Squash	Sweet Mama
		Barley	Island
Green Manures	***Legumes and Legume Mixes***	Red Clover	Endure
		Oats/Peas/Vetch	Nova/Golden /Common
		Field Peas	Golden
	Non-Legumes	Buckwheat	Macon
		Sorg. Sudangrass	Common
		Tillage Radish	Ecotill
Livestock Feed		Silage Corn	Pioneer 8210

Figure 1. Location of the organic rotation experiment at Harrington.



		Rotation							
		1	2	3	4	5	6	7	8
2013	Spring	Corn Silage	Corn Silage	Corn	Potato	Carrots	Carrots	Potato	Squash
	Fall	Fall Rye	Fall Rye	Corn	Winter Wheat	Carrots	Carrots	Fall Rye	Fall Rye
2014	Spring	Soybean	Soybean	Early Soybean	Winter Wheat	Barley	Barley	Soybean	Edible Bean
	Fall	Soybean	Soybean	Winter Wheat	Tillage Radish	Fall Rye	Fall Rye	Soybean	Edible Bean
2015	Spring	Buckwheat	Buckwheat	Winter Wheat	Early Soybean	Rye/ Pea	Rye	Wheat/ Underseeded Red Clover	Wheat/ Underseeded Red Clover
	Fall	Red Clover	Buckwheat	Tillage Radish	Winter Wheat	Pea/ Tillage Radish	Tillage Radish	Red Clover	Red Clover
2016	Spring	Red Clover	Oats/ Peas/ Vetch	Oats/Peas/ Vetch	Winter Wheat	Sorghum Sudan Grass	Sorghum Sudan Grass	Red Clover	Red Clover
	Fall	Red Clover	Tillage Radish	Tillage Radish	Fall Rye	Sorghum Sudan Grass	Sorghum Sudan Grass	Buckwheat	Buckwheat
Proponent		*Dairy Farmers of PEI*		*PEI Elevator Corp.*		*Red Soil Organics*		*PEI Organic Producers*	

🟦 Directly as Livestock Feed
🟩 Incorporation/Soil Building or Soil Protection
🟥 Disease or Pest Mitigation and/or Soil Building
🟪 Cash Crop

Figure 2. Schematic diagram of the rotation in the first row of the plots.

Table 2. Market price sources for the **comparison** of gross income: Organic vs conventional for the various cash crops.

Crop	Conventional Price Source	URL	Accessed	Organic Price Source	URL	Accessed
Grain Corn	PEI Elevator Corporation	http://www.peigec.com/prices.php	April 2017	Homestead Organics	http://www.homesteadorganics.ca/Buy-and-Sell-Grain.aspx	March 2017
Silage Corn	Local Dairy Farmers	NA	March 2017	Local Dairy Farmers	NA	March 2017
Barley	PEI Elevator Corporation	http://www.peigec.com/prices.php	April 2017	Homestead Organics	http://www.homesteadorganics.ca/Buy-and-Sell-Grain.aspx	March 2017
Wheat	PEI Elevator Corporation	http://www.peigec.com/prices.php	April 2017	Homestead Organics	http://www.homesteadorganics.ca/Buy-and-Sell-Grain.aspx	March 2017
Rye				Homestead Organics	http://www.homesteadorganics.ca/Buy-and-Sell-Grain.aspx	
Soybeans	PEI Elevator Corporation	http://www.peigec.com/prices.php	April 2017	Homestead Organics	http://www.homesteadorganics.ca/Buy-and-Sell-Grain.aspx	March 2017
Peas	AGRIWEEK	http://www.agriweek.com/czy980p.pdf	March 2017	Homestead Organics	http://www.homesteadorganics.ca/Buy-and-Sell-Grain.aspx	March 2017
Edible Beans	Field Crop News	http://fieldcropnews.com/2016/03/comparing-the-profitability-of-soybeans-and-dry-edible-beans/	March 2017	Local Farmers		
Potatoes	Local Farmers			Local Farmers		
Carrots	Red Soil Organics	http://redsoilorganics.ca/contact/	March 2017	Red Soil Organics	http://redsoilorganics.ca/contact/	March 2017
Squash	Local Farmers			CyberHelp	http://www.certifiedorganic.bc.ca/rcbtoa/services/prices.html	November 18, 2016

Economic Evaluation

Gross Returns

The overall gross returns and the returns within each year from the various cash crops were determined using prices obtained from various sources (Table 2). Where data was available the organic gross income was compared to the potential gross income from conventional production. Further the overall gross income of the rotations for the four years was statistically analysed.

Profitability

This report and all required data sets will be sent to Dr. Mohammad Khakbazan an economic scientist within Agriculture and Agri-Food Canada.

Soil Parameters

Soil Chemical

Soil fertility

Soil samples were taken in the spring of 2013, spring and fall of 2014, 2015 and 2016 and analysed for soil organic matter, pH and Mehlich III extractable nutrients according to procedures of the PEI Analytical Laboratories (Standards Council of Canada 2017).

Soil nitrate and ammonium

Soil cores to a depth of 60 cm were obtained in Fall 2013, Spring and Fall 2014 and Spring and Fall 2015 and Fall 2016 with a Giddings Drill (Giddings Machine Co Ltd., 631 Technology Circle, Windsor, CO 80550). The purpose of these cores was to ascertain whether NO_3-N was potentially moving out of the rooting zone and thus contribute to degradation of ground water. The cores, encased in a plastic sleeve, were subdivided into 0-15, 15-30, 30-45 and 45-60cm depth increments and nitrate and ammonium extracted with 2 N KCl using a method similar to that described in 4.2.1 by Maynard and Kalra (1993).

Soil Physical Parameters

Soil resistance to penetration

Soil resistance to penetration (RP) was measured in the Fall 2016 with a Rimik CP 20 recording penetrometer (Rimik Pty Ltd, 1079 Ruthven Street,Toowoomba, Queensland, 4350. Australia) 24 to 48 hours after a saturating rain; the profile would be in a field saturated state and the moisture content of the soil as uniform as possible (Rodd et al. 1998). Soil volumetric moisture content in the 0-15 cm soil depth range was measured concomitantly using a Campbell Scientific HydroSense 2 (Campbell Scientific Canada Ltd. 14532 131 Avenue NW, Edmonton AB T5L 4X4 Canada). Resistance to penetration measurements were taken only after all plots had gone through all the crops and inputs that were in their rotational sequences. This was done because RP is influenced dramatically by changes in soil moisture content making tracking of changes among years difficult (Rodd et al. 1998). Further, because of the staggered start nature of this experiment, it was only in the fall of 2016 when all the replicates had all the amendments applied and crops grown that were part of their rotation. Evaluated is the overall effect of the rotations on this parameter. In addition, for comparison purposes, RP measurements were taken in adjacent non-traffic, non- amended areas which were beside each replication and in perennial grass.

Bulk density

As with RP, soil bulk density (Db) was determined in the fall of 2016 for the reasons outlined previously in the RP section. The undisturbed core procedure used for Db determination and correction of coarse fragments was similar to that as outlined by Culley (1993).

Aggregate stability

As with RP, soil aggregate stability (AS) was determined in the fall of 2016. Aggregate stability changes with the nature of the crops grown (Angers et al. 1999), amendments applied (Annabi et al. 2011), and disruptive force such as tillage applied to the soil (Daraghmeh et al. 2009). Again because of the staggered start nature of this experiment, it was only in the fall of 2016 when all the replicates would have had all the amendments applied and crops grown that were part of any rotation thus, evaluating the overall effect of the rotations on this parameter. The procedure used for determination of AS was similar to 61.2.2 of Angers and Mehuys (1993).

Cornell Soil Test

Soil samples from the 0-15 cm soil depth increment were obtained from the plots in the fall of 2016 and sent to the Cornell Soil Health Laboratory for determination of specific parameters. The parameter included: soil texture, available water capacity (AWC), active carbon (AC) and respiration.

Soil texture

Soil texture was determined at Cornell Soil Laboratory on the soil samples sent there. This rapid soil texture procedure was similar to that outlined by Kettler et al. (2001).

Available water capacity

Available water capacity was also determined at the Cornell Soil Health Laboratory. The procedure for this test was similar to that outlined by Reynolds and Topp (2008).

Biological Properties

Active carbon

Active carbon was also determined on the soil samples sent to the Cornell Soil Health Laboratory. The procedure for this test was similar to that outlined by Weil et al. (2003).

Respiration

Respiration was measured at the Cornell Soil Health Laboratory as outlined by Moebius-Clune et al. (2016).

RESULTS AND DISCUSSION

Weather

Generally growing conditions in most years of the trial were good with temperate and growing degree days being higher than the climatic normal (Tables 3, 4 and 5). The spring of 2015, however, was considerably cooler than normal (Table 3 and 4). This coupled with it being wetter (Table 6), the high snow fall the previous winter (approximately 5.5 m), resulted in an approximate three week delay in planting which impacted some components of the trial- to be discussed further later. The effect of the delayed seeding on crop production was further exacerbated with the high amount of rainfall in June followed by drought in the July. 2015 was a challenging growing season. Description of the individual months follows.

In 2013, 2014 and 2016, the average growing season temperature and the growing degree days in April were slightly higher than normal whereas those of April 2015 were lower (Table 3 and 4). April precipitation was however, more variable, with 2013 and 2016 being drier and 2014 and 2015 being wetter than normal, respectively; 2015 being considerably wetter than normal) (Table 5).

May precipitation was generally below normal with it being substantially drier in 2015 (Table 5). Overall, the temperature and growing degree days in May approximated the 30 year norms; 2014 being cooler (Table 3 and 4).

Except for 2015, which had substantially more, precipitation in June was generally lower than the 30 year norm (Table 5). Generally temperature and growing degree days were within range of the 30 year norms (Table 3).

July temperatures and growing degree days were generally within the range of the 30 year norm (Table 3 and 4). Historically July is drier than the other months in the growing season (Table 6). During the course of this trial, the amount of precipitation in July was generally less than half the norm; this was especially true in 2015 (Table 5).

Except for 2013 and 2015 which were substantially drier and wetter than normal, respectively, August precipitation for the other two years approached normal amounts (Table 5). August average temperatures were only a couple of degrees cooler or warmer than the 30 year normal (Table 3). Growing degree days in August were substantially higher in 2015 whereas in the other years, they were closer to the climatic normal (Table 4).

Except for 2013 and 2015 where precipitation was substantially above and below the norm, respectively, September precipitation for the other two years was just slightly below normal amounts (Table 5). September temperatures in 2015 and 2016 approached were slightly higher than normal were as those of 2013 and 2014 approached the norm (Table 3). Growing degree days showed greater differentiation among the years than average temperature (Table 4). In all years, September growing degree days were greater than the climatic norm; 2015 being substantially higher (Table 3).

October precipitation in 2013 and 2015 in September were lower, whereas those for 2014 and 2016 were higher than the norms (Table 6). In terms of temperature, 2014 and 2016 were slightly above normal amounts whereas the other two years were only plus or minus 0.2 of a degree (Table 4 and 5).

It is interesting than even though there was considerable month to month variation in both precipitations and temperature, the average precipitation and temperature among the years and with respect to normal amounts, did not vary substantially (Table 3, 4 and 5).

Table 3. Growing season temperature (C) in the various years of the trial.

	2013	2014	2015	2016	Climate Norm
April	3.3	2.8	-0.04	2.3	3.1
May	10.6	8.3	10.7	9.0	9.2
June	14.8	14.5	13.0	14.5	14.5
July	19.7	20.9	18.0	18.9	18.7
August	18.8	18.1	21.0	18.6	18.3
September	14.8	14.4	16.4	15.5	14.1
October	8.6	10.8	8.0	10.0	8.3
Average	12.9	12.8	12.4	12.7	12.3

Data obtained online from http://climate.weather.gc.ca/historical_data/search_historic_data_e:html. Environment Canada's weather monitoring site at the Crops and Livestock Research and Development Centre Research Farm in Harrington, PE. However, when there was missing data, the next closest site was used.

Application of Amendments

Compost, liquid dairy manure (LD manure) and pelletized chicken manure (Nutri-Wave (Envirem Organics Inc., 122 Killarney Road Saint Mary's, NB, Canada E3G 9E2)) were applied to the various plots during the course of the experiment. As indicated previously, the amount, type and when applied are contained in Appendix A and B. However, the amount of the constituents of these materials (C, N, P and K) applied in the spring, summer and total amount (spring + summer) were statistically analysed to determine if there were significant application differences among the rotations. As expected, there was a relationship between the amounts of C, N, P and K applied; the other elements generally followed the statistical analysis of C due to this interrelationship of nutrients (Table 5A, 5B, 5C, 6A, 6B, 6C, 7A, 7B, 7C, 8A, 8B, 8C). Thus, the discussion on C, for the most part pertains to N, P, and K.

Table 4. Seasonal growing degree days (5 C baseline).

	2013	2014	2015	2016	Climate Norm.
April	26.8	18.0	0.5	23.2	2.5
May	173.7	107.6	178.7	150.3	136.3
June	294.4	285.1	238.5	283.4	299.2
July	454.8	492.8	400.6	428.7	429.1
August	428.3	405.4	493.6	417.9	413.6
September	292.8	282.3	340.7	307.2	260.0
October	120.8	177.0	106.8	160.6	98.0
Cumulative	1,791.7	1,771.4	1,759.2	1,771.2	1,638.7
Average	255.9	252.6	251.3	253.0	234.1

Data obtained online from Ag Weather Atlantic http://atl.agrometeo.org/index.php/weather/local

Table 5. Season precipitation (mm).

	2013	2014	2015	2016	Climate Norm
April	36.0	102.5	138.2	75.4	83.7
May	71.1	68.5	35.6	54.7	91.0
June	73.4	79.3	128.4	73.5	98.8
July	67.2	40.6	28.2	40.2	79.9
August	48.6	120.6	173.6	130.0	95.7
September	134.8	88.7	58.8	72.5	95.9
October	75.3	124.4	107.4	135.2	112.2
Cumulative	506.4	624.6	670.2	581.5	657.2
Average	72.3	89.2	95.7	83.1	85.3

Data obtained online from http://climate.weather.gc.ca/historical_data/search_historic_data_e.html. Environment Canada's weather monitoring site at the Crops and Livestock Research and Development Centre Research Farm in Harrington, PE. However, when there was missing data, the next closest site was used.

Table 5A. Effect of the rotations on the amount of carbon (C) applied in the spring.

Rotation	mean spring C (kg/ha)^z	lin spring C (kg/ha)	quad spring C (kg/ha)	2013 spring C (kg/ha)	2014 spring C (kg/ha)	2015 spring C (kg/ha)	2016 spring C (kg/ha)
Dairy1	923	-401.4	446.0	2100	292	663	639
Dairy2	998	-294.4	620.3	2100	406	350	1138
Elevator1	829	-418.0	134.3	1870	64	1325	56
Elevator2	1379	27.7	830.0	2142	609	488	2275
RSOrganic1	709	-203.4	275.8	1400	203	663	569
RSOrganic2	753	-185.7	275.7	1400	292	663	658
PEIOrgan1	1110	-53.5	639.4	1792	609	331	1706
PEIOrgan2	1212	4.1	516.3	1750	609	782	1706
Grand Mean	989	-190.6	467.2	1819	386	658	1093
SEM	254	288.1	200.7	413	261	423	722
LSD	731	827.8	576.7	1186	751	1216	2075
Upper	1355	223.3	755.6	2412	761	1266	2131
Lower	624	-604.5	178.9	1226	10	50	56
F pr							
Rot	ns	ns	ns	ns	ns	ns	ns
.. RSOrgan1 vs RSOrgan2	ns	ns	ns	ns	ns	ns	ns
.. Elev1 vs Elev2	ns	ns	0.025	ns	ns	ns	0.043
.. PEIOrgan1 vs PEIOrgan2	ns	ns	ns	ns	ns	ns	ns
.. Dairy1 vs Dairy2	ns	ns	ns	ns	ns	ns	ns
.. Intensive vs Non	ns	ns	ns	ns	ns	ns	ns
.. Buckwheat vs Rest	ns	ns	ns	ns	ns	ns	ns

Z To convert from the overall mean to the total amount applied multiply by four for the mean and LSD. The statistical results will not change.

The amount of C applied in the spring and the total amount of C applied did not vary significantly among the rotations (Table 5A and C). The amount of C applied in the fall of the year, however, did differ among the rotations with respect to the overall means (Table 5B); except for Fall

2015 (p=0.086), there were no differences in the amount applied within individual years. Here the differences appear to be driven by lack of C applied in the fall to the Elevator1 rotation and the relatively low amounts of carbon ~30 to 50 kg/ha applied to the two Dairy and the PEIOrgan1 rotation. Among the contrasts the intensive rotations received higher C inputs in the fall ~ 190 vs 60 kg/ha and rotations with buckwheat received less C than those without; ~180 vs 75 kg/ha, respectively. In the fall of 2015 the PEI Organic2 rotation received more carbon than the other rotations.

Table 5B. Effect of the rotations on the amount of carbon (C) applied in the fall.

Rotation	mean fall C (kg/ha) ^{z}	lin fall C (kg/ha)	quad fall C (kg/ha)	2013 fall C (kg/ha)	2014 fall C (kg/ha)	2015 fall C (kg/ha)	2016 fall C (kg/ha)
Dairy1	30	12	-30	0	0	119	0
Dairy2	50	-1	6	42	89	0	70
Elevator1	0	0	0	0	0	0	0
Elevator2	91	-21	-70	42	203	119	0
RSOrganic1	351	68	146	355	292	119	639
RSOrganic2	271	57	170	313	203	0	569
PEIOrgan1	50	-1	6	42	89	0	70
PEIOrgan2	169	68	-169	0	0	675	0
Grand Mean	126.6	22.7	7.2	99.1	109.6	129.0	168.4
SEM	57.5	99.9	96.2	142.5	122.5	154.6	254.4
LSD	165.2	287.2	276.5	409.4	352.1	444.3	731.2
Upper	209.1	166.3	145.5	303.8	285.7	351.1	534.0
Lower	44.0	-120.9	-131.0	-105.6	-66.4	-93.1	-197.1
F pr							
Rot	0.003	ns	ns	ns	ns	0.086	ns
.. RSOrgan1 vs RSOrgan2	ns	ns	ns	ns	ns	ns	ns
.. Elev1 vs Elev2	ns	ns	ns	ns	ns	ns	ns
.. PEIOrgan1 vs PEIOrgan2	ns	ns	ns	ns	ns	0.006	ns
.. Dairy1 vs Dairy2	ns	ns	ns	ns	ns	ns	ns
.. Intensive vs Non	0.005	ns	ns	0.095	0.059	ns	ns
.. Buckwheat vs Rest	0.020	ns	ns	ns	ns	ns	ns

Z To convert from the overall mean to the total amount applied multiply by four for the mean and LSD. The statistical results will not change.

Table 5C. Effect of the rotations on the total amount of carbon (C) applied in a year.

Rotation	mean total C (kg/ha) ^{z}	lin total C (kg/ha)	quad total C (kg/ha)	2013 total C (kg/ha)	2014 total C (kg/ha)	2015 total C (kg/ha)	2016 total C (kg/ha)
Dairy1	953	-390	416	2100	292	782	639
Dairy2	1049	-295	626	2142	496	350	1208
Elevator1	829	-418	134	1870	64	1325	56
Elevator2	1470	7	760	2184	813	607	2275
RSOrganic1	1060	-136	421	1754	496	782	1208
RSOrganic2	1024	-129	445	1712	496	663	1226
PEIOrgan1	1160	-54	645	1834	699	331	1776
PEIOrgan2	1381	72	348	1750	609	1456	1706
Grand Mean	1116.0	-167.9	474.4	1918.0	495.4	786.9	1262.0
SEM	257.7	319.8	178.5	436.8	253.9	387.6	785.6
LSD	740.5	919.0	513.0	1255.0	729.7	1114.0	2257.0
Upper	1486.0	291.7	730.9	2546.0	860.3	1344.0	2390.0
Lower	745.3	-627.4	218.0	1291.0	130.6	229.9	133.0
F pr							
Rot	ns	ns	ns	ns	ns	ns	ns
.. RSOrgan1 vs RSOrgan2	ns	ns	ns	ns	ns	ns	ns
.. Elev1 vs Elev2	0.096	ns	0.023	ns	0.052	ns	0.061
.. PEIOrgan1 vs PEIOrgan2	ns	ns	ns	ns	ns	0.055	ns
.. Dairy1 vs Dairy2	ns	ns	ns	ns	ns	ns	ns
.. Intensive vs Non	ns	ns	ns	ns	ns	ns	ns
.. Buckwheat vs Rest	ns	ns	ns	ns	ns	ns	ns

Z To convert from the overall mean to the total amount applied multiply by four for the mean and LSD. The statistical results will not change.

Table 6A. Effect of the rotations on the total amount of nitrogen (N) applied in the spring.

Rotation	mean spring N (kg/ha) ^{z}	lin spring N (kg/ha)	quad spring N (kg/ha)	2013 spring N (kg/ha)	2014 spring N (kg/ha)	2015 spring N (kg/ha)	2016 spring N (kg/ha)
Dairy1	67	-39	35	169	27	38	35
Dairy2	71	-36	39	169	38	26	53
Elevator1	68	-33	19	151	23	75	23
Elevator2	95	-22	44	173	56	44	105
RSOrganic1	49	-24	21	113	19	38	26
RSOrganic2	55	-20	23	113	27	38	42
PEIOrgan1	75	-24	37	145	56	19	79
PEIOrgan2	81	-19	29	141	56	48	79
Grand Mean	69.9	-27.1	30.8	146.5	37.7	40.6	55.0
SEM	14.4	16.7	12.9	33.0	23.6	23.8	33.4
LSD	41.4	48.0	36.9	94.8	67.7	68.2	96.1
Upper	90.6	-3.2	49.3	193.9	71.5	74.7	103.1
Lower	49.3	-51.1	12.4	99.1	3.8	6.5	7.0
F pr							
Rot	ns	ns	ns	ns	ns	ns	ns
.. RSOrgan1 vs RSOrgan2	ns	ns	ns	ns	ns	ns	ns
.. Elev1 vs Elev2	ns	ns	ns	ns	ns	ns	0.098
.. PEIOrgan1 vs PEIOrgan2	ns	ns	ns	ns	ns	ns	ns
.. Dairy1 vs Dairy2	ns	ns	ns	ns	ns	ns	ns
.. Intensive vs Non	ns	ns	ns	ns	ns	ns	ns
.. Buckwheat vs Rest	ns	ns	ns	ns	ns	ns	ns

Z To convert from the overall mean to the total amount applied multiply by four for the mean and LSD. The statistical results will not change.

Table 6B. Effect of the rotations on the total amount of nitrogen (N) applied in the fall.

Rotation	mean fall N (kg/ha)[z]	lin fall N (kg/ha)	quad fall N (kg/ha)	2013 fall N (kg/ha)	2014 fall N (kg/ha)	2015 fall N (kg/ha)	2016 fall N (kg/ha)
Dairy1	3	1	-3	0	0	11	0
Dairy2	5	0	1	4	8	0	8
Elevator1	0	0	0	0	0	0	0
Elevator2	8	-2	-6	4	19	11	0
RSOrganic1	26	-1	7	33	27	11	35
RSOrganic2	18	-2	9	28	19	0	26
PEIOrgan1	5	0	1	4	8	0	8
PEIOrgan2	13	5	-13	0	0	50	0
Grand Mean	9.8	0.1	-0.3	9.2	10.1	10.2	9.7
SEM	4.3	5.8	6.6	12.8	11.3	11.9	11.3
LSD	12.4	16.7	19.0	36.8	32.5	34.3	32.6
Upper	16.0	8.5	9.1	27.6	26.3	27.3	26.0
Lower	3.6	-8.2	-9.8	-9.2	-6.1	-7.0	-6.6
F pr							
Rot	0.007	ns	ns	ns	ns	ns	ns
.. RSOrgan1 vs RSOrgan2	ns	ns	ns	ns	ns	ns	ns
.. Elev1 vs Elev2	ns	ns	ns	ns	ns	ns	ns
.. PEIOrgan1 vs PEIOrgan2	ns	ns	ns	ns	ns	0.008	ns
.. Dairy1 vs Dairy2	ns	ns	ns	ns	ns	ns	ns
.. Intensive vs Non	0.006	ns	ns	0.089	0.059	ns	0.074
.. Buckwheat vs Rest	0.038	ns	ns	ns	ns	ns	ns

Z To convert from the overall mean to the total amount applied multiply by four for the mean and LSD. The statistical results will not change.

Table 6C. Effect of the rotations on the total amount of nitrogen (N) applied in the year.

Rotation	mean total N (kg/ha)[z]	lin total N (kg/ha)	quad total N (kg/ha)	2013 total N (kg/ha)	2014 total N (kg/ha)	2015 total N (kg/ha)	2016 total N (kg/ha)
Dairy1	70	-38	32	169	27	48	35
Dairy2	76	-36	41	173	46	26	61
Elevator1	68	-33	19	151	23	75	23
Elevator2	103	-24	38	178	75	55	105
RSOrganic1	75	-25	28	145	46	48	61
RSOrganic2	73	-23	31	141	46	38	68
PEIOrgan1	80	-23	38	149	64	19	87
PEIOrgan2	93	-14	16	141	56	98	79
Grand Mean	79.7	-27.0	30.5	155.7	47.7	50.8	64.7
SEM	14.2	18.1	11.9	35.5	23.2	22.4	36.0
LSD	40.7	52.1	34.1	101.9	66.7	64.3	103.5
Upper	100.1	-1.0	47.5	206.7	81.1	82.9	116.4
Lower	59.4	-53.0	13.4	104.7	14.4	18.7	13.0
F pr							
Rot	ns	ns	ns	ns	ns	ns	ns
.. RSOrgan1 vs RSOrgan2	ns	ns	ns	ns	ns	ns	ns
.. Elev1 vs Elev2	0.094	ns	ns	ns	ns	ns	ns
.. PEIOrgan1 vs PEIOrgan2	ns	ns	ns	ns	ns	0.022	ns
.. Dairy1 vs Dairy2	ns	ns	ns	ns	ns	ns	ns
.. Intensive vs Non	ns	ns	ns	ns	ns	ns	ns
.. Buckwheat vs Rest	ns	ns	ns	ns	ns	ns	ns

Z To convert from the overall mean to the total amount applied multiply by four for the mean and LSD. The statistical results will not change.

Table 7A. Effect of the rotation on the total amount of phosphorus (P) applied in the spring.

Rotation	mean spring P (kg/ha)[z]	lin spring P (kg/ha)	quad spring P (kg/ha)	2013 spring P (kg/ha)	2014 spring P (kg/ha)	2015 spring P (kg/ha)	2016 spring P (kg/ha)
Dairy1	19	-16	13	60	6	6	5
Dairy2	20	-16	13	60	9	5	8
Elevator1	19	-13	10	53	6	13	7
Elevator2	25	-14	13	61	13	10	15
RSOrganic1	14	-11	8	40	4	6	4
RSOrganic2	15	-10	9	40	6	6	8
PEIOrgan1	20	-13	12	51	13	3	11
PEIOrgan2	21	-12	10	50	13	8	11
Grand Mean	19.1	-13.1	11.1	51.8	8.8	7.2	8.5
SEM	3.3	4.3	3.6	11.8	5.5	4.1	4.9
LSD	9.4	12.5	10.3	34.0	15.8	11.6	14.2
Upper	23.8	-6.9	16.2	68.8	16.6	13.1	15.6
Lower	14.4	-19.4	6.0	34.8	0.9	1.4	1.5
F pr							
Rot	ns	ns	ns	ns	ns	ns	ns
.. RSOrgan1 vs RSOrgan2	ns	ns	ns	ns	ns	ns	ns
.. Elev1 vs Elev2	ns	ns	ns	ns	ns	ns	ns
.. PEIOrgan1 vs PEIOrgan2	ns	ns	ns	ns	ns	ns	ns
.. Dairy1 vs Dairy2	ns	ns	ns	ns	ns	ns	ns
.. Intensive vs Non	ns	ns	ns	ns	ns	ns	ns
.. Buckwheat vs Rest	ns	ns	ns	ns	ns	ns	ns

Z To convert from the overall mean to the total amount applied multiply by four for the mean and LSD. The statistical results will not change.

Table 7B. Effect of the rotations on the total amount of phosphorus (P) applied in the fall.

Rotation	mean fall P (kg/ha)[z]	lin fall P (kg/ha)	quad fall P (kg/ha)	2013 fall P (kg/ha)	2014 fall P (kg/ha)	2015 fall P (kg/ha)	2016 fall P (kg/ha)
Dairy1	0.5	0.2	-0.5	0.0	0.0	2.1	0.0
Dairy2	1.0	0.0	0.2	1.1	1.6	0.0	1.5
Elevator1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Elevator2	1.9	-0.5	-1.4	1.1	4.4	2.1	0.0
RSOrganic1	5.2	-1.0	1.1	7.3	6.0	2.1	5.3
RSOrganic2	3.6	-1.2	1.4	6.3	4.4	0.0	3.8
PEIOrgan1	1.0	0.0	0.2	1.1	1.6	0.0	1.5
PEIOrgan2	9.4	3.8	-9.4	0.0	0.0	37.5	0.0
Grand Mean	2.82	0.15	-1.03	2.09	2.23	5.48	1.50
SEM	2.17	1.18	2.12	2.84	2.59	7.75	1.63
LSD	6.23	3.40	6.09	8.17	7.43	22.28	4.68
upper	5.94	1.85	2.01	6.17	5.95	16.62	3.84
lower	-0.29	-1.55	-4.07	-2.00	-1.49	-5.67	-0.84
F pr							
Rot	0.095	ns	0.042	ns	ns	0.037	ns
.. RSOrgan1 vs RSOrgan2	ns	ns	ns	ns	ns	ns	ns
.. Elev1 vs Elev2	ns	ns	ns	ns	ns	ns	ns
.. PEIOrgan1 vs PEIOrgan2	0.014	0.037	0.005	ns	ns	0.003	ns
.. Dairy1 vs Dairy2	ns	ns	ns	ns	ns	ns	ns
.. Intensive vs Non	ns	0.061	0.081	0.086	0.060	ns	0.067
.. Buckwheat vs Rest	ns	0.063	0.094	ns	ns	ns	ns

Z To convert from the overall mean to the total amount applied multiply by four for the mean and LSD. The statistical results will not change.

Table 7C. Effect of the rotations on the total amount of phosphorus (P) applied in the year.

Rotation	mean total P (kg/ha)[z]	lin total P (kg/ha)	quad total P (kg/ha)	2013 total P (kg/ha)	2014 total P (kg/ha)	2015 total P (kg/ha)	2016 total P (kg/ha)
Dairy1	20	-16	13	60	6	8	5
Dairy2	21	-16	14	61	10	5	9
Elevator1	19	-13	10	53	6	13	7
Elevator2	27	-15	12	62	18	12	15
RSOrganic1	19	-12	9	47	10	8	9
RSOrganic2	19	-11	10	46	10	6	11
PEIOrgan1	21	-13	12	52	15	3	13
PEIOrgan2	30	-8	1	50	13	46	11
Grand Mean	21.9	-13.0	10.1	53.9	11.0	12.7	10.0
SEM	3.6	4.5	3.9	12.2	5.4	7.9	5.3
LSD	10.2	13.0	11.3	35.0	15.6	22.6	15.2
Upper	27.0	-6.5	15.7	71.4	18.8	24.0	17.6
Lower	16.8	-19.5	4.4	36.4	3.2	1.4	2.5
F pr							
Rot	ns	ns	ns	ns	ns	0.026	ns
.. RSOrgan1 vs RSOrgan2	ns	ns	ns	ns	ns	ns	ns
.. Elev1 vs Elev2	ns	ns	ns	ns	ns	ns	ns
.. PEIOrgan1 vs PEIOrgan2	0.078	ns	0.059	ns	ns	0.001	ns
.. Dairy1 vs Dairy2	ns	ns	ns	ns	ns	ns	ns
.. Intensive vs Non	ns	ns	ns	ns	ns	0.072	ns
.. Buckwheat vs Rest	ns	ns	ns	ns	ns	ns	ns

Z To convert from the overall mean to the total amount applied multiply by four for the mean and LSD. The statistical results will not change.

Table 8A. Effect of the rotations on the total amount of potassium (K) applied in the spring.

Rotation	mean spring K (kg/ha)[z]	lin spring K (kg/ha)	quad spring K (kg/ha)	2013 spring K (kg/ha)	2014 spring K (kg/ha)	2015 spring K (kg/ha)	2016 spring K (kg/ha)
Dairy1	45	-36	30	135	17	13	16
Dairy2	46	-36	31	135	19	11	18
Elevator1	42	-30	24	118	11	25	14
Elevator2	57	-32	30	140	28	26	35
RSOrganic1	30	-24	19	90	9	13	9
RSOrganic2	35	-21	20	90	17	13	21
PEIOrgan1	45	-30	27	118	28	6	26
PEIOrgan2	47	-26	22	113	28	23	26
Grand Mean	43.4	-29.4	25.5	117.2	19.7	16.1	20.6
SEM	7.2	9.7	7.6	26.1	12.0	9.0	11.7
LSD	20.6	28.0	21.9	75.1	34.4	26.0	33.6
Upper	53.7	-15.4	36.5	154.8	36.9	29.1	37.4
Lower	33.1	-43.3	14.5	79.7	2.5	3.1	3.8
F pr							
Rot	ns	ns	ns	ns	ns	ns	ns
.. RSOrgan1 vs RSOrgan2	ns	ns	ns	ns	ns	ns	ns
.. Elev1 vs Elev2	ns	ns	ns	ns	ns	ns	ns
.. PEIOrgan1 vs PEIOrgan2	ns	ns	ns	ns	ns	ns	ns
.. Dairy1 vs Dairy2	ns	ns	ns	ns	ns	ns	ns
.. Intensive vs Non	ns	ns	ns	ns	ns	ns	ns
.. Buckwheat vs Rest	ns	ns	ns	ns	ns	ns	ns

Z To convert from the overall mean to the total amount applied multiply by four for the mean and LSD. The statistical results will not change.

Table 8B. Effect of the rotations on the total amount of potassium (K) applied in the fall

Rotation	mean fall K (kg/ha)^{z}	lin fall K (kg/ha)	quad fall K (kg/ha)	2013 fall K (kg/ha)	2014 fall K (kg/ha)	2015 fall K (kg/ha)	2016 fall K (kg/ha)
Dairy1	3	1	-3	0	0	11	0
Dairy2	5	0	1	5	8	0	7
Elevator1	0	0	0	0	0	0	0
Elevator2	6	-1	-4	5	9	11	0
RSOrganic1	17	-3	3	23	17	11	16
RSOrganic2	9	-4	4	18	9	0	9
PEIOrgan1	5	0	1	5	8	0	7
PEIOrgan2	13	5	-13	0	0	50	0
Grand Mean	7.1	-0.2	-1.2	7.0	6.4	10.2	4.9
SEM	4.0	2.8	4.5	8.1	6.6	11.9	4.6
LSD	11.4	7.9	13.1	23.2	19.1	34.3	13.2
Upper	12.8	3.7	5.4	18.6	15.9	27.3	11.5
Lower	1.4	-4.2	-7.7	-4.6	-3.2	-7.0	-1.7
F pr							
Rot	ns	ns	ns	ns	ns	ns	ns
.. RSOrgan1 vs RSOrgan2	ns	ns	ns	ns	ns	ns	ns
.. Elev1 vs Elev2	ns	ns	ns	ns	ns	ns	ns
.. PEIOrgan1 vs PEIOrgan2	ns	ns	0.047	ns	ns	0.008	ns
.. Dairy1 vs Dairy2	ns	ns	ns	ns	ns	ns	ns
.. Intensive vs Non	ns	0.094	ns	0.061	0.073	ns	0.073
.. Buckwheat vs Rest	ns	ns	ns	ns	ns	ns	ns

Z To convert from the overall mean to the total amount applied multiply by four for the mean and LSD. The statistical results will not change.

Table 8

C. Effect of the rotations on the total amount of potassium (K) applied in the season.

Rotation	Mean total K (kg/ha)^{z}	lin total K (kg/ha)	quad total K (kg/ha)	2013 total K (kg/ha)	2014 total K (kg/ha)	2015 total K (kg/ha)	2016 total K (kg/ha)
Dairy1	48	-35	28	135	17	23	16
Dairy2	51	-36	32	140	26	11	25
Elevator1	42	-30	24	118	11	25	14
Elevator2	64	-33	27	146	38	37	35
RSOrganic1	47	-27	22	113	26	23	25
RSOrganic2	44	-25	25	108	26	13	29
PEIOrgan1	50	-30	29	123	36	6	34
PEIOrgan2	60	-21	9	113	28	73	26
Grand Mean	50.5	-29.6	24.3	124.2	26.1	26.3	25.5
SEM	7.6	10.0	8.3	27.6	12.0	13.7	12.5
LSD	21.8	28.6	23.9	79.4	34.4	39.5	35.9
Upper	61.4	-15.3	36.3	163.9	43.3	46.0	43.4
Lower	39.7	-43.9	12.4	84.6	8.9	6.6	7.5
F pr							
Rot	ns	ns	ns	ns	ns	0.066	ns
.. RSOrgan1 vs RSOrgan2	ns	ns	ns	ns	ns	ns	ns
.. Elev1 vs Elev2	0.058	ns	ns	ns	ns	ns	ns
.. PEIOrgan1 vs PEIOrgan2	ns	ns	ns	ns	ns	0.003	ns
.. Dairy1 vs Dairy2	ns	ns	ns	ns	ns	ns	ns
.. Intensive vs Non	ns	ns	ns	ns	ns	ns	ns
.. Buckwheat vs Rest	ns	ns	ns	ns	ns	ns	ns

Z To convert from the overall mean to the total amount applied multiply by four for the mean and LSD. The statistical results will not change.

Cover crops (Non-cash rotational crops with soil building or soil fumigation properties).

A number of different crops were incorporated in the various rotations for the purpose of providing soil building or soil fumigant properties within the rotations. The general and specific characteristics of these crops will be discussed briefly below.

Red Clover

Red clover is a short lived perennial legume with high nitrogen fixation capacity; between 75 and 150 kg N/ha with half being available to the succeeding crop when plowed (Clark 2007). It is also more tolerant of low pH than other legumes (Forage and Corn Variety Evaluation Task Group year unknown). It is well suited to the Maritimes and has been grown successfully for years. Its relatively cheap seed coupled with the above growth characteristics make it a good plow-down crop in organic systems for aiding in the provision of N to other crops.

Buckwheat

Buckwheat is a highly productive, easy to establish, rapid growing, short seasoned plow-down crop that has excellent weed suppression characteristics and thrives on poor soils (Clark 2007). Further it has been shown to be extremely effective in extracting soil P from the rhizosphere. Buckwheat is nearly three times as effective as barley in extracting phosphorus, and more than 10 times more effective than rye; the poorest P scavenger of the cereal grains (Robinson, 1980). Recently, buckwheat has shown bio fumigant properties for the control of wireworms; a pest that has had a devastating effect on some crops on PEI (Noronha 2017).

Sorghum-sudangrass

Sorghum- sudangrass is known to be a drought resistant grass species that can be used when emergency forage situations develop (Wright et al. 1998). They are heat-loving plants unrivaled for adding organic matter to the soil (Clark 2009). Sorghums are known to be drought resistant because they are more efficient at water absorption due to having twice as many secondary roots per unit of primary root as corn but only have half as much leaf area. Sorghum-sudangrass, however, may be a little difficult to establish due to the fact that it must be seeded into a warm soil (18- 21 C). Further, it has been found that it can improve subsoil conditions. Mowing when the plant reached approximately 1 to 1.3 m tall increased root mass five to eight times and forces the roots to penetrate deeper. However, four mowings at shorter heights can cause the plant roots to behave more like that of a grass (Mishanec, 1996). That sorghum-sudangrasses have been found to supress some species of nematodes but the effect is dependent on variety (Clark 2007).

Oats/Peas/Vetch

Oat/pea/vetch mixtures have been used successfully as a cover or plow- down crop in organic production (Alam et al. 2016). Oats are a dependable quick growing cover which can produce good biomass that will winterkill under our climatic conditions. In this mixture, the oats act as a nurse crop, provide weed suppression and structure to the crop canopy by forming a trellis for the hairy vetch and peas (Björkman and Shail 2010).

Clark (2007) indicates that field peas, under long cool moist growing conditions, can have a bountiful biomass. Because they are quick growing, they compete with weeds well. It should be noted that below normal rainfall terminates this grain legume early. Besides the biomass produced, nitrogen for subsequent crops comes from the pea and vetch portions of this mixture.

Hairy vetch is a widely adapted to many climatic zones and few species can match it in terms of nitrogen fixation (Clark 2007). Without another species to support its biomass, it will rarely exceed three feet in height however, because it is quick growing, it is good with regards to weed suppression. Further, it can act as a soil conditioner by creating thousands of macro pores to allow for increased water percolation. It is also good at scavenging soil P.

Tillage Radish

Tillage radish is an oil seed radish that has been selected to produce large taproots which are capable of breaking up some hard pans thus allowing for increased water percolation and scavenging of nutrients (Anonymous 2009). Its high glucosinolate content aids in decreasing soil-borne pests and pathogens.

The dry matter yield of the various cover crops harvested in the summer of each production year plus the overall average yield is presented in Table 9. When averaged over all years, sorghum sudangrass generally had the highest biomass yield will that of the oats/peas and vetch the lowest: the remaining crops, red clover and buckwheat being intermediate. We are uncertain as to the direct cause of the low yields associated with the oats/peas and vetch but they may be related to the generally below normal precipitation in the spring (Table 5). It was noted by Clark (2007) that water stress can terminate growth of field peas. Further, it should be noted oats/peas/vetch had the poorest dry matter production at Harrington in a trial, conducted in 2015 and 2016, evaluating various forage options for dairy farmers when first cut yields are below requirements (Rodd et al. 2016). With the exception of oats/peas/vetch which had the lower yields in 2016, yields of most plow- down species were lowest in 2015 than any other year (Table 9).

The amount of carbon, nitrogen, phosphorus and potassium returned to the soil in the summer is shown in Table 10. Generally, it appears that the higher the biomass produced the greater the amounts of nutrients returned to the soil (Table 9 and 10). For all elements, the effect of the rotation was significant, however this may have been due in part to the zero return of nutrients associated with the Elevator2 rotation (Table 10). In this rotation tillage radish was plow- down in the fall and no yield samples were taken from it. However, the LSD's indicate that among the other rotations differences in nutrient return occurred. The rotations with the highest return of carbon and nutrients to the soil were the two RSOrgan (Table 10) which utilized sorghum sudangrass exclusively as a plow-down crop. The contrast between these two rotations showed that RSOrgan2 produced more carbon and returned more C, N, P and K than RSOrgan1. The contrast between the two Dairy rotations showed that under the conditions of this trial, red clover produced more carbon and returned more carbon, nitrogen, phosphorus and potassium than oats/peas/vetch (Table 10).

Table 9. Dry matter yield of the plow-down crops in the summer.

	Buckwheat	Oats/Peas/Vetch	Red Clover	Sorghum Sudangrass
Rotation				
Dairy1	**4558**	**Nil**	**5693**	**Nil**
Avg. Dev.	**1257**	**Nil**	1305	Nil
2013	6325	Nil	3536	Nil
2014	5303	Nil	7760	Nil
2015	2113	Nil	5240	Nil
2016	4489	Nil	6235	Nil
Dairy2	**4228**	**2905**	Nil	Nil
Avg. Dev.	852	1019	Nil	Nil
2013	4852	866	Nil	Nil
2014	5215	3990	Nil	Nil
2015	2523	3211	Nil	Nil
2016	4321	3551	Nil	Nil
Elevator 1	Nil	**3758**	Nil	Nil
Avg. Dev.	Nil	457	Nil	Nil
2013	Nil	3502	Nil	Nil
2014	Nil	4649	Nil	Nil
2015	Nil	3099	Nil	Nil
2016	Nil	3780	Nil	Nil
Elevator 2	Nil	Nil	Nil	Nil
Avg. Dev.	Nil	Nil	Nil	Nil
2013	Nil	Nil	Nil	Nil
2014	Nil	Nil	Nil	Nil
2015	Nil	Nil	Nil	Nil
2016	Nil	Nil	Nil	Nil
RSOrganic1	Nil	Nil	Nil	**10911**
Avg. Dev.	Nil	Nil	Nil	3166
2013	Nil	Nil	Nil	17243
2014	Nil	Nil	Nil	9096
2015	Nil	Nil	Nil	6897
2016	Nil	Nil	Nil	10409
RSOrganic2	Nil	Nil	Nil	**11110**
Avg. Dev.	Nil	Nil	Nil	2096
2013	Nil	Nil	Nil	13174
2014	Nil	Nil	Nil	12591
2015	Nil	Nil	Nil	6918
2016	Nil	Nil	Nil	11757
PEIOrgan1	Nil	Nil	**5190**	Nil
Avg. Dev.	Nil	Nil	948	Nil
2013	Nil	Nil	3294	Nil
2014	Nil	Nil	5803	Nil
2015	Nil	Nil	5365	Nil
2016	Nil	Nil	6298	Nil
PEIOrgan2	Nil	Nil	**5909**	Nil
Avg. Dev.	Nil	Nil	1380	Nil
2013	Nil	Nil	3149	Nil
2014	Nil	Nil	7024	Nil
2015	Nil	Nil	6152	Nil
2016	Nil	Nil	7309	Nil

Table 10. The amount of carbon, nitrogen, phosphorus and potassium incorporated in the summer in the various rotations.

Rotation	Carbon	Nitrogen	Phosphorus	Potassium
Dairy1	3098	173	25	138
Dairy2	2190	153	14	73
Elevator1	1503	177	12	83
Elevator2	0	0	0	0
RSOrganic1	3352	204	26	197
RSOrganic2	4444	208	33	258
PEIOrgan1	2076	134	18	118
PEIOrgan2	2443	159	21	138
Grand Mean	2388	151	18.65	125.5
SEM	296.3	26.2	2.396	15.58
LSD	851.5	75.3	6.887	44.76
upper	2814	189	22.09	147.9
lower	1962	113	15.21	103.1
F pr				
Rot	<0.001	<0.001	<0.001	<0.001
.. RSOrgan1 vs RSOrgan2	0.018	Ns	0.037	0.013
.. Elev1 vs Elev2	0.002	<0.001	0.003	0.002
.. PEIOrgan1 vs PEIOrgan2	ns	Ns	ns	ns
.. Dairy1 vs Dairy2	0.045	Ns	0.004	0.009
.. Intensive vs Non	ns	Ns	ns	0.006
.. Buckwheat vs Rest	ns	Ns	ns	ns

Cash Crop Yield

Cash crop yields, both rotational averages and those for each year of the trial, are presented in Table 11). Statistical analysis of the data was preformed, however, it is not presented. All F probabilities from the Anova's were highly significant due to the inclusion of zeros. For this reason, similarly, the LSD associated with the Anova's are not presented. The overall mean and the average deviations (Avg. Dev.) as well as the individual year yields are presented. Except for a few notable exceptions, which will be discussed cash crop yields were generally good. Yields are compared, where applicable to PEI average yields from 2013 to 2015; 2016 was unavailable at the time of this report.

Cereals

Wheat

Winter wheat was included as part of the two Elevator rotations whereas spring wheat was included as part of the two PEIOrgan rotations (Table 11). Yields of spring wheat averaged 2.0 while that of winter wheat averaged 2.7 t/ha, respectively. It should be noted that in the 2013 growing season spring wheat was substituted for winter wheat due it being the year that the experiment was initiated. PEI average wheat yields, spring and winter not separated out, were 2.7 t/ha. Currently the differential between organic wheat and the price for conventional wheat at the PEI Elevator is approximately $225.00/t.

Rye

Winter rye was included in many rotations, however, it was mainly rolled in the spring as a weed suppression technique for the establishment of soybeans. In the RSOrganic2 rotation, fall rye was harvested (Table 11). Rye was not included in the rotations in 2013 since it was the initiation year of this trial and spring rye seed was unavailable. The rye yields averaged 1.5 t/ha. This is rather a low yield for rye compared to other trials in the Maritimes (Nelson et al. 2010). The exact cause of this lower yield is not ascertainable however, it may be related to the fact that it followed barley in the rotation (cereal following cereal) or that there was insufficient nutrients for it to reach its yield potential.

Barley

Barley was included as part of the RSOrgan1 and RSOrgan2 rotations (Table 11). The average yield of both rotations was 2.2 t/ha with a slight decline occurring in 2016. PEI average yield, between 2013 and 2015 (2016 unavailable), was 3.2 tonnes/ha (PEI Department of Agriculture Barley and Soybean 2017). Although the yields of barley under organic production were less than the provincial average the premium differential for production of organic barley is $450.00/t while the current price for conventional barley at the PEI Elevator is $175.00/t. Thus, even though the yields were lower, producers made more money with organic barley; $430/ha.

Corn

Corn yields were very variable; very good in 2013 but disappointing in 2016 resulting in an average yield of 3.7 tonnes/ha (Table 11). This is lower than the ~8 t/ha yields reported but the low average yield was due to the poor yield attained in 2016; 440 kg/ha was basically a crop failure. Generally this was a poor stand initially and was replanted twice. We believe that there could possibly have been issues with the corn seed. Gross returns from conventional corn run $267/t whereas the premium for organic corn is $525.00/t. In this situation the conventional corn gives higher returns per hectare by approximately $195.00/ha. However, if the crop failure in 2016 is taken out of the average then the returns are generally greater for the organically produced corn by ~$360.00/ha. It is noteworthy that the highest yields of corn occurred in the first year of the study where the corn plots benefited from plow- down of a red clover sward and the application of 25000 kg/ha of compost and 1500 kg/ha of Nutri-wave (Appendix A). This equates to approximately 300 kg of total N/ha; 185 form application of amendments and 125 kg N/ha returned by the red clover. If half were considered to be available to the corn (Clark 2007), then the corn would have received 150 kg N/ha. This is in the range of the recommendation by the PEI Analytical Labs; 120 kg N/ha. In the subsequent year (2014) the grain corn plots only received application of 1500 kg N/ha of Nutri-wave equating to 60 kg total N/ha. Given that the corn followed tillage radish after only half a year of oats/peas/vetch, the sward N contribution was probably less than that of the red clover in 2013. Thus it appears that the corn portion of the Elevator1 rotation would benefit from greater N contributions either through plow- down or application of amendments especially since soil levels of P_2O_5 and K_20 were high (Discussed later). The 2015 growing season was delayed due to weather conditions (indicated earlier) which also probably impacted on corn yields while poor stand establishment impacted yields in 2016.

Silage Corn

Silage corn was included in the two dairy farmer rotations. The same variety was used for silage corn as for grain corn. Except for 2016, the silage corn yields were not as variable as grain corn (Table 13). Yields averaged 22 t/ha @ 40% dry matter but that average included 2016 where yields averaged 6t/ha.

Average yields of the two rotations, excluding 2016, approach 29 t/ha. This equates to 12t/ha dry matter yield which is in the range of results obtained in cultivar test under conventional production at Harrington (Guide to Corn Hybrid Selection 2015). The reason for the poor corn performance in 2016 has been discussed previously.

The better yield results with silage corn relative to grain corn may be related to the higher amounts of fertility added; 512 vs 327 kg N/ha over the course of the experiment, greater preponderance of legumes in the rotation and less removal of N. Plus it should be noted that weather conditions on PEI favours silage vs grain corn production.

Pulses

Soybeans

Soybeans were part of five of the eight rotations studied; the two Dairy, the two Elevator and PEIOrgan1 (Table 11). In the case of the Elevator rotations, an early soybean, Tundra, was selected while DH 863 was used for the other rotations. Yield of Tundra averaged 1891 kg/ha overall years which included a crop failure in the Elevator2 rotation in 2015. In 2015 crop failures also occurred in the two Dairy and PEIOrgan1 rotations. In these rotations, the soybeans are direct sowed into rolled fall rye which provides weed suppression by creating a mulch. However, when using this technique, it is necessary to wait until the rye reaches flowering (Caldwell et al. 2016). Wet and cold conditions in the spring of 2015 delayed maturation of the rye thereby delaying rolling and subsequent seeding of the soybeans. This resulted in a crop failure as the soybeans were slow to break ground and volunteer red clover over took the plots. In cases of delayed spring due to weather, farmers should consider either letting the fall rye mature and harvest the grain or till in the rye and direct seed the soybeans. Due to the system approach of this research trial, where we want to determine the overall effect of the management regimes imposed, these options were not viable to us.

Average yield of organic soybeans under all rotational sequences was 1.6 t/ha equates whereas the average yield on PEI is 2.5 t/ha. Using $500.00 per tonne for conventional and $1000.00 per tonne for organic this equates gross margins of $1,600 and $1,250 for organic and conventional, respectively. Excluding the crop failures from this data, yields would have approached 2 t/ha equating to a gross margin of $2,000/ha. It is notable that under the conditions of this trial, Tundra yields were generally greater than the later maturing DH 863; in many instances, where growing conditions permit, later maturing soybeans will out yield early (Pendleton and Hartwig, 1973). Egli (1992) noted that yield potential does not appear to be related to the time that the cultivar is in vegetative growth but rather the length of time of seed fill; yield increasing with increasing time in seed fill.

Edible Beans

Edible beans are a term that we are using in this trial to delineate beans that would normally go for direct human consumption. In this case we used Turtle black beans. The black turtle bean is a small, shiny variety of common beans, especially popular in Latin American cuisine though it can also be found in Cajun and Creole cuisines of south Louisiana. Black beans (and all common beans) are native to the

Americas, but have been introduced around the world. These beans were incorporated in only one rotation; the PEIOrgan2 (Table 11). Yields of these beans were generally good, ranging 1.1 to 2 t/ha; the exception, like many crops, being 2015. Yields in that year were only ~750 kg/ha. Thus, the overall average yield of ~1.5 t/ha at a price of $1540/t equates to a gross profit of $2310/ha. We were unable to confirm yields at the time of writing this report. Conventional Bean prices were $705.00/tonne (Table 2).

Field Peas

Field peas were grown as a cash crop in only the RSOrganic1 rotation (Table 11). Yields averaged 2.3 t/ha and were fairly consistent among the years. This is slightly lower than reported values by Lynch et al. (2006). Gross returns for organic producers would be $1495.00 when costed at $650/t (Table 2).

Other Crops

Potatoes

Potatoes were grown as part of two rotations: Elevator2 and PEIOrgan1. Yields of the Red Norland were very variable and ranged from 0 to 22 t/ha. The crop in 2015 was lost to an infestation of wireworms and drought (Table 11). Delayed planting resulted in the crop being under stress during the month of July which impacted tuber set. In addition, short season varieties like Red Norland are normally harvested prior to wireworms appearing. However, due to the seeding delays that spring, the crop was still in the ground later in the fall and became infested with wireworms. Crops to mitigate the effects of wireworm were not incorporated into these two rotations; an oversight that will be addressed with some changes to these rotations. Red Norland yields in 2014 were impacted by a severe infestation of flea beetles. It should be noted that an organic variety trial adjacent to this trial had varieties that although impacted appeared to withstand flea beetles better than Red Norland. Thus, a small trial ancillary trial was initiated to test the effectiveness of PyGanic organic insecticide (Valent Canada, Inc., 3-728 Victoria Road South, Guelph, Ontario N1L 1C6). This material, while not eradicating the flea beetles, did seem to keep them at bay. Overall the gross returns of the potatoes would be $7700/ha (Table 2).

Carrots

Carrots, cv. Neptune, were grown in the two RSOrganic rotations (Table 11). Generally carrot yields were good during this trial averaging ~53 t/ha. There was, however, a tendency for yield to decline with time. Although carrots are used as bait for determination of wireworm numbers in Harrington, wireworms had minimal effect of the carrots during the course of this trial even though these plots were only a few meters from potato plots decimated by wireworms. In this trial, carrots followed sorghum sudangrass. This grass is well known to impact microbial communities (Perez et al. 2008) and may also have impacted wireworm populations, however, at this stage this is only conjecture and is not proven. Currently brown mustard and buckwheat are the only plow-down crops recommended for wireworm control. The gross return from the production of organic carrots was $104,940/ha (Table 2).

Table 11. Effect of the rotations on cash crops yields (kg/ha).

	Cereals						Pulses			Other		
	Winter Wheat	Winter Rye	Spring Wheat	Barley	Corn	Silage Corn@40% DM	Soybean	Edible Bean	Pea	Potato	Carrots	Squash
Rotation												
Dairy1	nil	nil	nil	nil	nil	22240	1336	nil	nil	nil	nil	nil
Avg. Dev.						7510	668					
2013	nil	nil	nil	nil	nil	29400	1639	nil	nil	nil	nil	nil
2014	nil	nil	nil	nil	nil	26160	2088	nil	nil	nil	nil	nil
2015	nil	nil	nil	nil	nil	26181	0	nil	nil	nil	nil	nil
2016	nil	nil	nil	nil	nil	7219	1616	nil	nil	nil	nil	nil
Dairy2	nil	nil	nil	nil	nil	24211	1421	nil	nil	nil	nil	nil
Avg. Dev.						9905	703					
2013	nil	nil	nil	nil	nil	34080	1773	nil	nil	nil	nil	nil
2014	nil	nil	nil	nil	nil	23381	2409	nil	nil	nil	nil	nil
2015	nil	nil	nil	nil	nil	34150	0	nil	nil	nil	nil	nil
2016	nil	nil	nil	nil	nil	5230	1441	nil	nil	nil	nil	nil
Elevator 1	2901	nil	nil	nil	3709	nil	1970	nil	nil	nil	nil	nil
Avg. Dev.	168				2817		398					
2013	2913	nil	nil	nil	9342	nil	1741	nil	nil	nil	nil	nil
2014	2564	nil	nil	nil	1933	nil	1950	nil	nil	nil	nil	nil
2015	3066	nil	nil	nil	3120	nil	1423	nil	nil	nil	nil	nil
2016	3058	nil	nil	nil	440	nil	2765	nil	nil	nil	nil	nil
Elevator 2	2609	nil	nil	nil	nil	nil	1813	nil	nil	10467	nil	nil
Avg. Dev.	870						951			6772		
2013	2883	nil	nil	nil	nil	nil	1725	nil	nil	20879	nil	nil
2014	4025	nil	nil	nil	nil	nil	2245	nil	nil	7390	nil	nil
2015	2658	nil	nil	nil	nil	nil	0	nil	nil	0	nil	nil
2016	870	nil	nil	nil	nil	nil	3283	nil	nil	13600	nil	nil
							951			6772		
RSOrganic1	nil	nil	nil	2214	nil	nil	nil	nil	2296	nil	54457	nil
Avg. Dev.				207					586		19681	
2013	nil	nil	nil	2472	nil	nil	nil	nil	3800	nil	64500	nil
2014	nil	nil	nil	2370	nil	nil	nil	nil	2138	nil	83776	nil
2015	nil	nil	nil	2127	nil	nil	nil	nil	3244	nil	49328	nil
2016	nil	nil	nil	1888	nil	nil	nil	nil	2563	nil	20225	nil
RSOrganic2	nil	1566		2195	nil	nil	nil	nil	nil	nil	52542	nil
Avg. Dev.		134		50							16222	
2013	nil	*		2243	nil	nil	nil	nil	nil	nil	71000	nil
2014	nil	1595		2245	nil	nil	nil	nil	nil	nil	66528	nil
2015	nil	1365		2197	nil	nil	nil	nil	nil	nil	51204	nil
2016	nil	1740		2094	nil	nil	nil	nil	nil	nil	21435	nil
PEIOrgan1	nil	nil	2079	nil	nil	nil	1471	nil	nil	12910	nil	nil
Avg. Dev.			514				736			7485		
2013	nil	nil	2766	nil	nil	nil	1896	nil	nil	22190	nil	nil
2014	nil	nil	1813	nil	nil	nil	2445	nil	nil	10852	nil	nil
2015	nil	nil	1317	nil	nil	nil	0	nil	nil	0	nil	nil
2016	nil	nil	2421	nil	nil	nil	1543	nil	nil	18600	nil	nil
PEIOrgan2	nil	nil	1880	nil	nil	nil	nil	1485	nil	nil	nil	19773
Avg. Dev.			664			nil		535				5037
2013	nil	nil	3209	nil	nil	nil	nil	2462	nil	nil	nil	27700
2014	nil	nil	1795	nil	nil	nil	nil	1577	nil	nil	nil	9700
2015	nil	nil	1400	nil	nil	nil	nil	745	nil	nil	nil	21093
2016	nil	nil	1118	nil	nil	nil	nil	1156	nil	nil	nil	20600

Squash

Squash cv. Sweet Mama was incorporated as part of the PEIOrgan2 rotation (Table 11). Squash yield generally were good and reasonably consistent; except in 2014 when yields were half the average (Table 11). The low yield in this year may have been due to powdery mildew. In subsequent years, this was brought under control with the application of a potassium silicate solution.

Economic Evaluation

Gross Returns

The total gross returns of the various rotations are presented (Table 12). As can be seen, the two RSOrganic rotations had the highest returns due to the inclusion of carrots. Similarly, even though there was a crop failure one year, the Elevator2 rotation which included potatoes, had higher returns than Elevator1. Squash coupled with edible beans resulted in higher returns from the PEIOrgan2 rotation than PEIOrgan1. This analysis may be unfair with regards to the two Dairy rotations. These two rotations had the lowest returns when the worth of their crop returns were evaluated. However, it is noteworthy that these crops are necessary to produce a higher value commodity; milk. This should be brought out to a greater extent with more in depth profit analysis.

Table 12. Gross returns ($/ha) over the four years of this trial.

Rotation	
Dairy1	4282
Dairy2	3755
Elevator1	5294
Elevator2	10873
RSOrganic1	109876
RSOrganic2	106051
PEIOrgan1	11136
PEIOrgan2	20923
Grand Mean	34023
SEM	11918
LSD	34249
upper	51148
lower	16899
F pr	
Rot	<0.001
.. RSOrgan1 vs RSOrgan2	ns
.. Elev1 vs Elev2	ns
.. PEIOrgan1 vs PEIOrgan2	ns
.. Dairy1 vs Dairy2	ns
.. Intensive vs Non	<0.001
.. Buckwheat vs Rest	<0.001

Soil Parameters

Soil Chemical

Soil fertility

Although this trial was initiated in the spring of 2013, fall soil samples were not obtained due to there being no funding. Soil samples for fertility analysis were obtained in Spring 2013, Fall 2014, Spring and Fall 2015 and Spring and Fall of 2016. Presented are the overall changes in the various soil test parameters as well as the effect of the various rotations imposed. In addition we evaluated the level of the nutrient in the soil relative to crop requirements using nutrient rating tables of the PEI Analytical Laboratories (PEI Analytical Laboratories, 2017).

Generally, for most of the parameters studied, there was greater differentiation among the rotations with time indicating that the effect of the rotations was becoming more pronounced with time. This suggests that some trends, which are not significant currently, may become so in subsequent years.

Soil Organic Matter

Soil organic matter (OM) influences many parameters of both agronomic and environmental significance. It has been found that increasing soil organic matter content increases water holding capacity (Hudson 1994), cation exchange capacity (Liang et al. 2006), nutrient release (Ring and Warman 1999), hydraulic conductivity (Eusufzai and Fujii 2012) and decreases soil resistance to penetration (Rodd et al. 1999), and bulk density (Rodd et al. 1999).

The overall effect of the rotations on soil organic matter levels was significant only at $p=0.092$ during the course of this experiment (Table 13). However, the general trend in most rotations was for it to increase with time, mainly in a quadratic manner (Table 13; Figure 3). The exception was mainly with the RSOrganic2 rotation (Figure 3). The contrasts showed higher organic matter levels in the PEIOrgan1 vs. the PEIOrgan2 rotation and where buckwheat was part of the rotation (Table 13). The lower organic matter levels in the two RSOrganic is somewhat surprising since sorghum sudangrass, the plow-down crops in these rotations, returned the highest amounts of carbon.

Within the various time periods, there was a significant effect of the rotations; Spring 2013, Spring 2015, Fall 2015 and Fall 2016 (Table 13; Figure 3). Since the Spring 2013 sampling was prior to initiation of the experiment, this cannot be attributed to an effect of the rotational treatments and will not be discussed further. In Spring 2015 there was a significant effect of the rotations on soil organic matter levels (Table 13). The contrast between the two RSOrganic rotations and between rotations with buckwheat and those without were significant; the latter being higher where buckwheat was part of the rotation (Table 13). In Fall 2015, the Dairy 2, Elevator 2, and COPC 1, all had similar organic matter contents which were significantly higher than RSOrganic2; the rest of the rotations being intermediate. Among the contrasts tested, the PEIOrgan1 was higher than the PEIOrgan2 as was the Dairy2 vs the Dairy1 ($p=0.061$)(Table 13). There was no effect of the rotations in Spring 2016 however, in the fall, there was a significant effect with PEIOrgan1 having the highest and RSOrganic2 the lowest OM content (Table 13; Figure 3). Among the specific contrasts, OM levels differed significantly between the two PEIOrgan rotations and where buckwheat had been grown; being higher (Table 13; Figure 3).

The changes in soil organic matter levels reflect changes in the amount of carbon added to the soil (+) versus depletion due to organic matter oxidization from exposure to air (-). Thus, even though higher amounts of carbon may have been applied in the RSOrganic plots with the incorporation of the sorghum sudangrass (Table 10) oxidation of the organic matter during the carrot phase may have contributed to the lack of organic matter buildup relative to the other rotations.

pH

Soil pH influences the bioavailability of many soil nutrients (both beneficial and toxic) to crops. This has been well documented in papers and monographs (Adams 1984). Generally as pH increased towards the neutral range (pH 7) the bioavailability of the beneficial nutrients is increased and those toxic to crops, decreased.

Generally soil pH, during the course of this experiment, increased with time and was within optimal ranges for crop production (Table 14; Figure 4). Overall, the rotations did not affect soil pH nor were there any significant effects among the various samplings (Table 14). Applications of lime and the various other amendments such as manure and compost can all raise soil pH.

Table 13. Effect of the rotations on soil organic matter (%).

Rotation	Overall	Lin	Quad	Spring 2013	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016
Dairy1	3.48	0.01019	0.02776	3.61	3.26	3.44	3.28	3.60	3.68
Dairy2	3.51	0.04216	0.0165	3.44	3.33	3.53	3.48	3.50	3.80
Elevator1	3.43	0.02041	0.0188	3.49	3.18	3.43	3.40	3.53	3.58
Elevator2	3.51	0.01801	0.02366	3.59	3.30	3.43	3.48	3.53	3.73
RSOrganic1	3.39	-0.01617	0.02486	3.64	3.10	3.43	3.20	3.53	3.43
RSOrganic2	3.29	-0.03041	0.01401	3.51	3.28	3.18	3.25	3.25	3.30
PEIOrgan1	3.63	0.04765	0.03572	3.66	3.30	3.60	3.48	3.70	4.05
PEIOrgan2	3.37	0.03459	0.03376	3.46	3.00	3.30	3.25	3.58	3.63
Grand Mean	3.45	0.016	0.024	3.55	3.22	3.42	3.35	3.53	3.65
SEM	0.07	0.021	0.006	0.052	0.132	0.066	0.071	0.169	0.135
LSD	0.20	0.060	0.018	0.150	0.380	0.189	0.203	0.486	0.389
upper	3.55	0.046	0.033	3.622	3.406	3.510	3.452	3.768	3.841
lower	3.35	-0.014	0.016	3.472	3.027	3.320	3.248	3.282	3.453
F pr									
Rot	0.092	ns	ns	0.043	ns	0.009	0.038	ns	0.033
.. RSOrgan1 vs RSOrgan2	ns	ns	ns	0.095	ns	0.015	ns	ns	ns
.. Elev1 vs Elev2	ns	ns	ns	ns	ns	ns	ns	ns	ns
.. PEIOrgan1 vs PEIOrgan2	0.018	ns	ns	0.016	ns	0.005	0.037	ns	0.039
.. Dairy1 vs Dairy2	ns	ns	ns	0.027	ns	ns	0.061	ns	ns
.. Intensive vs Non	ns	ns	ns	0.016	ns	ns	ns	ns	ns
.. Buckwheat vs Rest	0.083	0.027	0.078	ns	ns	0.038	ns	ns	0.009

Phosphorus

Phosphorus (P) is one of the macronutrients required for crop growth and can be found in the soil in both organic and mineral forms. Its availability however, is a function of both soil pH and P concentration (Mengel and Kirkby 1982). P is also a nutrient of environmental concern; movement of P from agricultural lands has been linked to eutrophication of freshwater lakes and rivers (Sharpley et al. 2003). Adequate levels of P are required for root growth especially under cool wet conditions (Hajabbasi and Schumacher 1994; Grant et al. 2001) due to it being an essential component of energy functions (ATP) and DNA and RNA synthesis within plants (Mengel and Kirkby 1982). Many organic farms have been shown to be marginal or deficient in P (Entz et a l. 2001). Further, in soils with a high levels of P fertilization, and low levels of zinc, zinc uptake may be restricted resulting in a zinc deficiency (OMAFRA 1998).

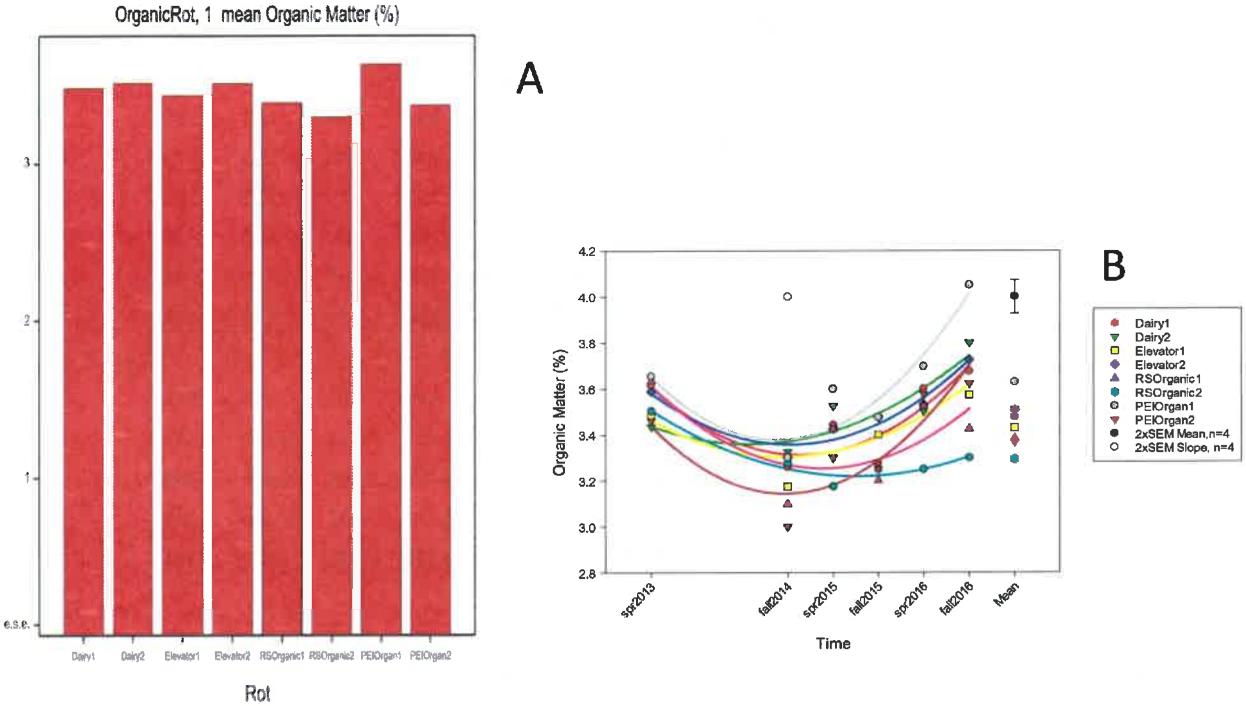


Figure 3. The overall effect (A) and change with time (B) of the rotations on soil organic matter content.

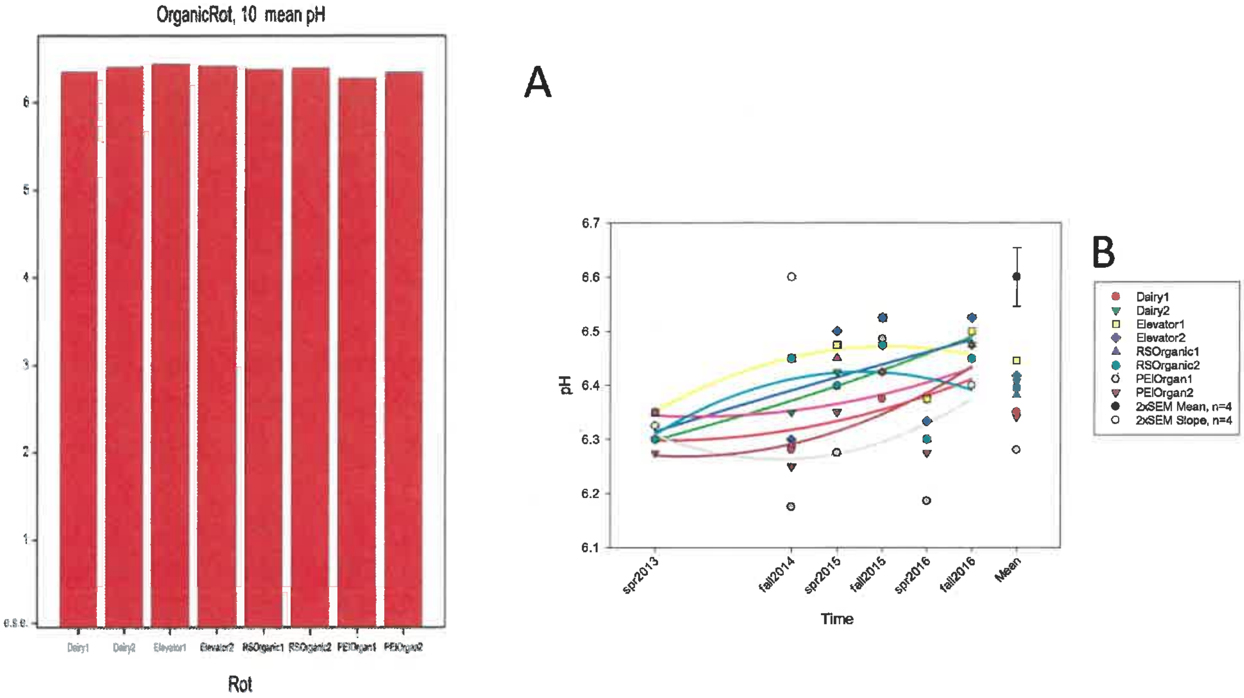


Figure 4. The overall effect (A) and change with time (B) of the rotations on soil pH.

Since the PEI Analytical Laboratories reports soil test P in its oxide form (P_2O_5), we will also do so for reader clarity. There was no effect of the rotations on soil P_2O_5 concentration either overall or within a sampling (Table 14; Figure 5). The lowest P concentrations reported in this study are still in the high or high plus range for most crops grown (PEI Analytical Laboratories. 2017) (Table 14). As indicated previously, most organic systems are normally low in P_2O_5. The high levels of P_2O_5 associated with these plots are probably due residual fertility from when the land was under conventional management.

Potassium

Potassium (K) is another macro element needed for crop growth. Naturally, most of the K is found bound to primary and secondary clay minerals in the soil (Mingel and Kirkby 1982). It is important in respect to plant structure (protein synthesis) and physiological and biochemical functions such as enzyme activation and production and translocation of photosynthates (metabolism) (Mingel and Kirkby 1982). It is unique in that it remains in soluble form in the cell solution and does not become an integral component of plant tissue. It is also a key element aiding plants to deal with physiological stresses such

Table 14 . Effect of the rotations on soil pH.

Rotation	Overall	Lin	Quad	Spring 2013	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016
Dairy1	6.35	0.016	0.002	6.30	6.28	6.40	6.38	6.30	6.45
Dairy2	6.41	0.027	0.001	6.30	6.35	6.43	6.48	6.38	6.53
Elevator1	6.45	0.016	-0.005	6.35	6.45	6.48	6.53	6.38	6.50
Elevator2	6.42	0.024	0.000	6.33	6.30	6.50	6.53	6.33	6.53
RSOrganic1	6.38	0.012	0.009	6.35	6.29	6.45	6.43	6.30	6.48
RSOrganic2	6.40	0.012	-0.006	6.30	6.45	6.40	6.48	6.30	6.45
PEIOrgan1	6.28	0.005	0.009	6.33	6.18	6.28	6.49	6.19	6.40
PEIOrgan2	6.34	0.023	0.004	6.28	6.25	6.35	6.43	6.28	6.48
Grand Mean	6.38	0.017	0.002	6.32	6.32	6.41	6.46	6.31	6.48
SEM	0.054	0.010	0.002	0.068	0.076	0.057	0.056	0.078	0.048
LSD	0.155	0.029	0.007	0.196	0.220	0.165	0.160	0.225	0.139
upper	6.455	0.031	0.005	6.413	6.428	6.492	6.544	6.418	6.544
lower	6.301	0.002	-0.001	6.218	6.208	6.327	6.384	6.193	6.406
F pr									
Rot	ns	ns	0.002	ns	ns	ns	ns	ns	ns
.. RSOrgan1 vs RSOrgan2	ns	ns	<0.001	ns	ns	ns	ns	ns	ns
.. Elev1 vs Elev2	ns	ns	ns	ns	ns	ns	ns	ns	ns
.. PEIOrgan1 vs PEIOrgan2	ns	ns	ns	ns	ns	ns	ns	ns	ns
.. Dairy1 vs Dairy2	ns	ns	ns	ns	ns	ns	ns	ns	ns
.. Intensive vs Non	ns	ns	ns	ns	ns	ns	ns	ns	ns
.. Buckwheat vs Rest	ns	ns	0.014	ns	0.06	0.032	ns	ns	ns

as drought tolerance, winter hardiness and disease stress (OMAFRA 1989). Issues can arise, however, with high levels of K relative to its balance with other elements; too much K can supress Ca and Mg uptake by plants leading to potential for grass tetany, milk fever and other disorders in animals (Rodd et al 2002).

Table 15. Effect of the rotations on soil P_2O_5 concentration (ppm).

Rotation	Overall	Lin	Quad	Spring 2013	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016
Dairy1	477.4	1.881	-1.118	456.2	500.3	503.0	443.2	467.8	494.0
Dairy2	511.0	6.226	-2.033	465.2	548.2	508.2	512.0	497.3	535.2
Elevator1	513.4	3.919	-1.41	482.8	541.2	516.0	503.0	509.0	528.5
Elevator2	540.1	10.21	-0.5677	487.0	563.8	531.5	533.0	542.3	583.0
RSOrganic1	480.6	1.307	0.47	474.2	489.1	484.8	463.0	472.8	499.5
RSOrganic2	490.6	1.595	-1.783	466.5	527.8	489.0	488.0	471.3	501.0
PEIOrgan1	519.5	7.322	-0.4778	478.8	543.8	518.0	508.0	509.9	558.8
PEIOrgan2	496.0	5.223	0.4889	471.8	512.0	486.2	483.8	493.8	528.2
Grand Mean	503.6	4.71	-0.8038	472.8	528.3	504.6	491.8	495.5	528.5
SEM	20.970	3.460	1.408	27.020	36.830	17.220	21.200	25.030	21.770
LSD	60.260	9.942	4.045	77.630	105.800	49.490	60.910	71.920	62.560
upper	533.700	9.681	1.219	511.600	581.200	529.300	522.200	531.500	559.800
lower	473.400	-0.261	-2.826	434.000	475.400	479.900	461.300	459.500	497.300
F pr									
Rot	ns	ns	ns	ns	ns	ns	ns	ns	ns
.. RSOrgan1 vs RSOrgan2	ns	ns	ns	ns	ns	ns	ns	ns	ns
.. Elev1 vs Elev2	ns	ns	ns	ns	ns	ns	ns	ns	0.094
.. PEIOrgan1 vs PEIOrgan2	ns	ns	ns	ns	ns	ns	ns	ns	ns
.. Dairy1 vs Dairy2	ns	ns	ns	ns	ns	ns	0.034	ns	ns
.. Intensive vs Non	ns	ns	ns	ns	ns	ns	ns	ns	ns
.. Buckwheat vs Rest	ns	ns	ns	ns	ns	ns	ns	ns	ns

Overall, there was no effect of the rotations on K_2O concentration (Table 16; Figure 6). There was however, a rotational effect in Spring and Fall 2015 and Spring 2016 (p=0.099). Consistently among those years, soil K_2O concentration was higher in the PEIOrgan1 vs PEIOrgan2 (Table 16). Additionally in Fall 2015, the Dairy1 rotation had higher concentrations of K_2O than Dairy 2 as did the Intensive rotations vs Non (p=-0.071) (Table 15). As is expected, levels of K_2O changed within and among the rotations with time being influenced by nutrient removals in cash crops and application in fertility sources such as, compost, Nuti-wave and liquid dairy manure (LD manure). The potential for change over time is probably higher with potassium than some of the other elements since it can be taken up by plants in excess of their requirement; luxury consumption (Kaiser et al 2016), has been known prior to the work of Bartholomew and Janssen (1929).

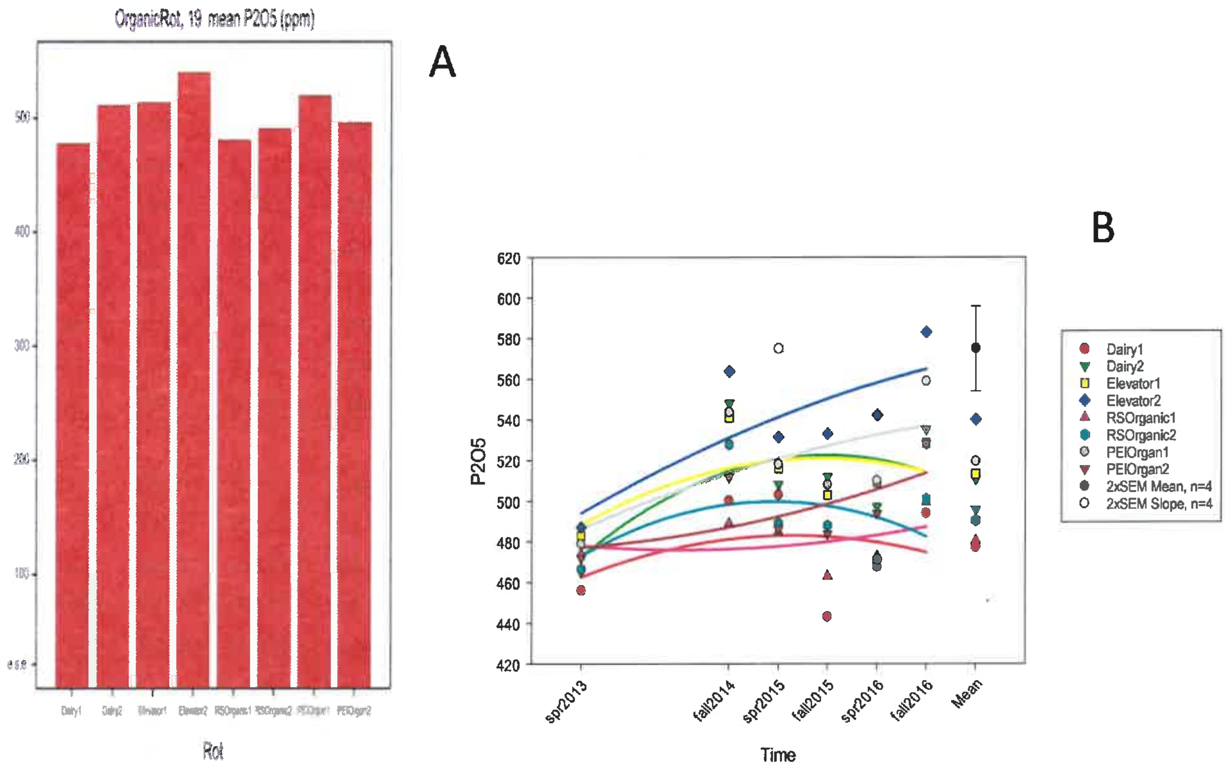


Figure 5. The overall effect (A) and change with time (B) of the rotations on soil P_2O_5 content (ppm).

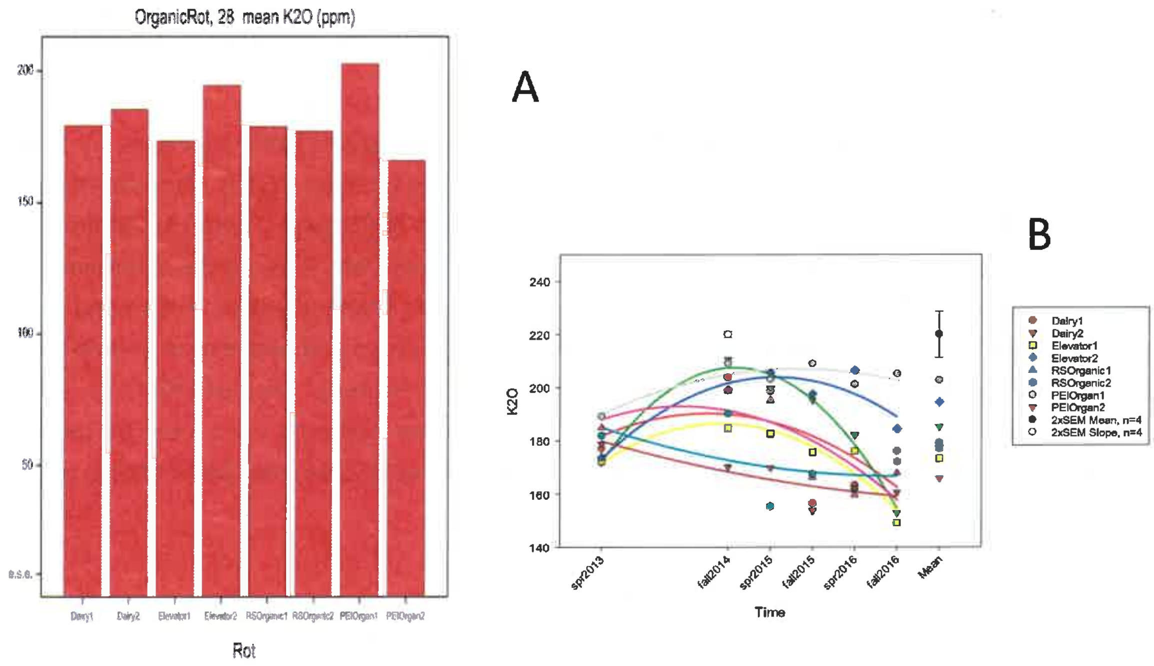


Figure 6. The overall effect (A) and change with time (B) of the rotations on soil K_2O content (ppm).

Table 16. Effect of the rotations on soil K_2O concentration (ppm).

Rotation	Overall	Lin	Quad	Spring 2013	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016
Dairy1	179.2	-2.595	-1.366	177.0	203.8	198.6	156.5	163.2	176.0
Dairy2	185.4	-2.104	-3.574	171.8	210.5	199.7	195.2	182.2	152.8
Elevator1	173.4	-2.355	-1.872	172.2	184.8	182.7	175.5	176.0	149.0
Elevator2	194.5	2.437	-1.802	173.8	199.2	205.5	197.5	206.4	184.5
RSOrganic1	178.8	-4.193	-1.356	185.0	199.0	195.2	166.2	159.5	167.8
RSOrganic2	177.1	-2.841	-0.7621	182.0	190.2	155.5	167.5	161.8	172.2
PEIOrgan1	202.8	1.89	-0.7874	189.2	209.0	203.0	209.0	201.2	205.2
PEIOrgan2	165.9	-2.964	0.2174	178.8	170.2	169.7	153.8	162.2	160.5
Grand Mean	182.1	-1.59	-1.413	178.7	195.9	188.8	177.7	176.6	171
SEM	8.649	1.825	1.184	9.076	19	9.333	10.92	12.88	13.22
LSD	24.85	5.244	3.404	26.08	54.6	26.82	31.38	37	37.99
upper	194.5	1.032	0.2891	191.8	223.1	202.2	193.3	195.1	190
lower	169.7	-4.213	-3.115	165.7	168.6	175.4	162	158.1	152
F pr									
Rot	ns	ns	ns	ns	ns	0.013	0.015	0.099	ns
.. RSOrgan1 vs RSOrgan2	ns	ns	ns	ns	ns	0.008	ns	ns	ns
.. Elev1 vs Elev2	ns	0.08	ns	ns	ns	ns	ns	ns	0.074
.. PEIOrgan1 vs PEIOrgan2	0.007	0.076	ns	ns	ns	0.022	0.002	0.047	0.028
.. Dairy1 vs Dairy2	ns	ns	ns	ns	ns	ns	0.022	ns	ns
.. Intensive vs Non	0.059	ns	ns	ns	ns	ns	0.071	ns	0.025
.. Buckwheat vs Rest	ns	ns	ns	ns	ns	ns	ns	ns	ns

Calcium

Generally, calcium (Ca) and magnesium (Mg) are considered to be liming elements, their application to agricultural lands is usually associated with application of lime. Ca is of fundamental importance in membrane permeability and maintenance of cell integrity (Mengel and Kirkby 1982). Synergetic and antagonistic effects of other elements on Ca uptake have been noted. If Ca deficiency occurs, there is a reduction in the growth of meristematic tissues which can be first observed in the growing tips of the youngest leaves. Further, many physiological disorders have been linked to inadequate Ca nutrition (Bangerth 1979).

Generally, over most of the plots, there was a decline in soil Ca concentrations with time (Figure 7). Ca concentrations generally ranged between 900 to 1200 ppm over the years (Table 17; Figure 7). Such concentrations would be considered to be medium to low plus range (PEI Analytical Laboratories 2017). Given that the soil pH is in the optimal range for most crops, further application of lime is probably not warranted. Gypsum additions, however, can substantially increase soil Ca levels without influencing soil pH, however, one should be cognizant in regards to how much S is also being supplied.

Except for Fall 2016, there was no effect of the rotations on soil Ca concentration (Table 17; Figure 7). In this year, only one contrast approached significance, PEIOrgan; rotation 1 having higher concentrations than rotation 2 (Table 17).

Magnesium

As indicated previously like Ca, magnesium (Mg) is usually applied to the soil as part of the liming process. Mg is usually taken up by crops in lower quantities than Ca. It is important in energy reactions within the plant (Megel and Kirkby 1992), structure of chlorophyll molecules, enzyme activation and protein synthesis (OMAFRA 1989).

There does not appear to be straight forward trends with soil Mg concentrations (Table 18; Figure 8). The amount of Mg in the soil rated as medium to medium plus range for most crops (PEI Analytical Laboratories 2017) (Table 18). Generally there was no effect of the rotations on soil Mg concentrations (Table 18; Figure 8).

Sulfur

Sulfur (S) may be added to the land in the form of acid rain deposition, gypsum and other amendments such as KMag. Sulfur is important in protein formation; a constituent in two of the amino acids involved in N fixation by legumes and is need for chlorophyll formation (OMAFRA 1989). Further, it adds odour and flavour to foods like garlic, cabbage etc. The concentration of S in the soil throughout the samplings was in the medium plus to high range for most crops (PEI Analytical Laboratories 2017).

There was an overall effect (p=0.066) of the rotations on the soil S content which generally followed a quadratic response with time (Table 19; Figure 9). The soil concentration was highest with PEIOrgan1 and lowest with the Dairy1 rotations (Table 19). Among the specific contrasts evaluated Dairy 2 was higher than Dairy 1 and PEIOrgan1 was higher than PEIOrgan2 (Table 19). Among the sampling dates, the effect of the various rotations was only significant for Fall 2015 (Table 19). Within this sampling date the Dairy 1 had the lowest and PEIOrgan1 the highest S concentrations. The contrast between the two PEIOrgan rotations approached significance (p=0.098).

Copper

Copper (Cu) is a micro element. Cu availability depends on texture and unlike many nutrients, its mobility decreases as pH increases. Some nutrients, such as zinc and phosphorous, if in high quantities, can depress Cu adsorption by plants (OMAFRA 1989). Cu plays a role in chlorophyll production, catalyst for enzymes and disease suppression. It should be noted that Cu may be added in the feed ration of pigs, cattle and poultry but in small quantities it may be toxic to sheep. In the OMAFRA (1989) publication, concern is raised about application of pig manure to forage land and toxicity to sheep consuming the forage. The concentrations of Cu that are deficient, sufficient and toxic to plant growth are relatively close (Donahue et al. 1983). However, it should be noted that Cu toxicity rarely occurs as Cu is normally tightly bound to organic materials (Donahue et al. 1983). They also noted that Cu deficiency may occur on heavily cropped, acidic sandy soils, receiving high rates of nitrogen, phosphorus and potassium.

Table 17. Effect of the rotations on soil Ca concentration (ppm).

Rotation	Overall	Lin	Quad	Spring 2013	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016
Dairy1	1062	-27.17	8.386	1111	1042	1074	967	1016	1033
Dairy2	1110	-4.932	-0.3351	1120	1158	1098	1093	1072	1119
Elevator1	1089	-12.41	-3.572	1108	1178	1081	1059	1063	1044
Elevator2	1135	2.095	0.2144	1124	1154	1123	1118	1146	1146
RSOrganic1	1029	-17.7	2.415	1120	1023	1034	994	1014	988
RSOrganic2	1024	-21.05	-0.8091	1095	1120	989	989	974	980
PEIOrgan1	1060	-9.242	-0.2877	1087	1118	1052	1003	1054	1044
PEIOrgan2	998.5	-6.412	5.023	1058	976	973	965	1016	1004
Grand Mean	1063	-12.1	1.379	1103	1096	1053	1024	1044	1045
SEM	40.03	7.129	3.369	61.81	74.95	39.61	47.06	48.87	37.09
LSD	115	20.49	9.682	177.6	215.4	113.8	135.2	140.4	106.6
upper	1121	-1.86	6.22	1192	1204	1110	1091	1114	1098
lower	1006	-22.35	-3.462	1014	988.4	996	955.9	974	991.3
F pr									
Rot	ns	ns	ns	ns	ns	ns	ns	ns	0.051
.. RSOrgan1 vs RSOrgan2	ns	ns	ns	ns	ns	ns	ns	ns	Ns
.. Elev1 vs Elev2	ns	ns	ns	ns	ns	ns	ns	ns	0.069
.. PEIOrgan1 vs PEIOrgan2	ns	ns	ns	ns	ns	ns	ns	ns	Ns
.. Dairy1 vs Dairy2	ns	0.041	0.084	ns	ns	ns	0.074	ns	Ns
.. Intensive vs Non	ns	ns	ns	ns	ns	ns	ns	ns	Ns
.. Buckwheat vs Rest	ns	ns	ns	ns	ns	ns	ns	ns	Ns

Overall the range in Cu concentration during the experiment was 1.9 ppm (medium plus) to 4.0 ppm (high plus). There was no overall effect of the rotations on the concentration of this element (Table 20). However, the effect of the rotations on soil Cu concentration approached significance (p=0.093) in Fall 2016 and the trend was for the PEIOrgan1 and the PEI Elevator2 to have the highest concentrations of soil Cu (Table 20; Figure 10). Further within the specific contrasts, the PEIOrgan1 was higher in soil Cu than the PEI Organ2 (Table 20). Although, not significant, the trend was for the Elevator2 to be higher than Elevator1. Both the Elevator2 and the PEIOrgan1 have potatoes within the rotation.

There are many sources of Cu in this experiment; the liquid dairy manure, the Nutri-wave and Parasol used for blight control. An analysis of the Nutri-wave pelleted chicken manure showed that it contained 416 ppm of Cu. Application of 1000 kg/ha, this would translate to 0.416 kg of Cu being applied per hectare. If we consider that a hectare furrow slice contains 2,000,000 kg (Donahue et al. 1983) then it would mean that soil Cu would be increased by 0.2 ppm. The Parasol used for late blight control contains 50% elemental Cu (Nufarm 2014). It may be applied at 2.5 kg/ha per spray with up to 10 treatments per year. This could raise soil Cu levels 6.3 ppm. Thus, it appears that the rise in Cu concentration in these plots was more likely associated with Parasol use.

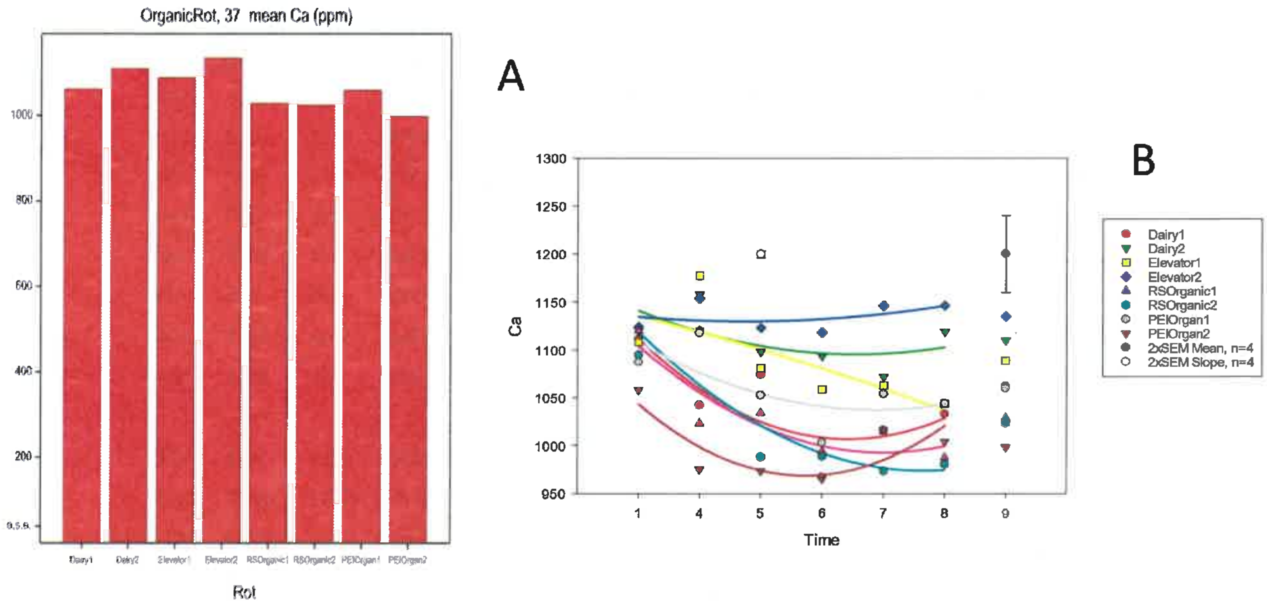


Figure 7. The overall effect (A) and change with time (B) of the rotations on soil Ca content (ppm).

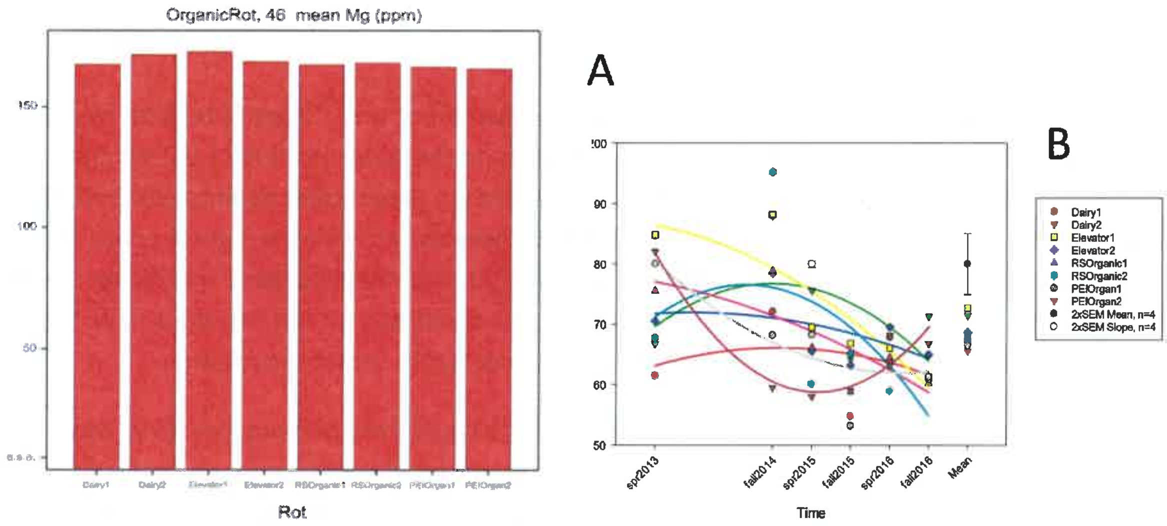


Figure 8. The overall effect (A) and change with time (B) of the rotations on soil Mg content (ppm).

Table 18. Effect of the rotations on soil Mg concentration (ppm).

Rotation	Overall	Lin	Quad	Spring 2013	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016
Dairy1	167.5	-1.309	0.5739	161.5	172.1	168.3	154.8	163.8	164.9
Dairy2	171.5	-0.7135	-0.8051	166.8	188.0	175.5	164.2	163.2	171.3
Elevator1	172.7	-3.811	-0.3772	184.8	188.2	169.5	166.8	166.0	161.3
Elevator2	168.7	-1.038	-0.2079	170.5	178.5	165.5	163.2	169.5	165.0
RSOrganic1	167.3	-2.582	-0.1906	175.5	178.8	166.2	158.8	164.5	160.3
RSOrganic2	168.1	-2.208	-0.9972	167.8	195.2	160.2	165.2	159.0	161.0
PEIOrgan1	166.5	-2.664	0.4617	180.0	168.2	168.2	153.2	167.8	161.3
PEIOrgan2	165.6	-1.859	1.323	182.0	159.5	158.0	159.0	168.2	166.8
Grand Mean	168.5	-2.023	-0.02745	173.6	178.6	166.4	160.7	165.3	164
SEM	5.034	0.9959	0.5368	6.727	11.63	6.306	5.876	5.59	5.411
LSD	14.47	2.862	1.543	19.33	33.43	18.12	16.88	16.06	15.55
Upper	175.7	-0.5922	0.7438	183.3	195.3	175.5	169.1	173.3	171.7
Lower	161.3	-3.454	-0.7987	163.9	161.9	157.4	152.2	157.2	156.2
F pr									
Rot	ns	ns	ns	ns	ns	ns	ns	ns	ns
.. RSOrgan1 vs RSOrgan2	ns	ns	ns	ns	ns	ns	ns	ns	ns
.. Elev1 vs Elev2	ns	0.065	ns	ns	ns	ns	ns	ns	ns
.. PEIOrgan1 vs PEIOrgan2	ns	ns	ns	ns	ns	ns	ns	ns	ns
.. Dairy1 vs Dairy2	ns	ns	0.086	ns	ns	ns	ns	ns	ns
.. Intensive vs Non	ns	ns	ns	ns	ns	ns	ns	ns	ns
.. Buckwheat vs Rest	ns	ns	0.042	ns	ns	ns	ns	ns	ns

Table 19. Effect of the rotations on soil S concentration (ppm).

Rotation	Overall	Lin	Quad	Spring 2013	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016
Dairy1	17.5	0.03087	0.186	18.3	17.8	15.8	16.0	17.8	19.3
Dairy2	19.0	-0.05676	-0.06491	18.3	19.3	17.0	18.5	18.0	19.5
Elevator1	18.3	0.08108	0.08454	18.3	19.0	16.5	18.0	18.5	19.3
Elevator2	18.5	0.159	0.1094	18.3	19.5	16.8	17.8	18.7	20.3
RSOrganic1	18.5	0.1289	0.0602	18.0	19.8	16.5	18.8	17.8	20.0
RSOrganic2	18.0	0.05676	0.02032	17.5	19.8	17.0	17.3	17.3	19.3
PEIOrgan1	19.1	0.213	0.01974	18.0	20.5	16.7	18.5	19.1	20.5
PEIOrgan2	17.7	-0.07838	0.1618	18.8	18.3	16.0	16.5	17.5	19.0
Grand Mean	18.31	0.0668	0.07214	18.16	19.24	16.53	17.66	18.07	19.62
SEM	0.378	0.1349	0.07536	0.43	0.6765	0.3258	0.5504	0.6192	0.743
LSD	1.086	0.3876	0.2166	1.236	1.944	0.9363	1.582	1.779	2.135
Upper	18.86	0.2606	0.1804	18.77	20.21	17	18.45	18.96	20.69
Lower	17.77	-0.127	-0.03614	17.54	18.27	16.06	16.87	17.18	18.56
F pr									
Rot	0.066	ns	ns	ns	ns	ns	0.019	ns	ns
.. RSOrgan1 vs RSOrgan2	ns	ns	ns	ns	ns	ns	0.07	ns	ns
.. Elev1 vs Elev2	ns	ns	ns	ns	ns	ns	ns	ns	ns
.. PEIOrgan1 vs PEIOrgan2	0.015	ns	ns	ns	0.031	ns	0.019	0.087	ns
.. Dairy1 vs Dairy2	0.011	ns	0.03	ns	ns	0.021	0.005	ns	ns
.. Intensive vs Non	ns	ns	ns	ns	0.014	ns	0.051	ns	ns
.. Buckwheat vs Rest	ns	ns	ns	ns	ns	ns	ns	ns	ns

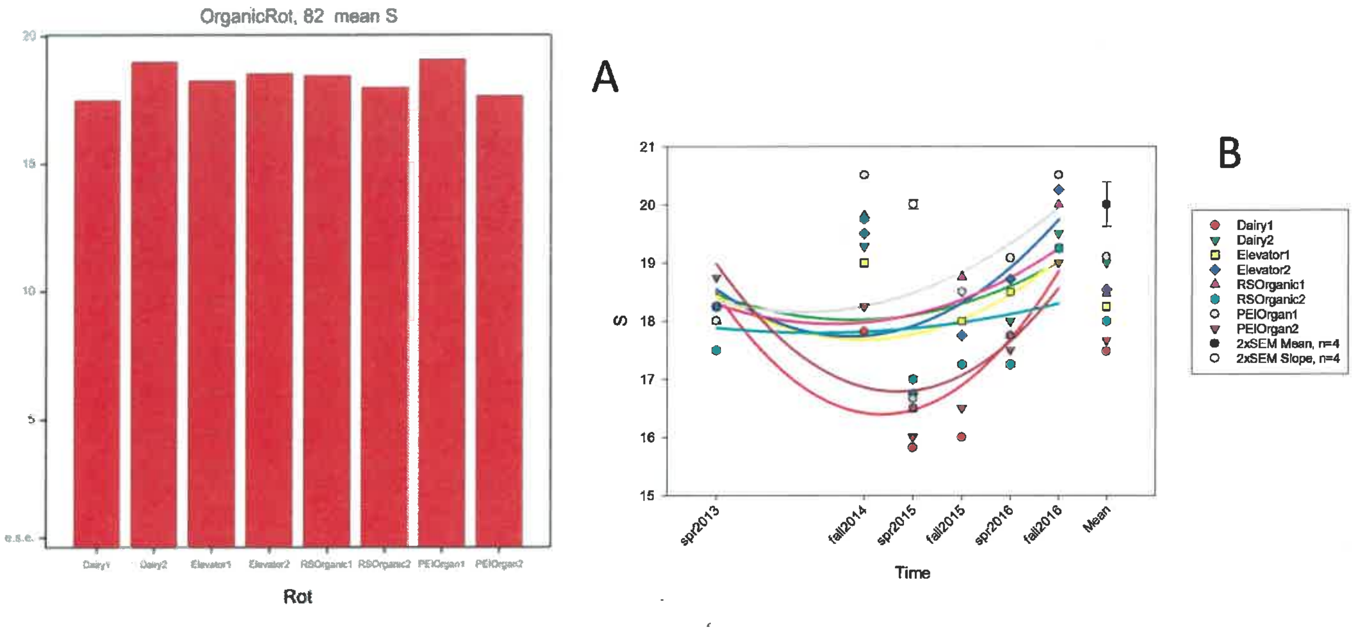


Figure 9. The overall effect (A) and change with time (B) on soil S content (ppm).

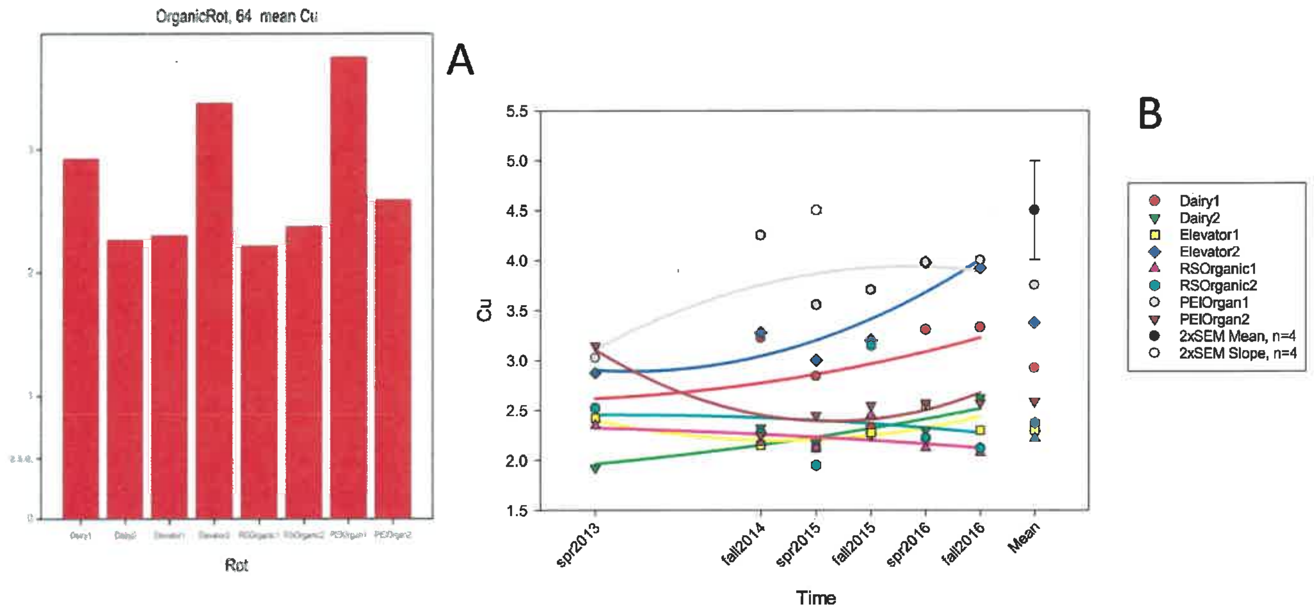


Figure 10. The overall effect (A) and change with time (B) of the rotations on soil Cu content (ppm).

Table 20. Effect of the rotations on soil Cu concentrations (ppm).

Rotation	Overall	Lin	Quad	Spring 2013	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016
Dairy1	2.92	0.08606	0.008883	2.53	3.22	2.84	2.33	3.30	3.33
Dairy2	2.27	0.07892	0.004012	1.93	2.33	2.18	2.25	2.30	2.63
Elevator1	2.30	0.003919	0.01803	2.43	2.15	2.13	2.28	2.55	2.30
Elevator2	3.38	0.1551	0.02784	2.88	3.28	3.00	3.20	3.98	3.93
RSOrganic1	2.22	-0.02831	-0.001948	2.35	2.18	2.13	2.45	2.13	2.08
RSOrganic2	2.38	-0.02514	-0.004038	2.53	2.28	1.95	3.15	2.23	2.13
PEIOrgan1	3.75	0.1154	-0.02588	3.03	4.25	3.55	3.70	3.98	4.00
PEIOrgan2	2.59	-0.06541	0.03885	3.15	2.25	2.45	2.55	2.58	2.58
Grand Mean	2.726	0.04007	0.008219	2.60	2.74	2.53	2.74	2.88	2.87
SEM	0.4931	0.03651	0.02451	0.540	0.679	0.461	0.585	0.556	0.534
LSD	1.417	0.1049	0.07044	1.551	1.951	1.324	1.680	1.598	1.534
Upper	3.434	0.09254	0.04344	3.375	3.717	3.189	3.578	3.678	3.636
Lower	2.017	-0.01239	-0.027	1.825	1.766	1.865	1.897	2.08	2.102
F pr									
Rot	ns	0.004	ns	ns	ns	ns	ns	ns	0.093
.. RSOrgan1 vs RSOrgan2	ns	ns	ns	ns	ns	ns	ns	ns	ns
.. Elev1 vs Elev2	ns	0.009	ns	ns	ns	ns	ns	0.086	0.045
.. PEIOrgan1 vs PEIOrgan2	ns	0.003	0.078	ns	0.052	ns	ns	0.091	0.075
.. Dairy1 vs Dairy2	ns	ns	ns	ns	ns	ns	ns	ns	ns
.. Intensive vs Non	ns	ns	ns	ns	ns	ns	0.077	ns	ns
.. Buckwheat vs Rest	ns	ns	ns	ns	ns	ns	ns	ns	ns

Zinc

Like copper, zinc (Zn) is also a micronutrient. It is relatively immobile in soils being adsorbed to surfaces of clays, carbonates, and oxide materials. It's important in early plant growth, grain and seed formation and in chlorophyll and carbohydrate production (OMAFRA 1989). As indicated earlier Zn may have an antagonistic relationship with other elements ie. P, especially when soil conditions are cold and wet (Donahue et al. 1983).

Soil Zn levels increased, remained the same or decreased with time (Table 21; Figure 11). The soil Zn concentration ranged from 2.05 to 3.53 during the course of the trial (Table 21); considered to be within the low to medium range, respectively, for most crops (PEI Analytical Laboratories 2017). Levels are such that it is warranted in the future to do tissue tests of the crops when they reach the appropriate stages of development; especially the higher value crops (Mills and Jones 1996) to ensure that yields are not inadvertently limited.

The overall effect of the rotations on soil Zn concentration approached significance (p=0.079) (Table 21; Figure 11) with the concentration being lowest for the PEIOrgan2 and highest for the Elevator 2 rotation, respectively. Among the contrasts studied, differences occurred between the two PEIOrgan rotations and Intensive vs Non; being higher in the Intensive where potatoes and carrots were grown. Among the various samplings there was a significant effect of the rotations from Spring 2015 onward. Generally the PEIOrgan rotation had the lowest concentration of soil Zn and Elevator2 rotation either the highest or among the highest. Among the contrasts studied, soils in the PEIOrgan1 rotation had significantly higher Zn concentrations than the PEI Organ2 (Table 21). Further, in Fall 2016, the contrast between the Elevator rotations was also significant being higher with the Elevator2 rotation (Table 21).

Boron

Like both copper and zinc, boron (B) is a micronutrient. It has been linked to the structural integrity of cell walls, fruit set, seed development and carbohydrate and protein metabolism (OMAFRA 1989). They noted that B should be used with care; toxic symptoms occurred with sweet corn, and soybeans when they followed red beets where B had been applied.

The concentration of soil B followed a quadratic fashion during the course of this trial and the differentiation among the rotations increased (Table 22; Figure 12)). During this experiment, the concentration ranged from 0.33 to 0.60 ppm; this would be considered to be within the low range for most crops (PEI Analytical Laboratories 2017). Overall, there was a significant effect of the rotations on soil B concentration with the Elevator 1, the RSOrganic2, and PEIOrgan1 having the lowest concentrations and PEIOrgan1 the highest. Among the contrasts studied, there were significant differences between the two Elevator, two PEI Organ and the Intensive vs Non rotations; being higher where potatoes and carrots were grown (Table 22). Among the various samplings, there was an effect of the rotations in Fall 2014, Spring 2015 (p=0.074), Spring 2016 and Fall 2016 (Table 22). In Fall 2014, the PEI Organ2 rotation had the lowest and Dairy 2 the highest. The Dairy contrast showed higher

Table 21. Effect of the rotations on soil Zn concentration.

Rotation	Overall	Lin	Quad	Spring 2013	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016
Dairy1	2.50	0.0004384	-0.002438	2.40	2.79	2.60	2.15	2.33	2.70
Dairy2	2.77	0.02932	-0.01191	2.53	3.05	2.68	2.85	2.60	2.93
Elevator1	2.70	-0.002297	-0.01544	2.58	2.90	2.88	2.48	2.70	2.65
Elevator2	3.18	0.07367	-0.01006	2.73	3.55	3.13	3.00	3.16	3.53
RSOrganic1	2.47	-0.09506	0.02083	2.98	2.56	2.40	2.20	2.30	2.40
RSOrganic2	2.50	-0.09149	-0.01575	2.68	3.20	2.43	2.10	2.25	2.33
PEIOrgan1	3.10	0.08597	-0.01983	2.55	3.43	3.13	2.98	3.18	3.35
PEIOrgan2	2.09	-0.03041	-0.0006457	2.18	2.30	2.05	1.90	2.05	2.05
Grand Mean	2.66	-0.003731	-0.006904	2.58	2.97	2.66	2.46	2.57	2.74
SEM	0.239	0.04729	0.01351	0.338	0.375	0.187	0.260	0.254	0.274
LSD	0.686	0.1359	0.03883	0.970	1.079	0.538	0.746	0.730	0.787
upper	3.005	0.06422	0.01251	3.06	3.511	2.929	2.829	2.935	3.134
lower	2.319	-0.07168	-0.02632	2.09	2.433	2.391	2.083	2.206	2.347
F pr									
Rot	0.079	ns	Ns	ns	ns	0.008	0.038	0.039	0.017
.. RSOrgan1 vs RSOrgan2	ns	ns	0.072	ns	ns	ns	ns	ns	ns
.. Elev1 vs Elev2	ns	ns	Ns	ns	ns	ns	ns	ns	0.037
.. PEIOrgan1 vs PEIOrgan2	0.008	0.099	Ns	ns	0.048	<0.001	0.009	0.006	0.004
.. Dairy1 vs Dairy2	ns	ns	Ns	ns	ns	ns	0.073	ns	ns
.. Intensive vs Non	0.092	ns	Ns	ns	ns	ns	ns	ns	ns
.. Buckwheat vs Rest	ns	ns	Ns	ns	ns	ns	ns	ns	ns

Table 22. Effect of the rotations on soil B concentration (ppm).

Rotation	Overall	Lin	Quad	Spring 2013	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016
Dairy1	0.41	0.0244	0.008702	0.35	0.37	0.34	0.38	0.45	0.55
Dairy2	0.43	0.02108	0.003314	0.35	0.45	0.33	0.43	0.50	0.50
Elevator1	0.39	0.01973	0.00371	0.33	0.40	0.33	0.38	0.45	0.48
Elevator2	0.44	0.02988	0.007402	0.35	0.43	0.38	0.40	0.49	0.60
RSOrganic1	0.40	0.01975	0.00632	0.35	0.39	0.35	0.38	0.43	0.53
RSOrganic2	0.39	0.01824	0.002936	0.33	0.40	0.30	0.40	0.45	0.45
PEIOrgan1	0.45	0.02497	0.00269	0.35	0.39	0.38	0.40	0.56	0.53
PEIOrgan2	0.39	0.02311	0.005587	0.33	0.35	0.33	0.38	0.48	0.48
Grand Mean	0.41	0.02264	0.005083	0.34	0.40	0.34	0.39	0.48	0.51
SEM	0.010	0.004	0.002	0.021	0.019	0.017	0.018	0.023	0.023
LSD	0.029	0.011	0.005	0.059	0.054	0.050	0.052	0.067	0.066
upper	0.4255	0.02812	0.007537	0.3703	0.4229	0.3641	0.4164	0.5089	0.55
lower	0.3963	0.01717	0.002629	0.311	0.3688	0.3143	0.3649	0.4416	0.48
F pr									
Rot	0.002	ns	Ns	ns	0.041	0.074	ns	0.022	0.005
.. RSOrgan1 vs RSOrgan2	ns	ns	Ns	ns	ns	0.056	ns	ns	0.032
.. Elev1 vs Elev2	0.003	0.076	Ns	ns	ns	0.056	ns	ns	0.001
.. PEIOrgan1 vs PEIOrgan2	<0.001	ns	Ns	ns	ns	0.056	ns	0.021	ns
.. Dairy1 vs Dairy2	ns	ns	0.039	ns	0.007	ns	0.064	ns	ns
.. Intensive vs Non	0.029	ns	Ns	ns	ns	0.094	ns	ns	ns
.. Buckwheat vs Rest	ns	ns	Ns	ns	ns	ns	ns	0.023	ns

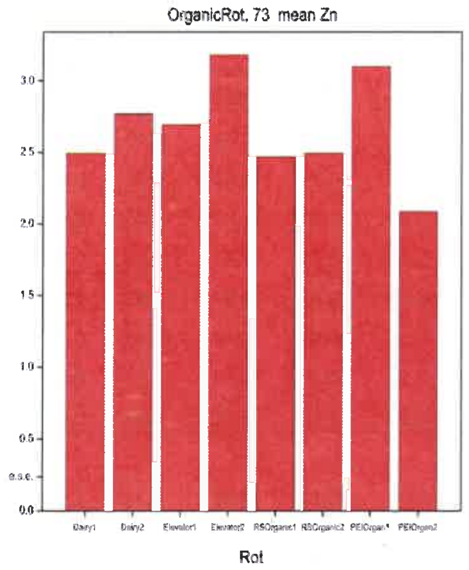


Figure 11. The overall effect of the rotations on soil Zn content (ppm).

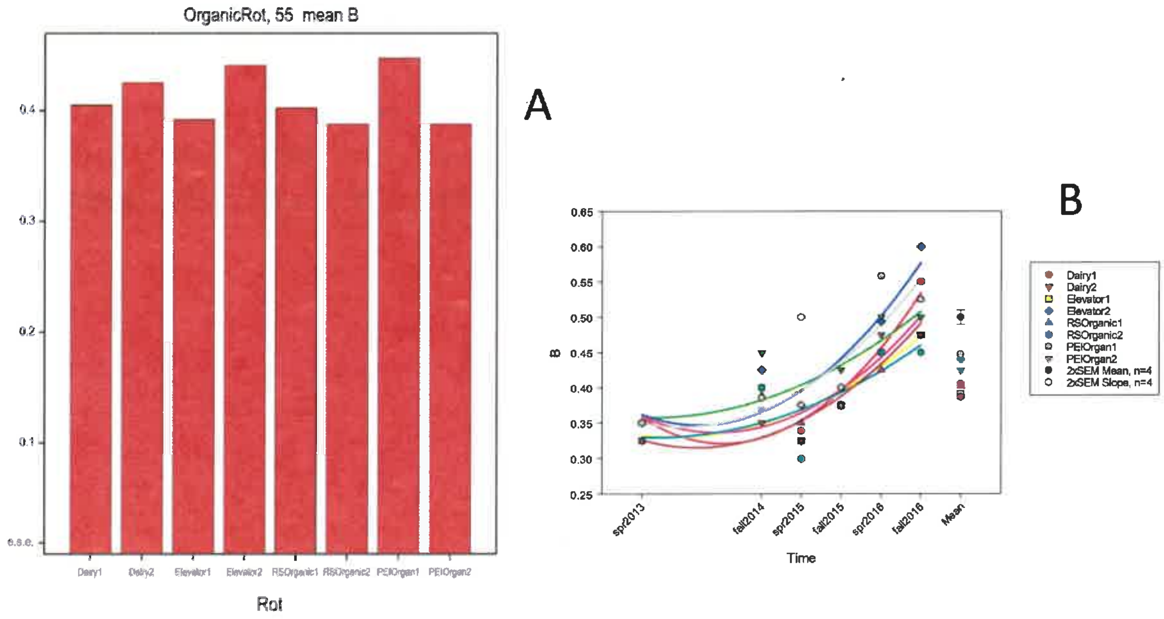


Figure 12. The overall effect (A) and change with time (B) of the rotations on soil B content (ppm).

B concentrations with Dairy2 rotation. In Spring 2015 the effect of rotation was only significant at p=0.074. At that sampling, with the exception of the Dairy and Buckwheat contrasts, most of the other contrasts were significant at p=0.056; except the Intensive vs Non (p=0.094); the latter being higher where potatoes and carrots were grown. In Spring and Fall 2016, rotations affected soil B concentrations (Table 22). The PEIOrgan1 had higher concentration than PEIOrgan2 as did rotations which contained buckwheat (Spring 2016) while RSOrganic1 and Elevator2 had higher concentrations than RSOrganic2 and Elevator1, respectively (Fall 2016).

Manganese

Manganese (Mn) is a micronutrient involved in photosynthesis and chlorophyll production. It aids the enzymes involved in the distribution of growth regulators within the plant (OMAFRA 1989). They note that deficiency mostly occurs in high organic matter situations.

In the course of this experiment soil Mn levels ranged from 19.8 to 35.5 which would be in the low to medium range, respectively (PEI Analytical Laboratories 2017). Generally differentiation in soil Mn concentration among the rotations increased with time (Table 23 Figure 13). Except for the overall lower Mn concentrations in Spring 2015, the grand mean of soil Mn at the various samplings generally remained consistent (Table 23). The lower concentrations of Mn in Spring 2015 may be related to the weather conditions which were cooler and wetter than normal (Table 3, 4 and 5). Lower oxidation reduction potentials associated with water logged conditions have been found to increase Mn solubility (Bohn et al. 1979). Normally if this occurs under stagnant water conditions there is limited Mn loss however, it was noted that water movement at the time of lower redox potentials may result in leaching losses. Thus, melting of the 5 m of snow in the spring of 2015 may have contributed to some Mn removal and the lower levels of Mn found in Spring 2015 sampling.

Overall the concentration of Mn was affected by the rotations (p=0.067) with the PEIOrgan1 having the lowest and Dairy2 the highest. The PEIOrgan and Dairy contrasts where affected by the rotations with Mn levels being higher for PEIOrgan1 and Dairy2, respectively (Table 23). From Spring 2015 onward the rotations appear to affect soil Mn levels; p=0.062 and p=0.056 for Spring and Fall 2016, respectively. For these three samplings, PEIOrgan1 had higher Mn levels than PEIOrgan2 (Table 23). In Spring and Fall 2015 the Dairy contrast was also significant; soil Mn levels being higher with the Dairy2 rotation (Table 23).

Table 23. Effect of rotations on soil Mn concentration (ppm).

Rotation	Overall	Lin	Quad	Spring 2013	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016
Dairy1	28.16	0.2687	0.3558	28.8	29.3	23.1	26.5	29.5	31.8
Dairy2	31.83	0.2	0.258	32.3	32.8	27.5	32.0	31.8	34.8
Elevator1	28.58	0.2081	0.4366	30.0	28.8	24.0	26.3	30.0	32.5
Elevator2	29.71	0.6434	0.4905	29.5	30.3	23.3	28.3	31.5	35.5
RSOrganic1	29.66	-0.3032	0.4393	33.3	30.7	23.8	28.8	29.3	32.3
RSOrganic2	28.79	-0.3986	0.1996	31.3	32.0	22.8	29.3	28.3	29.3
PEIOrgan1	29.48	0.6401	0.2774	28.3	29.3	26.0	28.5	31.6	33.3
PEIOrgan2	25.62	-0.1743	0.4645	29.0	25.8	19.8	24.5	26.8	28.0
Grand Mean	29.0	0.1355	0.3652	30.3	29.8	23.8	28.0	29.8	32.2
SEM	1.14	0.3279	0.1071	2.26	2.42	1.26	1.22	1.14	1.606
LSD	3.28	0.9422	0.3077	6.48	6.97	3.61	3.51	3.29	4.616
Upper	30.6	0.6066	0.5191	33.5	33.3	25.6	29.8	31.5	34.5
Lower	27.3	-0.3356	0.2113	27.0	26.4	22.0	26.3	28.2	29.9
F pr									
Rot	0.067	ns	ns	ns	ns	0.019	0.016	0.062	0.056
.. RSOrgan1 vs RSOrgan2	ns	ns	ns	ns	ns	ns	ns	ns	ns
.. Elev1 vs Elev2	ns	ns	ns	ns	ns	ns	ns	ns	ns
.. PEIOrgan1 vs PEIOrgan2	0.028	0.096	ns	ns	ns	0.002	0.032	0.008	0.033
.. Dairy1 vs Dairy2	0.035	ns	ns	ns	ns	0.025	0.005	ns	ns
.. Intensive vs Non	ns	ns	ns	ns	ns	ns	ns	ns	ns
.. Buckwheat vs Rest	ns	ns	ns	ns	ns	ns	ns	ns	ns

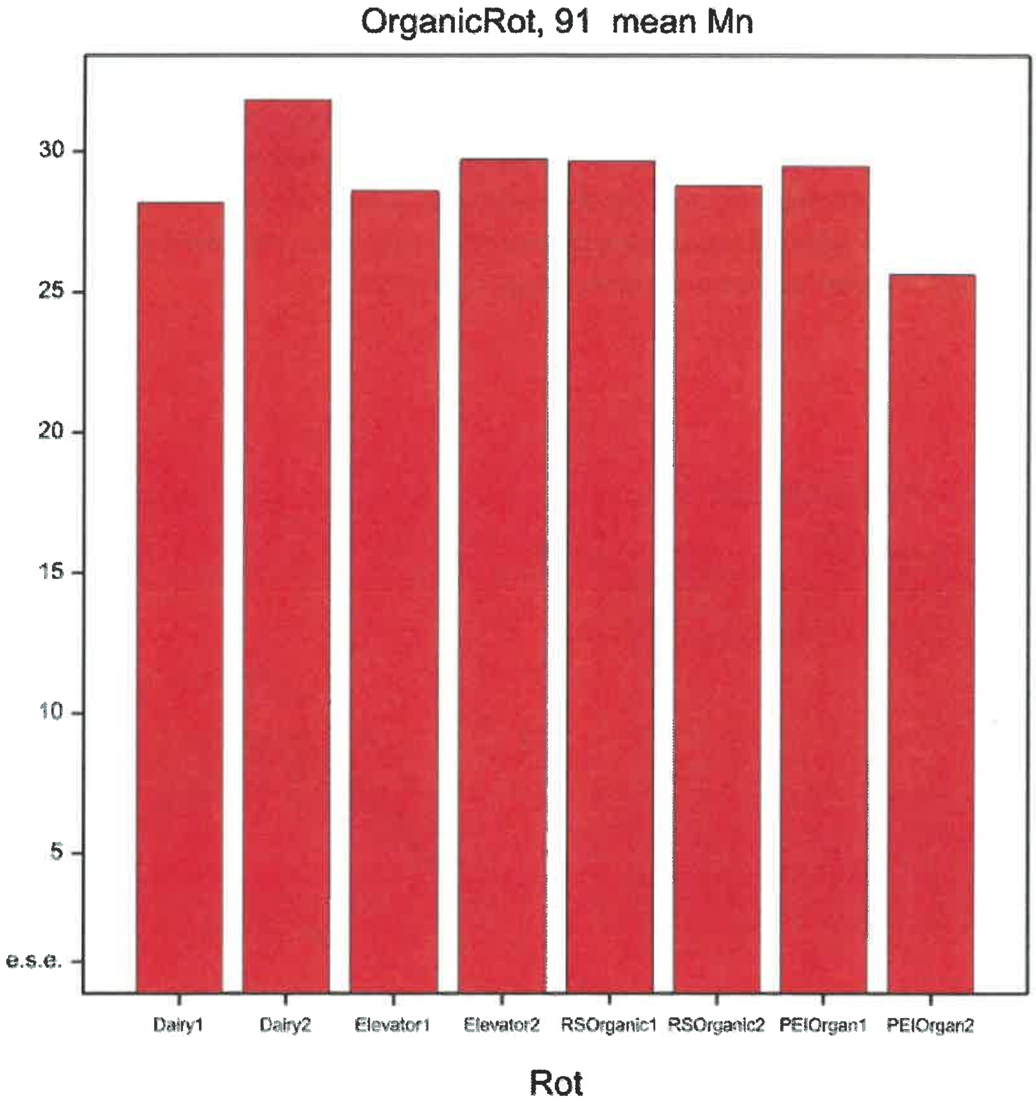


Figure 13. The overall effect of the rotations on soil Mn content (ppm).

Phosphorus Saturation Index

Phosphorus has been tied to algae blooms and eutrophication of freshwater lakes and rivers (Sharpley et al. 1994; Sharpley et al 2003). Such events have been thought to be due to P moving from agricultural lands through the process of erosion; P was thought to be fixed within the soil profile (Donahue et al. 1983). Soil scientists, however, realized that P was not as tightly bound as first thought especially when soil test phosphorus levels were high and started investigating P availability index's (Brar and Cox 1991; work of Simard cited by Parent et al. 2009) and pathways for P movement within the soil profile (Simard et al. 2000). Due to the relatively high P levels in this study we also investigated the P/Al saturation index; 14 or greater may be indicative of P movement within the profile.

Generally the P/Al ratio remained consistent through most of this study with mean in each of the sampling dates ranging from 14 to 17 (Table 24). This suggests that in the short term in these rotations, there may be movement of P down the profile. Thus, it would be warranted to take soil samples from deeper soil depths to confirm this hypothesis. As with other fertility parameters, divergence among the rotations increased with time (Figure 14). However, there was no effect of the rotations overall or within any of the sampling times (Table 24).

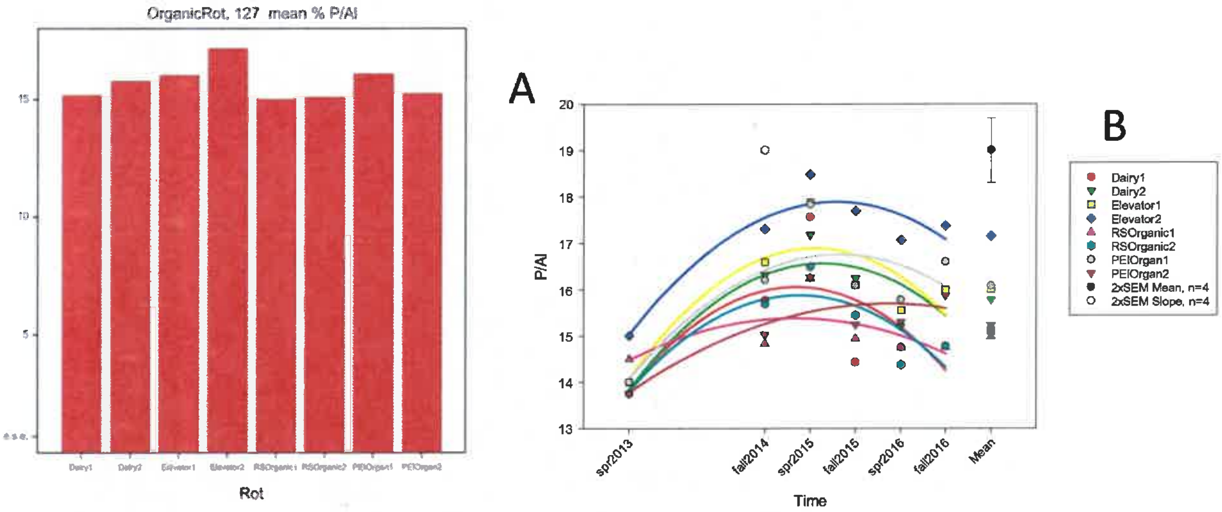


Table 14. Effect of the rotations on the soil P/Al ratio.

Rotation	Overall	Lin	Quad	Spring 2013	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016
Dairy1	15.2	0.07563	-0.1627	13.8	15.8	17.6	14.4	14.8	14.8
Dairy2	15.8	0.2443	-0.1496	13.8	16.3	17.2	16.2	15.2	16.0
Elevator1	16.0	0.2136	-0.1685	14.0	16.6	17.9	16.1	15.6	16.0
Elevator2	17.2	0.3075	-0.1371	15.0	17.3	18.5	17.7	17.1	17.4
RSOrganic1	15.0	0.02792	-0.06774	14.5	14.8	16.3	14.9	14.8	14.8
RSOrganic2	15.1	0.08905	-0.1468	13.8	15.7	16.5	15.5	14.4	14.8
PEIOrgan1	16.1	0.2975	-0.1248	14.0	16.2	17.8	16.1	15.8	16.6
PEIOrgan2	15.2	0.2656	-0.05842	13.8	15.0	16.3	15.2	15.3	15.9
Grand Mean	15.7	0.1901	-0.127	14.1	16.0	17.2	15.8	15.4	15.8
SEM	0.6932	0.1064	0.04867	0.79	1.22	0.63	0.70	0.85	0.824
LSD	1.992	0.3056	0.1399	2.28	3.51	1.82	2.02	2.44	2.368
upper	16.69	0.3429	-0.05702	15.2	17.72	18.15	16.78	16.56	16.95
lower	14.7	0.03732	-0.1969	12.92	14.21	16.33	14.76	14.13	14.58
F pr									
Rot	ns	ns	ns	Ns	ns	ns	ns	ns	ns
.. RSOrgan1 vs RSOrgan2	ns	ns	ns	Ns	ns	ns	ns	ns	ns
.. Elev1 vs Elev2	ns	ns	ns	Ns	ns	ns	ns	ns	ns
.. PEIOrgan1 vs PEIOrgan2	ns	ns	ns	Ns	ns	0.099	ns	ns	ns
.. Dairy1 vs Dairy2	ns	ns	ns	Ns	ns	ns	0.087	ns	ns
.. Intensive vs Non	ns	ns	ns	Ns	ns	ns	ns	ns	ns
.. Buckwheat vs Rest	ns	ns	ns	Ns	ns	ns	ns	ns	ns

Soil Nitrate and Ammonium Content

Soil nitrate within the profile at the various samplings is shown in Figure 15. Nitrogen in this form is quite mobile, with the concentration normally decreasing with depth. What is startling is the high soil nitrate concentration in Spring 2015. Further, although the tread of soil N concentration decreasing with depth still holds, there was minimal differentiation among the depths. Cropping in Spring 2015 was delayed due to melting of the record setting snowfall (~5 m); substantial water flow in a nearby tiled research facility occurred from April 22 to May 16. There were eight substantial freeze thaw events during January, a couple in March and almost every day in April (Data not presented). In many of the April events the change in air temperature was substantial; 10-20 C. Such events disrupt soil aggregates allowing access by microbes and subsequent release of nitrogen. This coupled with the water flow may be the reason for the notable spike in nitrate concentration.

Generally soil NO_3- N concentrations were an order of magnitude higher than the NH_4-N (Table 25). There was no effect of the rotations on soil NO_3-N concentration or the total N content within the profile at any of the samplings or at any of the soil depths (Table 25). This lack of effect may be related the nature of the staggered start statistical design. As indicated previously all aspects of the rotation are in the field at the same time. From a cropping standpoint this is good since the overall effect of the treatment on yield is evaluated among a variety of years. However, it does pose issues when evaluating the environmental consequences since one phase of the rotation may contribute to substantial quantities of N while another phase contributes almost none. This results problems with the statistical analysis due to great variability. This can be rectified by looking at one phase of the rotation over years. This could not be done in time for this report.

There was however, an effect of the rotations on the ammonium content of the soil at the deeper soil depths (30-45 and 45-60 cm) for Overall, Fall 2013, Spring and Fall 2014 and Spring 2015 although the quantities of nitrogen are not as substantial as with nitrate (Table 26 and 27). The concentration of ammonium was higher with the Elevator2 which had potatoes as part of the rotation vs Elevator1 rotation which did not; similar trends were evident for the Fall 2016 but were not significant. At the 45-60 cm soil depth increment, soil ammonium content was also affected by the rotations in Fall 2013, Spring and Fall 2014 and Spring 2015; $p=0.073$, $p=0.081$, $p=0.080$ and $p=0.062$, respectively (Table 27). At this depth and within these years the RSOrganic2 rotation appears to have higher ammonium content than the RSOrganic1. The reason for this cannot be ascertained at this time.

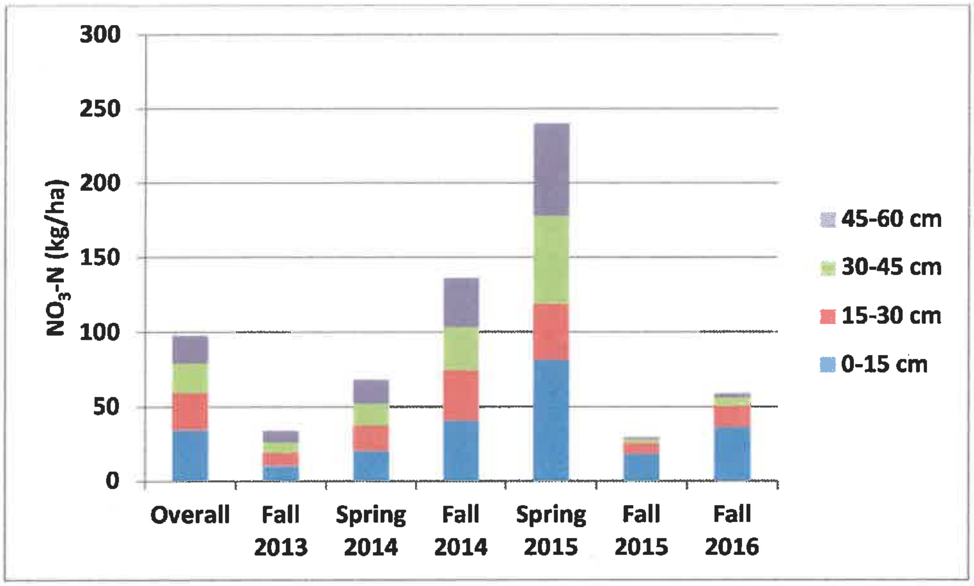


Figure 15. Variations in nitrate N content at the various samplings.

Soil Physical Parameters

Soil Resistance to Penetration

Soil resistance to penetration (RP) ascertains the resistance that a plant root would experience as it extends into the soil profile (Rodd et al. 1999). Roots of many plant species can extend into the soil profile to a depth of 1 m or greater when no impediments exist (Scott, 1977; Schenk and Jackson 2002). This parameter has been found to be more sensitive to changes in the soil physical environment than soil bulk density (Rodd et al. 1999) but care is needed since it is influenced both by moisture content (increasing as moisture content decreases) and density (increasing as density increases) such that erroneous conclusions are not made; higher readings being related to changes in soil moisture and not compaction (Rodd et al. 1999).

RP measurements were undertaken in the fall of 2016 after all inputs and crops had sequenced through all the plots in the various rotations to establish the overall effect of the rotations on this parameter. Such determinations were not done previously because not all crops had sequenced through, and the variability associated with this type of measurement coupled with the staggered start nature of this trial. Further, to gain greater precision on determination of the rotational effects, measurements were conducted on non-traffic non-amended areas left in grass at the end of each block.

Soil resistance to penetration increased with soil depth within the range tested (Figure 16). As indicated, measurements were conducted 24-48 hours after a saturating rain; ~ 30% volumetric water

Table 25. Means of nitrate, ammonium and total N from the soil cores taken at various depth intervals at the various sampling times.

	kg N/ha														
	0-15 cm			15-30 cm			30-45 cm			45-60 cm			Total Profile (0-60 cm)		
	NO_3	NH_4	Total	NO_3	NH_4	Total N	NO_3	NH_4	Total N	NO_3	NH_4	Total N	NO_3	NH_4	Total N
Overall	34.5	5.5	40.0	24.7	3.0	28.2	19.9	1.1	21.5	18.9	1.8	20.9	97.4	12.1	109.5
	(NS)^z	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(0.001)	(NS)	(NS)	(NS)	(NS)	(NS)	(0.062)	(NS)
Fall 2013	10.2	1.0	11.2	8.5	0.9	9.5	7.3	0.3	7.9	8.1	0.6	8.7	33.9	3.2	37.1
	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(0.001)	(NS)	(NS)	(0.073)	(NS)	(NS)	(0.033)	(NS)
Spring 2014	20.4	2.1	22.4	16.9	1.7	19.1	14.7	0.7	15.7	16.4	1.3	17.4	67.5	6.5	73.9
	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(0.004)	(NS)	(NS)	(0.081)	(NS)	(NS)	(0.032)	(NS)
Fall 2014	40.7	4.1	44.8	33.9	3.5	38.2	29.2	1.3	31.4	32.8	2.5	34.7	134.9	12.9	147.8
	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(0.003)	(NS)	(NS)	(0.080)	(NS)	(NS)	(0.031)	(NS)
Spring 2015	81.5	8.2	89.7	37.7	7.0	76.3	59.2	2.6	63.4	62.3	3.8	66.1	259.4	25.4	284.7
	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(0.005)	(NS)	(NS)	(0.062)	(NS)	(NS)	(0.027)	(NS)
Fall 2015	18.2	5.8	24.1	7.1	1.6	8.7	2.8	0.5	3.3	1.5	0.3	1.8	29.6	8.3	38.0
	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(0.073	(NS)
Fall 2016	36.4	11.7	48.1	14.1	3.2	17.3	5.6	1.0	6.6	3.1	0.6	3.8	59.2	16.6	75.8
	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(0.070)	(NS)

Z (NS)- Non significant; (0.073)- p=0.073

Table 26. Effect of the rotations on NH_4-N concentration at the 45 cm soil depth increment.

Rotation	Overall	Lin	Quad	Fall 2013	Spring 2014	Fall 2014	Spring 2015	Fall 2015	Fall 2016
Dairy1	0.8	0.0875	-0.07649	0.2	0.5	1.0	1.9	0.5	0.9
Dairy2	0.6	0.02429	-0.0756	0.2	0.4	0.8	1.6	0.3	0.4
Elevator1	0.6	0.1343	-0.02887	0.2	0.3	0.6	1.2	0.5	1.0
Elevator2	2.6	0.06321	-0.3265	0.9	1.7	3.4	6.8	0.9	1.7
RSOrganic1	1.0	0.1764	-0.06131	0.2	0.5	1.0	2.0	0.7	1.4
RSOrganic2	0.6	0.002931	-0.09261	0.2	0.4	0.8	1.5	0.2	0.3
PEIOrgan1	1.3	0.227	-0.0645	0.3	0.7	1.4	2.6	0.8	1.6
PEIOrgan2	1.1	-0.01964	-0.2747	0.4	0.7	1.4	2.8	0.5	0.9
Grand Mean	1.1	0.087	-0.1251	0.3	0.7	1.3	2.6	0.5	1.0
SEM	0.2502	0.09188	0.07883	0.09536	0.2019	0.3916	0.8	0.1983	0.4157
LSD	0.72	0.26	0.23	0.27	0.58	1.13	2.40	0.57	1.20
Upper	1.426	0.219	-0.01181	0.4526	0.937	1.845	3.7	0.8037	1.604
Lower	0.7068	-0.04501	-0.2383	0.1786	0.3567	0.7202	1.4	0.2338	0.4089
F pr									
Rot	<0.001	ns	ns	0.001	0.004	0.003	0.005	ns	ns
.. RSOrgan1 vs RSOrgan2	ns	ns	ns	ns	ns	ns	ns	0.066	0.066
.. Elev1 vs Elev2	<0.001	ns	0.017	<0.001	<0.001	<0.001	<0.001	ns	ns
.. PEIOrgan1 vs PEIOrgan2	ns	0.076	0.078	ns	ns	ns	ns	ns	ns
.. Dairy1 vs Dairy2	ns	ns	ns	ns	ns	ns	ns	ns	ns
.. Intensive vs Non	0.008	ns	ns	0.026	0.027	0.022	0.031	ns	ns
.. Buckwheat vs Rest	ns	ns	ns	ns	ns	ns	ns	ns	ns

content. Thus soil moisture content would be at its most uniform state and root growth least impeded. Further, the depth where resistance to penetration, at this moisture content, would start to impact and cease root growth has been delineated (Barley et al. 1970; Hakansson et al. 1988). Drying of the soil would result in the delineated lines moving closer to the soil surface.

Table 27. Effect of the rotations on NH_4-N concentration at the 45-60 cm soil depth increment.

Rotation	Overall	Lin	Quad	Fall 2013	Spring 2014	Fall 2014	Spring 2015	Fall 2015	Fall 2016
Dairy1	1.0	-0.002143	-0.1527	0.3	0.7	1.5	2.9	0.3	0.5
Dairy2	1.4	0.03585	-0.1879	0.4	0.8	1.7	3.9	0.4	0.8
Elevator1	0.7	0.08714	-0.05833	0.2	0.4	0.8	1.5	0.4	0.8
Elevator2	0.4	0.1077	-0.01135	0.1	0.3	0.6	0.2	0.4	0.8
RSOrganic1	1.0	0.09036	-0.09911	0.3	0.6	1.2	2.3	0.2	0.3
RSOrganic2	7.2	-0.6829	-1.317	2.8	5.7	11.4	22.8	0.2	0.3
PEIOrgan1	0.0	0.2335	0.2237	0.5	0.9	1.8	-4.1	0.4	0.8
PEIOrgan2	3.2	-0.2132	-0.5396	0.5	0.5	1.1	1.0	0.3	0.7
Grand Mean	1.8	-0.04296	-0.2677	0.6	1.3	2.5	3.8	0.3	0.6
SEM	1.63	0.1663	0.2963	0.6	1.2	2.4	4.95	0.09	0.19
LSD	4.67	0.478	0.8514	1.70	3.46	6.84	14.22	0.2663	0.535
upper	4.092	0.196	0.158	1.463	2.984	5.949	10.93	0.44	0.8814
lower	-0.5825	-0.2819	-0.6935	-0.2368	-0.4725	-0.9354	-3.289	0.1737	0.3463
F pr									
Rot	ns	0.051	0.079	0.073	0.081	0.08	0.062	ns	ns
.. RSOrgan1 vs RSOrgan2	0.02	0.007	0.014	0.007	0.008	0.008	0.012	ns	ns
.. Elev1 vs Elev2	ns	ns	ns	ns	Ns	ns	ns	ns	ns
.. PEIOrgan1 vs PEIOrgan2	ns	0.084	0.096	ns	Ns	ns	ns	ns	ns
.. Dairy1 vs Dairy2	ns	ns	ns	ns	Ns	ns	ns	ns	ns
.. Intensive vs Non	ns	ns	ns	ns	Ns	ns	ns	ns	ns
.. Buckwheat vs Rest	ns	ns	ns	ns	Ns	ns	ns	ns	ns

The control non-amended areas had higher soil resistance to penetration relative to the various rotations (Figure 16; Table 28). Among the various rotations, the two RSOrganic rotations had lower and the two Elevator rotations had higher RP values, respectively. That the RSOrganic rotations had among the lowest RP values is surprising due to the fact that these rotations had among the lowest organic matter contents in Fall 2016. Rodd et al. (1999) has found that high inputs of carbon can decrease both resistance to penetration and bulk density in surface soils. This does not appear the case here, at least in respect to added carbon, since this was similar among the rotations (Table 5C). Even though biomass inputs from the sorghum sudangrass were substantial (Table 10), they also did not translate to increase soil organic matter content (Table 13). Soil loosening during the carrot phase of the two rotations does not appear to be the reason for the lower RP since the measurements were equally split between the carrot beds and furrows and similar disturbances would have occurred in the potato phase of the Elevator2 and PEIOrgan1 rotations; these have higher RP values. The inclusion of sorghum sudangrass in the two RSOrganic rotation may account for the lower RP values. Sorghum sudangrass is known to have twice as many secondary roots per unit of primary root as corn but only have half as much leaf area. It has been found that it can improve subsoil conditions (Mishanec 1996).

Bulk density

There was no effect of the rotations either with or without inclusion of the control areas in the analysis on soil bulk density (dB) either uncorrected or corrected for coarse fragments (Table 29). Bulk density does not appear to be as responsive to changes in the soil physical environment as resistance to penetration (Rodd et al. 1999). Soil penetration resistance is sensitive to changes in micro-cracks and fracture planes as well as porosity whereas dB is sensitive to only changes in porosity (Voorhees 1983).

Fines (Silt + Clay)

Although the entire site is considered a sandy loam, substantial variation in the amount of fines can occur within this textural class; clay and silt contents can range from 0-20% and 0-30%, respectively (Haynes 1998). Thus, it was prudent to evaluate if such differences occurred within the various rotational plots. There was no variation related to the rotations regardless of whether the control plots were included as part of the analysis (Table 29).

Available water capacity

Available water was measured on samples sent to Cornell for the Cornell Soil Test. Available water capacity is that water held by the soil between field capacity and permanent wilting point. This is in many ways an integration of soil texture, compaction and soil organic matter content (van Es et al 2016). There was no effect of the rotations either with or without inclusion of the control plots (Table 29).

Aggregate stability

Higher aggregate stabilities were attained in the control areas where no tillage had been applied than in the rotational areas (Table 29) (p=0.081). Among the rotations there was no effect of the rotations on aggregate stability. It is well known that soil organic matter contributes to improving soil physical properties (Beare et al. 1994; Six et al. 2004). Aggregate stability is often weakly correlated with total soil organic matter content (Beare et al. 1994) with changes in aggregate distributions and stabilities often occurring prior to significant declines in soil organic matter from the cultivation of sod or pasture soils (Angers et al. 1992). The number of water stable aggregates generally declines with tillage (Beare et al. 1994) which would account for the control areas having higher aggregate stability than the rotational areas. In this trial, although soil organic matter increased with time and differences occurred among the rotations (Table 13), there was no effect of the rotations on the percentage of water stable aggregates (Table 29). Elliot (1986) postulated that macro-aggregates contain more labile and less processed organic matter than micro-aggregates and that this soil organic matter is lost upon cultivation. Thus, the lack of differentiation in aggregate stability among the rotations in 2016, relative to the soil organic matter content, could have been due to a large portion of the added carbon in the rotations being more processed less labile ie. compost.

Biological Properties

Active carbon

Active carbon is a measure of the fraction of soil organic matter that is a source of readily available food and energy for the microbial communities and thereby contributes to the release of nutrients required for plant growth. There was no effect of the rotations, regardless of whether the control plots were included in the statistical analysis on the quantity of active carbon in the soil (Table 29).

Respiration

Soil respiration is a measure of the activity of soil biota. Soil organisms influence nutrient transformations including mineralization and immobilization, solubilisation and transport of plant nutrients, formation and stabilization of nutrients etc. Soil respiration is a measure of the activity of the microbial population. Soil respiration was higher in the control plots than the rotational plots and there were no differences among the rotational plots (Table 29).

CONCLUSIONS

The following are conclusions obtained from the trial to date:

- Sorghum sudangrass produced the greatest biomass and generally returned the greatest amounts of carbon and nutrients to the soil.
- Under the conditions of this trial, it was apparent that the red clover was of greater benefit than Oat/Peas and Vetch in terms of nitrogen fixing capacity.
- Sorghum sudangrass higher returns of carbon did not translate into higher organic matter levels due in part to the effect carrot management may have on organic matter oxidation.
- Roots of sorghum sudangrass appear to be beneficial in lowering the resistance to penetration on the plots it was sown.
- Among the various cash crops, carrots gave by far the greatest gross returns.
- Pyganic did not eradicate the flea beetles but appeared to keep them from decimating the crop.
- Wireworm control measures should be incorporated into the crop rotations which include potatoes.
- When delayed seeding issues are encountered when no-till seeding soybeans into a rolled fall rye crop farmers should either let the rye crop mature and harvest it as grain or till in the crop and direct seed the soybeans.
- Generally differentiation among the rotations increased with time for many of the parameters measured in routine soil fertility tests. It is reasonable to assume that this differentiation will become more pronounced the longer that the trial runs.
- It should also be noted that high soil P_2O_5 concentrations were found at the onset of this trial; related to previous fertilizer inputs and management. The ratios of P/Al were above 14 in many of the plots. This is the predicted thresholds where P may move down

the soil profile. This can be verified by measure P_2O_5 concentrations further down the profile.

- High concentrations of P can be antagonistic to the uptake of various micro-nutrients; this should be determined to see if it is limiting crop yields.
- Many of the soil physical and biological parameters studied from the various rotations were only significant when compared to time zero areas which had received no traffic or amendments. Again differentiation among the rotations is increasing with time.

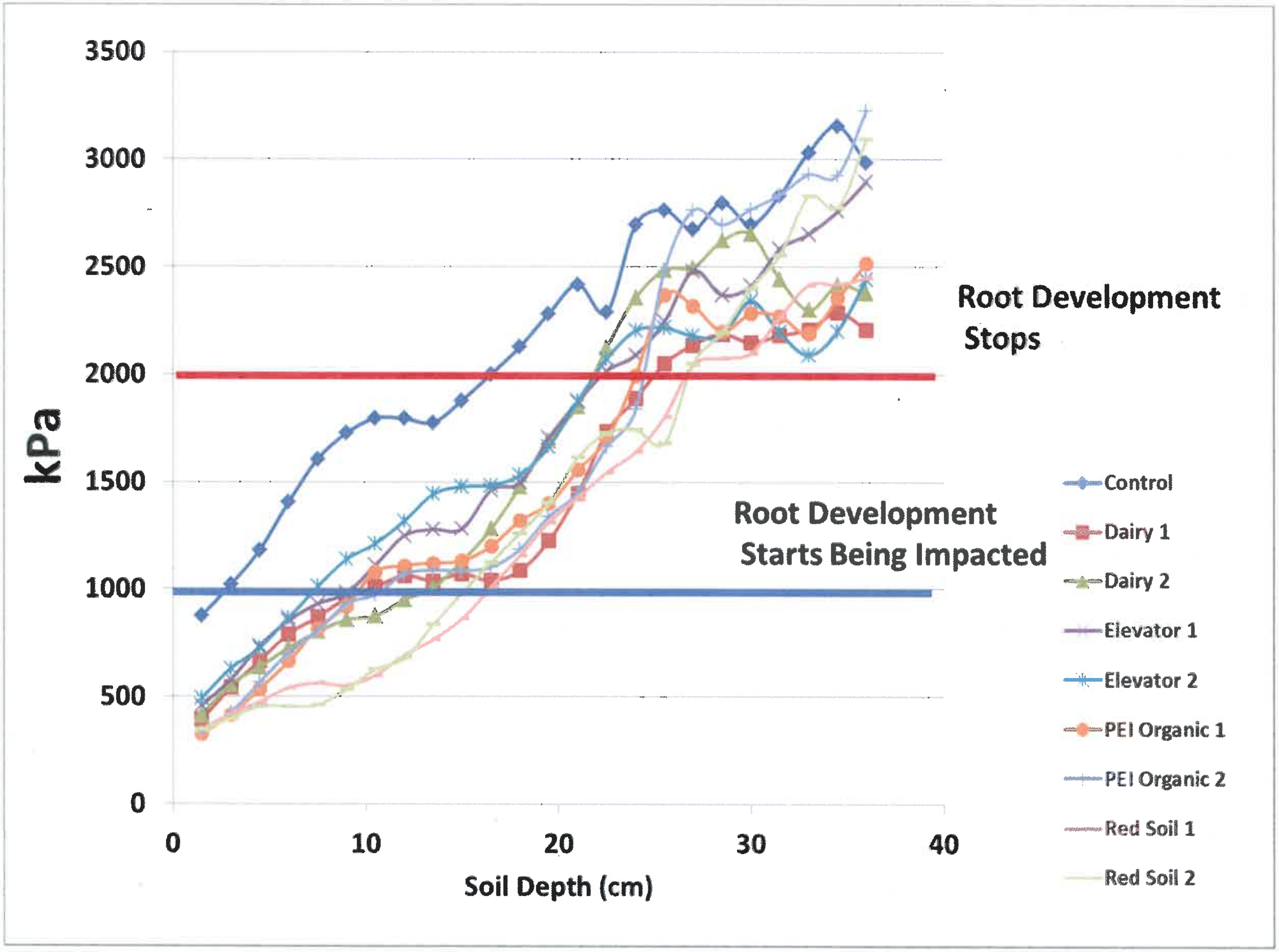

kPa
3500
3000
2500
2000
1500
1000
500
0
0
10
20
30
40
Soil Depth (cm)
Root Development Stops
Root Development Starts Being Impacted
Control
Dairy 1
Dairy 2
Elevator 1
Elevator 2
PEI Organic 1
PEI Organic 2
Red Soil 1
Red Soil 2

Table 28. Effect of the rotations on soil resistance to penetration.

Depth	kPa									With Control		Without Control	
(cm)	Control	Dairy1	Dairy2	Elevator1	Elevator2	RSOrganic1	RSOrganic2	PEIOrgan1	PEI Organ2	LSD	F Prob.	LSD	F Prob.
1.5	876	392	417	459	493	349	347	326	333	161.8	0.001	137.0	0.141
3.0	1017	541	554	578	628	420	400	417	426	171.3	0.001	159.4	0.021
4.5	1180	666	636	734	725	477	54	534	564	200.7	0.001	183.7	0.012
6.0	1404	790	726	852	864	541	453	664	702	232.1	0.001	213.4	0.001
7.5	1605	869	800	931	1008	562	461	815	804	243.0	0.001	228.4	0.001
9.0	1726	958	956	979	1137	553	534	922	931	250.1	0.001	245.5	0.001
10.5	1796	1008	875	1111	1211	599	626	1080	972	251.2	0.001	248.7	0.001
12.0	1794	1062	949	1248	1316	694	677	1109	1069	269.2	0.001	264.4	0.001
13.5	1776	1037	1005	1277	1441	766	835	1122	1086	284.4	0.001	275.2	0.001
15.0	1878	1070	1130	1280	1470	864	981	1132	1084	299.8	0.001	294.2	0.004
16.5	1999	1038	1280	1461	1483	1009	1125	1202	1101	327.8	0.001	322.8	0.019
18.0	2126	1069	1478	1497	1531	1158	1261	1320	1185	360.2	0.001	1172.8	0.221
19.5	2281	1227	1694	1770	1664	1313	1404	1399	1338	381.4	0.001	372.9	0.052
21.0	2417	1449	1852	1874	1876	1427	1616	1557	1450	400.4	0.001	395.5	0.057
22.5	2288	1735	2124	2016	2071	1546	1729	1702	1665	417.8	0.005	407.4	0.040
24.0	2695	1887	2355	2089	2202	1641	1743	1995	1836	422.5	0.001	424.4	0.019
25.5	2808	1966	2410	2285	2220	1811	1893	2194	2062	416.6	0.001	413.0	0.064
27.0	2496	2049	2485	2245	2215	1802	1681	2370	2481	518.2	0.001	530.3	0.018
28.5	2674	2137	2498	2481	2178	2045	2051	2318	2763	438.3	0.005	448.8	0.018
30.0	2799	2188	2622	2369	2180	2076	2195	2201	2696	447.1	0.006	451.7	0.062
31.5	2696	2148	2654	2413	2341	2099	2399	2282	2768	452.0	0.032	467.8	0.075
33.0	2833	2182	2442	2584	2193	2267	2555	2272	2836	427.2	0.006	438.5	0.040
34.5	3033	2209	2299	2654	2089	2416	2830	2189	2929	426.5	0.001	439.0	0.001
36.0	3155	2288	2414	2758	2200	2418	2778	2354	2926	430.7	0.001	453.9	0.001
37.5	2984	2209	2376	2897	2443	2448	3095	2518	3227	444.7	0.001	443.2	0.001
39.0	2813	2251	2513	2820	2452	2375	3168	2529	3184	436.3	0.001	453.9	0.001
40.5	2996	2529	2575	2710	2628	2582	3261	2747	3278	488.7	0.006	493.3	0.009
42.0	3086	2522	2859	2843	2780	2698	3658	2940	3166	485.6	0.001	485.9	0.001
43.5	2620	2663	2762	2527	2801	2586	3141	2947	3072	454.5	0.081	466.4	0.088
45	2881	2760	3009	2599	2544	2426	3146	2910	3296	486.5	0.010	502.0	0.008

Table 29. Effect of the rotations on bulk density, fines, available water capacity, aggregate stability, active carbon, and respiration.

Parameter										With Control		Without Control	
	Control	Dairy1	Dairy2	Elevator1	Elevator2	RSOrganic1	RSOrganic2	PEIOrgan1	PEI Organ2	LSD	F Prob.	LSD	F Prob.
Bulk Density Uncorrected (g/cm^3)	1.25	1.23	1.18	1.21	1.28	1.15	1.16	1.20	1.24	0.123	0.397	0.129	0.428
Bulk Density Corrected (g/cm^3)	1.20	1.20	1.15	1.18	1.26	1.18	1.22	1.12	1.14	0.124	0.420	0.131	0.406
Fines (Silt + Clay) (%)	42.1	43.6	43.3	43.3	43.2	45.2	53.8	44.1	42.8	2.01	0.196	2.10	0.435
Available Water Capacity (%)	25.3	24.9	26.2	26.2	25.4	26.8	26.8	25.2	25.1	2.97	0.839	0.03	0.694
Aggregate Stability (%)	85.6	77.4	78.0	77.5	72.0	80.9	80.1	75.8	75.2	7.87	0.081	7.42	0.322
Active Carbon (mg/kg)	570	659	685	629	679	638	623	679	593	116.2	0.441	114.2	0.655
Respiration (mg CO_2/g soil)	0.76	0.48	0.51	0.47	0.52	0.53	0.61	0.56	0.51	0.169	0.042	0.153	0.584

References

Adams, F. 1984. Soil Acidity and Liming. Agronomy Monograph Series No 12., American Society of Agronomy, Madison, Wisconsin.

AgWeather Atlantic. 2017. Atlantic Weather http://atl.agrometeo.org/index.php/indices/category/general. Accessed March 12, 2017.

Alam, M.Z., Lynch, D.H., Sharifi, M., Burton, D.L., and Hammermeister, A.M. 2016. The effect of green manure and organic amendments on potato yield, nitrogen uptake and soil mineral nitrogen. Bio. Agric. Hort. 32: 221-236.

Angers, D.A., Pesant, A., and Vineux, J. 1992. Early cropping induced changes in soil aggregation, organic matter, and microbial biomass. Soil Sci. Soc. Am. J. 56: 115-119.

Angers, D.A., Bullock, M.S., and Mehuys, G.R. 2007. Aggregate stability to water. *in* M.R. Carter and E.G. Gregorich edt. pgs. 607-616. Soil Sampling and Methods of Analysis, Second Edition. CRC Press.

Angers, D. A., Edwards, L. M., Sanderson, J. B. and Bissonnette, N. 1999. Soil organic matter quality and aggregate stability under eight potato cropping sequences in a fine sandy loam of Prince Edward Island. Can. J. Soil Sci. 79: 411–417.

Annabi, M., Le Bissonais, Y., Le Villio-Poitrenaud, M. and Houot, S. 2011. Improvement of soil aggregate stability by repeated applications of organic amendments to a cultivated silty loam soil. Agric. Eco. Environ. 144: 382–389.

Anonymous 2009. Radishes: A new cover crop option. Crops and Soils. American Soc. Agon. November- December.

Bangerth, F. 1979. Calcium related physiological disorders of plants. Ann. Rev. Phytopatho. 17:97-122

Bardgett, R.D., Frankland, J.C., Whittaker, J.B., 1993. The effects of agricultural management on the soil biota of some upland grasslands. Agriculture, Ecosystems and Environment 45, 25-45.

Barley, K. P., Farrell, D. A. and Graecen, E. L. 1970. The configuration of root system in relation to nutrient uptake. Adv. Agron. **22**: 159–201.

Bartholomew, R.P., and Janssen, G. 1929. Luxury consumption of potassium by plants and its significance. J. Am. Soc. Agron. 21: 751-765.

Bell, L.W. Sparling, B., Tenuta, M. and Entz, M.H. 2012. Soil profile carbon and nutrient stocks under long-term conventional and organic crop and alfalfa-crop rotations and re-established grassland. Agr. Eco. Environ. 158: 156-163.

Björkman, T. and J.W. Shail. 2010. Cornell cover crop guide for oats. Cornell University. 2pp. Ver. 1.100716

Błażejczak D., Śnieg M., Tomaszewicz T., Dawidowski J. B. 2006. The possibility of application of shear (tore) vane to assessment of soil cohesion. Inzynieria Rolnicza. 2: 159-164

Bohn, H.L., McNeal, B.L., and O'Connor, G.A. 1979. Soil Chemistry. Whiley-Interscience Pub. John Wiley and Sons, New York.

Brar, S.P.S. and Cox F.R. 1983. Phopshorus sorption and availability indices as affected by properties of calcareous soils. Commun Soil Sci. Plant Anal. 22: 1225-1241.

Caldwell, B., Liebert, J., and Ryan, M. 2016. On-farm organic no-till planted soybean in rolled cover crop mulch. http://blogs.cornell.edu/whatscroppingup/2016/09/29/on-farm-organic-no-till-planted-soybean-in-rolled-cover-crop-mulch/ Accessed March 2017.

Campbell, C.A. and Zentner, R.P. 1993. Soil organic matter as influenced by crop rotations and fertilization. Soil Sci. Soc. Am. J. 57: 1034-1040.

Chaney, K., Swift, R.S. 1984. The influence of organic matter on aggregate stability in some British soils. J. Soil Sci. 35:223-230.

Clark, A. (ed.) 2007. Managing cover crops profitably. 3rd ed. National SARE Outreach Handbook Series Book 9. National Agricultural Laboratory, Beltsville, MD.

Clark, M.S., Horwath, W.R., Shennan, C., and Scow, K.M. 1998. Change in soil chemical properties resulting from organic and low-input farming practices. Agron. J. 90: 662-671.

Moebius-Clune, B.N., Moebius-Clune, D.J., Gugino, B.K., Idowu, O.J., Schindelbeck, R.R., Ristow, A.J., van Es, H.M., Thies, J.E., Shayler, H.A., McBride, M.B., Wolfe, D.W., and Abawi, G.S. 2016. Comprehensive Assessment of Soil Health. The Cornell Framework Manual. Training Manual. School of Integrative Plant Science. Ithaca, New York.

Culley, J.L.B. 1993. Density and compressibility. In M. R. Carter ed. Soil Sampling and Methods of Analysis, Canadian Society of Soil Science, Lewis Publishers, Boca Raton, Florida. pgs. 529-539.

Daraghmeh, O.A., Jensen, J.R., Petersen, C.T., 2009. Soil structure stability under conventional and reduced tillage in a sandy loam. Geoderma 150, 64–71.

Donahue, R.L., Miller R.W. and Shickluna, J.C. 1983. Soils- An introduction to soils and plant growth. Prentice Hall Inc. New Jersey.

Earl, R. 1997. Prediction of trafficability and workability from soil moisture deficit. Soil Till. Res. 40: 155-168.

Egli, D.B., 1993. Cultivar maturity and potential yield of soybean. *Field Crops Res.,* 32: 147-158.

Einhellig, F.A. and Leather, G.R. 1988. Potentials for exploiting allelopathy to enhance crop production. J. Chem. Ecol. 14: 1829-1844.

Entz, M. H., Guilford, R. and Gulden, R. 2001. Crop yield and soil nutrient status on 14 organic farms in the eastern portion of the northern great plains. Can. J. Plant Sci. 81: 351–354.

Eusufzai, M.K., and Fujii, K. 2012. Effect of organic matter amendment on hydraulic and pore charateristics of a clay loam soil. OJSS 2: 372-381 http://dx.doi.org/10.4236/ojss.2012.24044 Published Online December 2012 (http://www.SciRP.org/journal/ojss)

Forage and Corn Variety Evaluation Task Group. Atlantic Forage Guide. Forage and Corn Variety Evaluation Task Group, Atlantic Canada.

Flowers, M.D., and Lal, R. 1998. Axle load and tillage effects on soil physical properties and soybean grain yield on a mollic ochraqualf in northwest Ohio. Soil Till. Res. 48: 21-35.

Forcella, F. 2013. Short- and full-season soybean in stale seedbeds versus rolled-crimped winter rye mulch. Ren. Agr. Food Sys.

Frostegård, A., Bååth, E., 1996. The use of phospholipid fatty acid analysis to estimate bacterial and fungal biomass in soil. Biology and Fertility of Soils 22, 59-65.

Frostegård, Å., Bååth, E., Tunlio, A., 1993. Shifts in the structure of soil microbial communities in limed forests as revealed by phospholipid fatty acid analysis. Soil Biology and Biochemistry 25, 723-730.

Frostegård, Å., Tunlid, A., Bååth, E., 2011. Use and misuse of PLFA measurements in soils. Soil Biology and Biochemistry 43, 1621-1625.

Gomiero, T., Pimentel, D., and Paoletti, M.G. 2011. Environmental impact of different agricultural management practices: Conventional vs. organic agriculture. Crit. Rev. Plant Sci. 30: 95-124.

Grant, C. A., Flaten, D. N., Tomasiewicz, D. J. and Sheppard, S. C. 2001. The importance of early season phosphorus nutrition. Can. J. Plant Sci. 81: 211–224.

Gregorich, E.A., Angers, D.A., Campbell, C.A., Carter, M.R., Drury, C.F., Ellert, B.H., Groenevelt, P.H., Holmstrom, D.A. Monreal, C.M., Rees, H.W., Voroney, R.P. and Vyn, T.J. 1995. Changes in soil organic matter. *in* D.F Acton and L.J. Gregorich (eds.) The health of our soils - toward sustainable agriculture in Canada. Centre for Land and Biological Resources Research, Research Branch, Agriculture and Agri-Food Canada, Ottawa, Ont.

Guide to Corn Hybrid Selection 2015. http://www.gov.pe.ca/agriculture/Corn

Hudson, B.D. 1994. Soil organic matter and available water capacity. J. Soil and Water Cons. 49: 189-194.

Gregorich, E.G. and Beare, M.H. 2007. Physically uncomplexed organic matter *in* M.R. Carter and E.G. Gregorich edt. pgs. 811-819. Soil Sampling and Methods of Analysis, Second Edition. CRC Press 2007

Hajabbasi, M.A. and Schumacher, T.E. 1994. Phosphorus effects on root growth and development in two maize genotypes. Plant Soil 158: 39-46.

Hakansson, I., Voorhees, W. B. and Riley, H. 1988. Vehicle and wheel traffic influencing soil compaction and crop response in different traffic regimes. Soil Tillage Res. **11**: 239–282.

Jarecki, M. and Lal, R. 2003. Crop management for soil carbon sequestration. Crit. Rev. Plant Sci. 22: 471-502.

Kaiser, D.E., Rosen, C.J., and Lamb, J.A. 2016. Potassium for crop production. University of Minnesota Extension. FO-6794-D. Accessed March 24, 2017.

Karlen, D.L., Varvel, G.E., Bullock, D.G., and Cruse, R.M. 1994. Crop rotations for the 21st century. Advances in Agronomy 53: 1-45.

Liang, B., Lehmann, J., Solomon, D., Kinyangi, J., Grossman, J., O'Neill, B., Skjemstad, J.O., Thies, J., Luizao, F. J., Petersen, J. and Neves, E.G. 2006. Black carbon increases cation exchange capacity in soils. Soil Sci. Soc. Am. J. 70: 1719-1730.

Loughin, T.M., 2006. Improved experimental design and analysis for long-term experiments. Crop Science 46, 2492-2502.

Lynch D., Bertheleme, C. and Nass H. 2006. Evaluating field pea and cereal mixtures for high protein organic feed production. . http://www.organicagcentre.ca/ResearchDatabase/res_soils_pea_cereal.asp

Lynch, D.H., Voroney, R.P., and Warman, P.R. 2006. Use of ^{13}C and ^{15}N natural abundance techniques to characterize carbon and nitrogen dynamics in composting and in compost-amended soils. Soil Biology and Biochemistry, 38:103-114.

Lynch, D.H., Sharifi, M., Hammermeister, A. and Burton, D. 2012. Nitrogen management in organic potato production. *In* He, edt. Sustainable Potato Production: Global Case Studies. Springer Science. pgs 209-231.

McRae, K.B., and Ryan, D.A.J., 1996. Design and planning of long-term experiments. Canadian Journal of Plant Science 76, 595-602.

Main, D., Sanderson, K.R., Ivany, J.A., and Fillmore, S.A.E. (inprep) Comparison of conventional and organic herbicides banded for weed control in carrots (*Daucus carota* L.) Can. J. Plant Sci.

Maynard, D.G. and Kalra, Y.P. 1993. Nitrate and exchangeable ammonium nitrogen. In M. R. Carter ed. Soil Sampling and Methods of Analysis, Canadian Society of Soil Science, Lewis Publishers, Boca Raton, Florida. pgs. 25-38.

Mengel K. and Kirby, E.A. 1992. Principles of Plant Nutrition. International Potash Institute, Worblaufen-Bern Switzerland.

Michanec J. 1996. Use of sorghum-sudangrass for improved yield and quality of vegetables produced on mineral and muck soils in New York: Part II- Sudan trials on muck soils in Orange County. Research report. Cornell Cooperative Extension. Ithaca, NY.

Nelson, K., MacKenzie, J. and Hammermeister, A. 2010. Winter and spring cereal production in the Maritimes. OACC. *Final Research Report E2010-56*

Nielsen, U.N., Ayres, E., Wall, D.H., Bardgett, R.D., 2011. Soil biodiversity and carbon cycling: A review and synthesis of studies examining diversity-function relationships. European Journal of Soil Science 62, 105-116.

Noronha C., 2017. Personal communication.

Nyiraneza, J., N'Dayegamiye, A., Chantigny, M.H., and Laverdiere, M.R. 2009. Variations in corn yield and nitrogen uptake in relation to soil attributes and nitrogen availability indicies. Soil Sci. Soc. Am. J. 73: 317-327.

Nyiraneza, J., M.C. Nolin, N. Ziadi, and A. N. Cambouris. 2011. Short-range Variability of NO_3^- and PO_4^{-3} Desorbed from Anionic Exchange Membranes. Soil Science Society of America Journal 75: 2242-2250.

Noronha, C. 2010. Corp rotation as a management tool for wireworms. Pest Management Centre Report - PRR- 07-030.

OMAFRA (Ontario Ministry of Agriculture, Food and Rural Affairs) 1998. Soil Fertility Handbook. Publication 611.

Parent, L.-E´ ., Bolinder, M. A. and Gallichand, J. 2009. Contribution of Regis R. Simard to phosphorus research in agroecosystems and future prospects. Can. J. Soil Sci. 89: 145_155.

PEI Analytical Laboratories. 2017. Soil and feed test laboratory rating tables.

PEI Department of Agriculture 2017. Barley and soybean statistics. www.gov.pe.ca/photos/original/af_stat_tab18.pdf Accessed March 2017.

PEI Department of Agriculture Wheat Yields, 2017. Wheat statistics. https://www.princeedwardisland.ca/sites/default/files/publications/af_stat_tab17.pdf Accessed March 2017.

Pendleton, J.W. and Hartwig, E.E., 1973. Management. In: B.E. Caldwell (Editor), Soybeans: Improvement, Production, and Uses, 1st edn. Agronomy, 16:211-237.

Perez, C., Dill-Macky, R., & Kinkel, L. L. (2008). Management of soil microbial communities to enhance populations of Fusarium graminearum-antagonists in soil. Plant and Soil, *302*(1-2), 53-69.

Peters, R.D., Sturtz, A.V., Carter, M.R. and Sanderson, J.B. 2003. Developing disease-suppressive soils through crop rotation and tillage management practices. Soil Tillage Res. 72. 181-192.

Reynolds, W.D. and Topp. G.C. 2008. Soil water desorption and imbibition: tension and pressure techniques. *In* M.R. Carter and E.G. Gregorish Ed. Soil Sampling and Methods of Analysis. 2nd edition. CRC Press, Boca Raton, FL, 981-997.

Ring R. and Warman, P.R. 1999. Phosphorus mineralization from three similar municipal solid waste composts subject to leaching. In P.R. Warman and B.R. Taylor Eds. Proceedings of the International Composting Symposium, Halifax, NS.

Robinson, R. G. 1980. The buckwheat crop in Minnesota. Bulletin 539. Agricultural Experiment Station, University of Minnesota, St. Paul.

Rodd, A.V., Papadopoulos, Y.A., Laflamme, L.F., McRae, K.B., Fillmore, S.A.E. and Wilson, R.W. 1999. Effect of rotational grazing on selected physical properties of a Gleyed Brunisolic Gray Luvisol loam in Nova Scotia. Can. J. Soil Sci. **79**: 117–125.

Rodd, A.V., Warman, P., Hicklenton, P., Webb, K., Halsey, R., Friesen, B., Breau, P., Antler, S., and Hennessey, T. 1999. Comparison of source-separated municipal solid waste compost and solid manure. In P.R. Warman and B.R. Taylor Eds. Proceedings of the International Composting Symposium, Halifax, NS.

Rodd, A.V., Warman, P.R., Hicklenton, P. and Webb, K. 2002. Comparison of N fertilizer, source separated municipal solid waste compost and semi-solid beef manure on the nutrient concentration in boot-stage barley and wheat tissue. Can. J. Soil Sci. 82: 33-43.

Russel, S. 1997. Plant Root Systems: Their function and interaction with the soil. McGraw-Hill, London.

Schenk, H.J., and Jackson, R.B. 2002. Rood depths, lateral root spreads and below-ground/above-ground allometrics of plants in water limited ecosystems. J. Ecol. 90: 480-494.

Schulte, R.P.O., Fealy, R., Creamer, R.E., Towers, W., Harty, T. and Jones, R.J.A. 2012. A review of the role excess soil moisture conditions in constraining farm practices under Atlantic conditions. Soil Use Manag 28: 580-589.

Sharifi, M., Lynch, D.H., Zebarth, B.J., Zheng, Z. and Martin R. C. 2009. Evaluation of nitrogen supply rate measured by in situ placement of plant root simulator™ probes as a predictor of nitrogen supply from soil and organic amendments in potato crop. Am. J. Pot. Res. 86: 356-366.

Sharpley, A.N., Chapra, S.C., Wedepohi, R., Sims, J.T., Daniel, T.C., and Reddy, Y.R. 1994. Managing agricultural phosphorus for protection of surface waters: Issues and options. 23: 437-451.

Sharpley, A.N., T. Daniel, T. Sims, J. Lemunyon, R. Stevens, and R. Parry. 2003. Agricultural Phosphorus and Eutrophication, 2nd ed. U.S. Department of Agriculture, Agricultural Research Service, ARS.149, 44 pp.

Simard, R. R., Beauchemin, S. and Haygarth, P.M. 2000. Potential for preferential pathways of phosphorus Transport. J. Environ. Qual. 29:97-105.

Standards Council of Canada. 2017. Laboratory Accreditation PEI Analytical Laboratories. Accredited Laboratory 424. http://palcan.scc.ca/SpecsSearch/SpecsSearchAction.do. Accessed March 18, 2017.

Statistics Canada. 2011 (November). Farm Cash Receipts. Catalogue No. 21-011-X.

van Es, H., Schindelbeck, R., Ristow, A., Kurtz, K., and Fennell, L. 2016. Available water capacity. School of Interactive Plant Science, Cornell University, Factsheet No. 16-05.

Voorhees, W.B. 1983. Relative effectiveness of tillage and natural forces in alleviating wheel-induced soil compaction. Soil Sci. Soc. Am. J. 47:129-133.

SN International 2015. Genstat for Windows 18th Edition. VSN International, Hemel Hempstead, UK. Web page: Genstat.co.uk

Wander, M.M., Traina, S.J., Stinner, B.R. and Peters, S.E. 1994. Organic and conventional management effects on biologically active soil organic matter pools. Soil Sci. Soc. Am J. 58: 1130-1139.

Ward, S.E., Ostle, N.J., McNamara, N.P., Bardgett, R.D., 2010. Litter evenness influences short-term peatland decomposition processes. Oecologia 164, 511-520.

Wardle, D.A., Bardgett, R.D., Klironomos, J.N., Setälä, H., Van Der Putten, W.H., Wall, D.H., 2004. Ecological linkages between aboveground and belowground biota. Science 304, 1629-1633.

Weil, R., Islam, K.R., Stine, M.A., Gruver, J.B., Samson-Liebig, S.E. 2003. Estimating active carbon for soil quality assessment: A simple method for laboratory and field use. Amer. J. Alternative Agric. 18:3-17.

Wright, T., Wheeler, B., and McKinlay S. 1998. Forage Sorghum-Sudan Grass. OMAFRA Fact Sheet 08/98 Agdex 126

Appendix A. Schematic of the amendments added to the various crops in the rotation based on the staggered start in 2013.

Table A-1. Schematic of the amendments added to the various crops in the rotations based on the staggered start in 2013.

	Dairy Farmers of PEI		PEI Elevator Corporation		Red Soil Organics		PEI Certified Organic Producers Co-Op	
	1	2	1	2	1	2	1	2
Block 1								
Spring								
Crop	Red Clover	Oat/Peas/Vetch	Oat/Peas/Vetch	Wheat	Sorg. Sudan Grass	Sorg. Sudan Grass	Red Clover	Red Clover
Amendment	Compost	Compost	Compost	Compost	Compost	Compost	Compost	Compost
Rate	25,000 kg/ha	25,000 kg/ha	25,000 kg/ha	50,000 kg/ha	25,000 kg/ha	25,000 kg/ha	25,000 kg/ha	25,000 kg/ha
Analysis	0.5-0.16-0.36	0.5-0.16-0.36	0.5-0.16-0.36	0.5-0.16-0.36	0.5-0.16-0.36	0.5-0.16-0.36	0.5-0.16-0.36	0.5-0.16-0.36
Fall								
Amendment		LD Manure			Compost		LD Manure	
Rate		7000 kg/ha			25,000 kg/ha		7000 kg/ha	
Analysis		0.0025-0.006-0.008			0.45-0.1-0.28		0.0025-0.006-0.008	
Block 2								
Spring								
Crop	Buckwheat	Buckwheat	Wheat	Early Soybean	Pea	Soybean	Wheat	Wheat
Amendment	Compost	Compost	Compost	Compost	Compost	Compost	Compost	Compost
Rate	25,000 kg/ha	25,000 kg/ha	50,000 kg/ha	25,000 kg/ha	25,000 kg/ha	25,000 kg/ha	50,000 kg/ha	50,000 kg/ha
Analysis	0.5-0.16-0.36	0.5-0.16-0.36	0.5-0.16-0.36	0.5-0.16-0.36	0.5-0.16-0.36	0.5-0.16-0.36	0.5-0.16-0.36	0.5-0.16-0.36
Fall								
Amendment					LD Manure			
Rate					7000 kg/ha			
Analysis					0.0025-0.006-0.008			
Block 3								
Spring								
Crop	Corn Silage	Corn Silage	Grain Corn	Potato	Carrot	Carrot	Potato	Squash
Amendment	Compost	Compost	Compost	Compost	Compost	Compost	Compost	Compost
Rate	75,000 kg/ha	75,000 kg/ha	25,000 kg/ha	25,000 kg/ha	25,000 kg/ha	25,000 kg/ha	25,000 kg/ha	25,000 kg/ha
Analysis	0.5-0.16-0.36	0.5-0.16-0.36	0.5-0.16-0.36	0.5-0.16-0.36	0.5-0.16-0.36	0.5-0.16-0.36	0.5-0.16-0.36	0.5-0.16-0.36
Amendment			Nutriwave					
Rate			1000 kg/ha					
Analysis								
Block 4								
Spring								
Crop	Soybean	Soybean	Early Soybean	Wheat	Soybeans	Edible Beans	Barley	Barley
Amendment	Compost	Compost	Compost	Compost	Compost	Compost	Compost	Compost
Rate	25,000 kg/ha	25,000 kg/ha	25,000 kg/ha	50,000 kg/ha	25,000 kg/ha	25,000 kg/ha	25,000 kg/ha	25,000 kg/ha
Analysis	0.5-0.16-0.36	0.5-0.16-0.36	0.5-0.16-0.36	0.5-0.16-0.36	0.5-0.16-0.36	0.5-0.16-0.36	0.5-0.16-0.36	0.5-0.16-0.36
Fall								
Amendment				LD Manure				
Rate				7000				
Analysis								

Table A-2. Schematic of the amendments added to the various crops in the rotations based on the staggered start in 2014.

	Dairy Farmers of PEI		PEI Elevator Corporation		Red Soil Organic		PEI Certified Organic Producers Co-Op	
	1	2	1	2	1	2	1	2
Block 1								
Spring								
Crop	Silage Corn	Silage Corn	Grain Corn	Potato	Carrots	Carrots	Potato	Squash
Amendment	LD Manure	Compost	Nutri-wave	Compost			Compost	Compost
Rate	10500	25000	1500	50,000			25000	25000
Analysis	0.31-0.06-0.29	0.3-0.7-0.15	4-1-2	0.3-0.7-0.15			0.3-0.7-0.15	0.3-0.7-0.15
Block 2								
Spring								
Crop	Red Clover	Oats/Peas/Vetch	Oats/Peas/Vetch	W Wheat	Sorghum Sudan Grass	Sorghum Sudan Grass	Red Clover	Red Clover
Amendment				Compost		LD Manure		
Rate				25,000		10500		
Analysis				0.31-0.06-0.29		0.31-0.06-0.29		
Fall								
Amendment		LD Manure			Compost	Compost	LD Manure	
Rate		10,500			25,000	25,000	10500	
Analysis		0.31-0.06-0.29			0.3-0.07-0.15	0.3-0.07-0.15	0.31-0.06-0.29	
Block 3								
Spring								
Crop	Soybean	Soybean	Early Soybean	W Wheat	Barley	Barley		
Amendment					Compost	Compost		
Rate					25,000 kg/ha	25,000 kg/ha		
Analysis					0.31-0.06-0.29	0.31-0.06-0.29		
Amendment				Compost				
Rate				25,000 kg/ha				
Analysis				0.31-0.06-0.29				
Block 4								
Spring								
Crop	Buckwheat	Buckwheat	W Wheat	Early Soybean	Peas	W Rye	Sp Wheat	Sp Wheat
Amendment	Compost	Compost	Nutriwave				Compost	Compost
Rate	25,000 kg/ha	25,000 kg/ha	750 kg/ha				50,000 kg/ha	50,000 kg/ha
Analysis	0.31-0.06-0.29	0.31-0.06-0.29	4-1-2				0.31-0.06-0.29	0.31-0.06-0.29
Fall								
Amendment					LD Manure			
Rate					10,500 kg/ha			
Analysis								

Table A-3. Schematic of the amendments added to the various crops in the rotations based on the staggered start in 2015.

	Dairy Farmers of PEI		PEI Elevator Corporation		Red Soil Organic		PEI Certified Organic Producers Co-Op	
	1	2	1	2	1	2	1	2
Block 1								
Spring								
Crop	Soybean	Soybean	Early Soybean	W Wheat	Barley	Barley	Soybean	Edible Bean
Amendment				Compost	Compost	Compost		
Rate				25000 kg/ha	25000 kg/ha	25000 kg/ha		
Analysis				0.3-0.05-0.1	0.3-0.05-0.1	0.3-0.05-0.1		
Block 2								
Spring								
Crop	Corn Silage	Corn Silage	Grain Corn	Potato	Carrot	Carrot	Potato	Squash
Amendment	LD Manure	Compost	Nutri-Wave	Compost			Compost	Compost
Rate	14000 kg/ha	25000 kg/ha	1500 kg/ha	50000 kg/ha			25000 kg/ha	25000 kg/ha
Analysis	0.3-0.06-0.3	0.3-0.05-0.1		0.3-0.05-0.1			0.3-0.05-0.1	0.3-0.05-0.1
Block 3								
Spring								
Crop	Buckwheat	Buckwheat	W Wheat	Early Soybean	Pea	Rye	Wheat/Red Clover	Wheat/ Red Clover
Amendment	Compost	Compost	Nutri-Wave				Compost	Compost
Rate	25000 kg/ha	25000 kg/ha	750 kg/ha				50000 kg/ha	50000 kg/ha
Analysis	0.3-0.05-0.1	0.3-0.05-0.1	4-1.2-2.5				0.3-0.05-0.1	0.3-0.05-0.1
Fall								
Amendment					LD Manure			
Rate					14000 kg/ha			
Analysis					0.3-0.6-0.3			
Block 4								
Spring								
Crop	Red Clover	Oats/Peas/Vetch	Oats/Peas/Vetch	W Wheat	Sorghum Sudan Grass	Sorghum Sudan Grass	Red Clover	Red Clover
Amendment				Compost		LD Manure		
Rate				25000 kg/ha		14000 kg/ha		
Analysis				0.3-0.05-0.1		0.3-0.06-0.3		
Fall								
Amendment		LD Manure			Compost	Compost	LD Manure	
Rate		14000 kg/ha			25000 kg/ha	25000 kg/ha	14000 kg/ha	
Analysis		0.3-0.06-0.3			0.3-0.05-0.1	0.3-0.05-0.1	0.3-0.06-0.3	

Table A- 4. Schematic of the amendments added to the various crops in the rotations based on the staggered start in 2016.

	Dairy Farmers of PEI		PEI Elevator Corporation		Red Soil Organic		PEI Certified Organic Producers Co-Op	
	1	2	1	2	1	2	1	2
Block 1								
Spring								
Crop	Buckwheat	Buckwheat	W Wheat	Early Soybean	W Wheat	W rye	Wheat	Wheat
Amendment	Compost	Compost	Nutri-Wave				Compost	Compost
Rate	25000 kg/ha	25000 kg/ha	750 kg/ha				50000 kg/ha	50000 kg/ha
Analysis	0.42-0.06-0.14	0.42-0.06-0.14	4-1.2-2.5				0.42-0.06-0.14	0.42-0.06-0.14
Fall								
Amendment					LD Manure			
Rate					10000 kg			
Analysis					0.33-0.06-0.29			
Block 2								
Spring								
Crop	Soybean	Soybean	Early Soybean	W Wheat	Barley	Barley	Soybean	Edible Bean
Amendment				Compost	Compost	Compost		
Rate				25000 kg/ha	25000 kg/ha	25000 kg/ha		
Analysis				0.42-0.06-0.14	0.42-0.06-0.14	0.42-0.06-0.14		
Block 3								
Spring								
Crop	Red Clover	Oats/Peas/Vetch	Red Clover	W Wheat	Sorghum	Sorghum	Red Clover	Red Clover
Amendment				Compost		LD Manure		
Rate				25000 kg/ha		1000 kg/ha		
Analysis				0.42-0.06-0.14		0.33-0.06-0.29		
Fall								
Amendment		LD Manure			Compost	Compost	LD Manure	
Rate		1000 kg/ha			25000 kg/ha	25000 kg/ha	1000 kg/ha	
Analysis		0.33-0.06-0.29			0.42-0.06-0.14	0.42-0.06-0.14	0.33-0.06-0.29	
Block 4								
Spring								
Crop	Corn Silage	Corn Silage	Corn	Potato	Carrot	Carrot	Potato	Squash
Amendment	LD Manure	Compost	Nurti-Wave	Compost			Compost	Compost
Rate	10000 kg/ha	25000 kg/ha	1500 kg/ha	50000 kg/ha			25000 kg/ha	25000 kg/ha
Analysis	0.33-0.06-0.29	0.42-0.06-0.14	4-1.2-2.5	0.42-0.06-0.14			0.42-0.06-0.14	0.42-0.06-0.14

Appendix B. Amount and timing of carbon, nitrogen, phosphorus and potassium additions to each block in the various years.

Table B-1 . Amount and timing of carbon (C), nitrogen (N), phosphorus (P), and potassium (K) additions to each block.

2013		Dairy Farmers of PEI		PEI Elevator Corporation		Red Soil Organics		PEI Certified Organic Producers Co-Op	
		1	2	1	2	1	2	1	2
Block 1	kg/ha								
Spring	C	1400	1400	1400	2800	1400	1400	1400	1400
Spring	N	112.5	112.5	112.5	225	112.5	112.5	112.5	112.5
Spring	P	40	40	40	80	40	40	40	40
Spring	K	90	90	90	180	90	90	90	90
Fall	C		168			1250	1250	168	
Fall	N		17.5			112.5	112.5	17.5	
Fall	P		4.2			25	25	4.2	
Fall	K		21			70	70	21	
Total Applied	C	1400	1568	1400	2800	2650	2650	1568	1400
Total Applied	N	112.5	130	112.5	225	225	225	130	112.5
Total Applied	P	40	44.2	40	80	65	65	44.2	40
Total Applied	K	90	111	90	180	160	160	111	90
Block 2									
Spring	C	1400	1400	2800	1400	1400	1400	2800	2800
Spring	N	112.5	112.5	225	112.5	112.5	112.5	225	225
Spring	P	40	40	80	40	40	40	80	80
Spring	K	90	90	180	90	90	90	180	180
Fall	C					168			
Fall	N					17.5			
Fall	P					4.2			
Fall	K					21			
Total Applied	C	1400	1400	2800	1400	1568	1400	2800	2800
Total Applied	N	112.5	112.5	225	112.5	130	112.5	225	225
Total Applied	P	40	40	80	40	44.2	40	80	80
Total Applied	K	90	90	180	90	111	90	180	180
Block 3									
Spring	C	4200	4200	1880	1568	1400	1400	1568	1400
Spring	N	337.5	337.5	152.5	130	112.5	112.5	130	112.5
Spring	P	120	120	50	44.2	40	40	44.2	40
Spring	K	270	270	110	111	90	90	111	90
Total Applied	C	4200	4200	1880	1568	1400	1400	1568	1400
Total Applied	N	337.5	337.5	152.5	130	112.5	112.5	130	112.5
Total Applied	P	120	120	50	44.2	40	40	44.2	40
Total Applied	K	270	270	110	111	90	90	111	90
Block 4									
Spring	C	1400	1400	1400	2800	1400	1400	1400	1400
Spring	N	112.5	112.5	112.5	225	112.5	112.5	112.5	112.5
Spring	P	40	40	40	80	40	40	40	40
Spring	K	90	90	90	180	90	90	90	90
Fall	C				168				
Fall	N				17.5				
Fall	P				4.2				
Fall	K				21				
Total Applied	C	1400	1400	1400	2968	1400	1400	1400	1400
Total Applied	N	112.5	112.5	112.5	242.5	112.5	112.5	112.5	112.5
Total Applied	P	40	40	40	84.2	40	40	40	40
Total Applied	K	90	90	90	201	90	90	90	90

Table B-2. Amount and timing of carbon (C), nitrogen (N), phosphorus (P), and potassium (K) additions to each plot within each block .

2014		Dairy Farmers of PEI		PEI Elevator Corporation		Red Soil Organics		PEI Certified Organic Producers Co-Op	
		1	2	1	2	1	2	1	2
Block 1	**kg/ha**								
Spring	**C**	357	812.5	171	1625	0	0	812.5	812.5
Spring	**N**	32.55	75	60	150	0	0	75	75
Spring	**P**	6.3	17.5	15	35	0	0	17.5	17.5
Spring	**K**	30.45	37.5	30	75	0	0	37.5	37.5
Total Applied	**C**	357	812.5	171	1625	0	0	812.5	812.5
Total Applied	**N**	32.55	75	60	150	0	0	75	75
Total Applied	**P**	6.3	17.5	15	35	0	0	17.5	17.5
Total Applied	**K**	30.45	37.5	30	75	0	0	37.5	37.5
Block 2									
Spring	**C**	0	0	0	812.5	0	357	0	0
Spring	**N**	0	0	0	75	0	32.55	0	0
Spring	**P**	0	0	0	17.5	0	6.3	0	0
Spring	**K**	0	0	0	37.5	0	30.45	0	0
Fall	**C**	0	357	0	0	812.5	812.5	357	0
Fall	**N**	0	32.55	0	0	75	75	32.55	0
Fall	**P**	0	6.3	0	0	17.5	17.5	6.3	0
Fall	**K**	0	30.45	0	0	37.5	37.5	30.45	0
Total Applied	**C**	0	357	0	812.5	812.5	1169.5	357	0
Total Applied	**N**	0	32.55	0	75	75	107.55	32.55	0
Total Applied	**P**	0	6.3	0	17.5	17.5	23.8	6.3	0
Total Applied	**K**	0	30.45	0	37.5	37.5	67.95	30.45	0
Block 3									
Spring	**C**	0	0	0	0	812.5	812.5	0	0
Spring	**N**	0	0	0	0	75	75	0	0
Spring	**P**	0	0	0	0	17.5	17.5	0	0
Spring	**K**	0	0	0	0	37.5	37.5	0	0
Fall	**C**	0	0	0	812.5	0	0	0	0
Fall	**N**	0	0	0	75	0	0	0	0
Fall	**P**	0	0	0	17.5	0	0	0	0
Fall	**K**	0	0	0	37.5	0	0	0	0
Total Applied	**C**	0	0	0	812.5	812.5	812.5	0	0
Total Applied	**N**	0	0	0	75	75	75	0	0
Total Applied	**P**	0	0	0	17.5	17.5	17.5	0	0
Total Applied	**K**	0	0	0	37.5	37.5	37.5	0	0
Block 4									
Spring	**C**	812.5	812.5	85.5	0	0	0	1625	1625
Spring	**N**	75	75	30	0	0	0	150	150
Spring	**P**	17.5	17.5	7.5	0	0	0	35	35
Spring	**K**	37.5	37.5	15	0	0	0	75	75
Fall	**C**	0	0	0	0	357	0	0	0
Fall	**N**	0	0	0	0	32.55	0	0	0
Fall	**P**	0	0	0	0	6.3	0	0	0
Fall	**K**	0	0	0	0	30.45	0	0	0
Total Applied	**C**	812.5	812.5	85.5	0	357	0	1625	1625
Total Applied	**N**	75	75	30	0	32.55	0	150	150
Total Applied	**P**	17.5	17.5	7.5	0	6.3	0	35	35
Total Applied	**K**	37.5	37.5	15	0	30.45	0	75	75

Table B-3 . Amount and timing of carbon (C), nitrogen (N), phosphorus (P), and potassium (K) additions to each plot within each block.

2015		**Dairy Farmers of PEI**		**PEI Elevator Corporation**		**Red Soil Organics**		**PEI Certified Organic Producers Co-Op**	
		1	**2**	**1**	**2**	**1**	**2**	**1**	**2**
Block 1	**kg/ha**								
Spring	**C**	1325	0	0	476	0	0	1325	1325
Spring	**N**	75	0	0	42	0	0	75	75
Spring	**P**	12.5	0	0	8.4	0	0	12.5	12.5
Spring	**K**	25	0	0	42	0	0	25	25
Fall	**C**	0	0	0	0	0	0	0	0
Fall	**N**	0	0	0	0	0	0	0	0
Fall	**P**	0	0	0	0	0	0	0	0
Fall	**K**	0	0	0	0	0	0	0	0
Total Applied	**C**	1325	0	0	476	0	0	1325	1325
Total Applied	**N**	75	0	0	42	0	0	75	75
Total Applied	**P**	12.5	0	0	8.4	0	0	12.5	12.5
Total Applied	**K**	25	0	0	42	0	0	25	25
Block 2									
Spring	**C**	1325	75	1325	150	2650	0	0	1325
Spring	**N**	75	30	75	60	150	0	0	75
Spring	**P**	12.5	9	12.5	18	25	0	0	12.5
Spring	**K**	25	18.75	25	37.5	50	0	0	25
Fall	**C**	0	0	0	0	0	0	0	0
Fall	**N**	0	0	0	0	0	0	0	0
Fall	**P**	0	0	0	0	0	0	0	0
Fall	**K**	0	0	0	0	0	0	0	0
Total Applied	**C**	1325	75	1325	150	2650	0	0	1325
Total Applied	**N**	75	30	75	60	150	0	0	75
Total Applied	**P**	12.5	9	12.5	18	25	0	0	12.5
Total Applied	**K**	25	18.75	25	37.5	50	0	0	25
Block 3									
Spring	**C**	0	1325	2650	1325	0	2650	0	476
Spring	**N**	0	75	150	75	0	150	0	42
Spring	**P**	0	12.5	25	12.5	0	25	0	8.4
Spring	**K**	0	25	50	25	0	50	0	42
Fall	**C**	476	0	0	0	0	0	0	1350
Fall	**N**	42	0	0	0	0	0	0	100
Fall	**P**	8.4	0	0	0	0	0	0	75
Fall	**K**	42	0	0	0	0	0	0	100
Total Applied	**C**	476	1325	2650	1325	0	2650	0	1826
Total Applied	**N**	42	75	150	75	0	150	0	142
Total Applied	**P**	8.4	12.5	25	12.5	0	25	0	83.4
Total Applied	**K**	42	25	50	25	0	50	0	142
Block 4									
Spring	**C**	0	0	1325	0	0	0	0	0
Spring	**N**	0	0	75	0	0	0	0	0
Spring	**P**	0	0	12.5	0	0	0	0	0
Spring	**K**	0	0	25	0	0	0	0	0
Fall	**C**	0	0	0	476	476	0	0	1350
Fall	**N**	0	0	0	42	42	0	0	100
Fall	**P**	0	0	0	8.4	8.4	0	0	75
Fall	**K**	0	0	0	42	42	0	0	100
Total Applied	**C**	0	0	1325	476	476	0	0	1350
Total Applied	**N**	0	0	75	42	42	0	0	100
Total Applied	**P**	0	0	12.5	8.4	8.4	0	0	75
Total Applied	**K**	0	0	25	42	42	0	0	100

Table B-4. Amount and timing of carbon (C), nitrogen (N), phosphorus (P), and potassium (K) additions to each plot within each block in 2016.

2016		**Dairy Farmers of PEI**		**PEI Elevator Corporation**		**Red Soil Organics**		**PEI Certified Organic Producers Co-Op**	
		1	**2**	**1**	**2**	**1**	**2**	**1**	**2**
Block 1	**kg/ha**								
Spring	**C**	2275	2275	75	0	0	75	4550	4550
Spring	**N**	105	105	30	0	0	30	210	210
Spring	**P**	15	15	9	0	0	9	30	30
Spring	**K**	35	35	18.75	0	0	18.75	70	70
Fall	**C**	0	0	0	0	280	0	0	0
Fall	**N**	0	0	0	0	33	0	0	0
Fall	**P**	0	0	0	0	6	0	0	0
Fall	**K**	0	0	0	0	29	0	0	0
Total Applied	**C**	2275	2275	75	0	280	75	4550	4550
Total Applied	**N**	105	105	30	0	33	30	210	210
Total Applied	**P**	15	15	9	0	6	9	30	30
Total Applied	**K**	35	35	18.75	0	29	18.75	70	70
Block 2									
Spring	**C**	0	0	0	2275	2275	2275	0	0
Spring	**N**	0	0	0	105	105	105	0	0
Spring	**P**	0	0	0	15	15	15	0	0
Spring	**K**	0	0	0	35	35	35	0	0
Fall	**C**	0	0	0	0	0	0	0	0
Fall	**N**	0	0	0	0	0	0	0	0
Fall	**P**	0	0	0	0	0	0	0	0
Fall	**K**	0	0	0	0	0	0	0	0
Total Applied	**C**	0	0	0	2275	2275	2275	0	0
Total Applied	**N**	0	0	0	105	105	105	0	0
Total Applied	**P**	0	0	0	15	15	15	0	0
Total Applied	**K**	0	0	0	35	35	35	0	0
Block 3									
Spring	**C**	0	0	0	2275	0	280	0	0
Spring	**N**	0	0	0	105	0	33	0	0
Spring	**P**	0	0	0	15	0	6	0	0
Spring	**K**	0	0	0	35	0	29	0	0
Fall	**C**	0	280	0	0	2275	2275	280	0
Fall	**N**	0	33	0	0	105	105	33	0
Fall	**P**	0	6	0	0	15	15	6	0
Fall	**K**	0	29	0	0	35	35	29	0
Total Applied	**C**	0	280	0	2275	2275	2555	280	0
Total Applied	**N**	0	33	0	105	105	138	33	0
Total Applied	**P**	0	6	0	15	15	21	6	0
Total Applied	**K**	0	29	0	35	35	64	29	0
Block 4									
Spring	**C**	280	2275	150	4550	0	0	2275	2275
Spring	**N**	33	105	60	210	0	0	105	105
Spring	**P**	6	15	18	30	0	0	15	15
Spring	**K**	29	35	37.5	70	0	0	35	35
Fall	**C**	0	0	0	0	0	0	0	0
Fall	**N**	0	0	0	0	0	0	0	0
Fall	**P**	0	0	0	0	0	0	0	0
Fall	**K**	0	0	0	0	0	0	0	0
Total Applied	**C**	280	2275	150	4550	0	0	2275	2275
Total Applied	**N**	33	105	60	210	0	0	105	105
Total Applied	**P**	6	15	18	30	0	0	15	15
Total Applied	**K**	29	35	37.5	70	0	0	35	35

Appendix C. Field Activities

Table C- 1. Field activities for Organic Rotation Experiment 2013 all crops.

2013 crop	Potatoes	Carrots	Squash	Grain corn	Silage Corn	Soybean	Early Soybean	Peas	Black Beans	Barley	Spr Wheat	W Wheat	Spr Wheat	Buchwheat	Red Clover	Sorghum Sudangrass	O/P/V
Plot #	117,120	122,123	124	118	119,121	129,131,132	112,128	110	125	126,127	111,113	107,114,130	126,127	109,116	101,104,105	103,106	102,108
Activity																	
spring plow at startup	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	Yes	yes
Apply Nutri-wave				27-May								May 27-114					
apply R1 compost*	24-May	24-May	24-May	24-May	24-May	24-May	24-May	24-May	24-May	24-May	24-May	24-May	24-May	24-May	24-May	24-May	24-May
apply compost R2*											28-May						
apply R3 compost*					28-May												
disc harrow 2x	20-May	20-May	20-May	20-May	20-May	20-May	20-May	20-May	20-May	20-May	20-May	20-May	20-May	20-May	20-May	20-May	20-May
field cultivate 1X	28-May	28-May	28-May	28-May	28-May	28-May	28-May	28-May	28-May	28-May	28-May	28-May	28-May	28-May	28-May	28-May	28-May
row shaped carrot rows		27-May															
plant	30-May	08-Jun	12-Jun	05-Jun	05-Jun	04-Jun	04-Jun	29-May	04-Jun	29-May	29-May	03-Jun	03-Jun	04-Jun		12-Jun	29-May
Apply liq dairy manure	28-May																
blind harrow	16-Jun		20-Jun	Jun 12,16	jun 12,16	12-Jun	12-Jun	03-Jun		03-Jun	03-Jun						
roll plot									04-Jun								
fingerweed										16-Jun	16-Jun	16-Jun					16-Jun
seed clover with brillion											17-Jun						
in-row cultivate				25-Jun	25-Jun	25-Jun	25-Jun		25-Jun								
in-row cultivate				04-Jul	04-Jul	04-Jul	04-Jul		04-Jul								
in-row cultivate		19-Jul		10-Jul	10-Jul												
side-knives on rows		15-Jul															
hand weeded tops of row		10-Jul															
hilled rows	15-Jul	01-Aug															
in row cultivate	28-Jun		30-Jul	17-Jul	17-Jul		30-Jul		30-Jul								
spray entrust/parasol	12-Jul																
spray parasol	24-Jul																
spray parasol	06-Aug																
flail			26-Sep											01-Aug	18-Jul	Jul 18& sept 9	
flail and disc 1x															Aug 4-125,132		
rotovate 1x														01-Aug			
plant																	
harvest	15-Sep	16-Oct	24-Sep	16-Oct	02-Oct	21-Oct	21-Oct	13-Aug 18-Sep	21-Oct	10-Sep	10-Sep	10-Sep	10-Sep		Aug 2-101,105		Aug 13-102
apply liq dairy manure								26-Sep				Sept 26-130			Sept 26-101		Sept 26-102
apply compost R1																Sept 26-103	
disced 2x	24-Sep		08-Oct		08-Oct		08-Oct	03-Sep		03-Sep		Sep3-107,118	03-Sep				Sep 3-129
plant oil radish								04-Oct				Oct4-114&130					Oct 4-102
plant wrye	Oct 4-120		04-Oct		04-Oct					Oct 4-126							
plant w wheat	Oct 4 - 117						04-Oct										
* Compost R1	25000kg/ha																
* Compost R2	50000kg/ha																
* Compost R3	75000kg/ha																

Table C- 2. Field activities for Organic Rotation Experiment 2014 all crops.

2014 Crop	Potatoes	Carrots	Squash	Grain Corn	Silage Corn	No-till Soybean	Soybean	Peas	Black Beans	Barley	Spr Wheat	W Wheat	W Rye	Buchwheat	Red Clover	Sorghum Sudangrass	O/P/V
Plot #	107,101	103,106	105	108	102,104	119,120,121	118,130	127	124	122,123	125,132	128,117,112	126	129,131	109,111, 113	110,115	116,114
Activity																	
soil sample	15-May	15-May	15-May	15-May	15-May	15-May	15-May	15-May	15-May	15-May	15-May	15-May	15-May	15-May	15-May	15-May	15-May
frost seed red clover												May 11-130					
mouldboard plow	20-May	20-May	20-May	20-May	20-May												
apply Compost R1*	21-May		21-May		102-may 21					21-May		112- May 21		21-May			
apply compost R2*	107- May 21										21-May						
disc harrow 2x	21-May	21-May	21-May	21-May	21-May		21-May	21-May	21-May	21-May	21-May			21-May		21-May	
Apply Nutri-wave				20-May								128-May 20					
No till plant																	21-May
field cultivate 1x	29-May		29-May	29-May	29-May				29-May					29-May		29-May	
roll)prepare false seedbed)			29-May	29-May	29-May				29-May					29-May		29-May	
row shaped carrot rows		26-May															
plant	29-May	09-Jun	10-Jun	04-Jun	04-Jun	18-Jun	30-May	29-May	09-Jun	30-May	30-May			05-Jun		10-Jun	29-May
Apply liq dairy manure					104- May 22											115-May 22	
blind harrow			Jun 9&23	09-Jun	09-Jun		04-Jun		04-Jun	04-Jun	04-Jun			04-Jun		04-Jun	
flame		13-Jun															
fingerweed										23-Jun	23-Jun						09-Jun
seed clover with brillion											23-Jun						
in-row cultivate	06-Jul	06-Jul	10-Jul	10-Jul	10-Jul		10-Jul		10-Jul								
in-row cultivate			18-Jul	18-Jul	18-Jul		18-Jul		18-Jul								
Replant				20-Jun	20-Jun											10-Jul	
side-knives on rows		10-Jul															
hand weeded tops of row		10-Jul															
hilled rows	15-Jul	28-Jul															
in row cultivate		10-Jul	30-Jul	17-Jul	17-Jul		30-Jul		30-Jul								
spray entrust/parasol	14-Jul																
spray K2SiO 2x			Sept 4,5														
spray parasol	24-Jul																
spray parasol	04-Aug																
disc 1x														13-Aug			13-Aug
plant red clover														131-Aug 21			
plant buckwheat															111,113-Aug 21		
flail	18-Aug														08-Aug	01-Oct	
harvest	24-Sep	06-Nov	29-Sep	06-Nov	09-Oct	06-Oct	24-Sep	25-Aug	28-Oct	26-Aug	26-Aug	13-Aug	26-Aug				24-Jul
apply liq dairy manure	101-sept27							27-Sep							113 Sept 27		Aug 21 - 116
apply compost R1												Oct 7-117				07-Oct	
rototill	Oct 1-101		01-Oct		Oct 15		25-Oct			Aug 28&Oct 1		117/128-aug 27	27-Aug				
plant oil radish												117/128-aug 28	28-Aug				Aug 26 - 116
plant w rye	Oct 1 - 101		01-Oct		15-Oct					01-Oct							
plant w wheat	Sept 26-107						26-Sep										

* Compost R1 25000kg/ha

* Compost R2 50000kg/ha

Table C- 3. Field activities for Organic Rotation Experiment 2015 all crops.

2015 Crop	Potatoes	Carrots	Squash	Grain Corn	Silage Corn	No-till Soybean	Soybean	Peas	Black Beans	Barley	Spr Wheat	W Wheat	W Rye	Buchwheat	Red Clover	Sorghum sudangrass	O/P/V
Plot #	112,113	110,115	111	114	109,116	101,102,104	108,117	123	105	103,106	120,124	107,118,130	122	119,121	125,131,132	126,127	128,129
Activity																	
Apply Nutri-wave												May 11-118					
frost seed red clover												May 11-130					
mouldboard plow	25-May	25-May	25-May	25-May	25-May												
apply Compost R1*	May 27-113		27-May		May 27-116					27-May		May 27-107,130		27-May			
apply compost R2*	May 27-112										27-May						
disc harrow 2x	27-May	27-May	27-May	27-May	27-May		27-May	27-May	27-May	27-May	27-May			27-May		27-May	27-May
Apply Nutri-wave				27-May													
row shaped carrot rows		27-May															
plant	28-May	08-Jun		04-Jun	04-Jun	30-Jun	29-May	29-May	02-Jun	29-May	29-May			02-Jun		16-Jun	29-May
Apply liq dairy manure					June 2-109											June 2-126	
blind harrow			09-Jun	09-Jun	09-Jun		09-Jun	02-Jun		02-Jun	02-Jun						
blind harrow																	
flame		15-Jun															
fingerweed										15-Jun	17-Jun						
seed clover with brillion											17-Jun						
blind harrow			15-Jun	15-Jun	15-Jun												
in-row cultivate	06-Jul	06-Jul	13-Jul	06-Jul	06-Jul		06-Jul		06-Jul								
replant				23-Jun	23-Jun											07-Jul	
side-knives on rows		07-Jul															
hand weeded tops of row		15-Jul															
hilled rows	15-Jul	04-Aug															
in row cultivate			30-Jul	17-Jul	17-Jul		30-Jul		30-Jul								
spray entrust/parasol	14-Jul																
spray K2SiO 2x			aug 7,30														
spray parasol	24-Jul																
spray parasol/pyganic	04-Aug																
flail															Aug 4-131		
flail and disc 1x														30-Jul	Aug 4-125,132		
plant														04-Aug			
notill seed buckwheat															aug 20-125,132		
harvest				12-Nov				18-Sep		31-Aug	18-Sep	31-Aug	31-Aug				
flail																23-Sep	
harvest	24-Sep	28-Oct	28-Sep	12-Nov	07-Oct	crop lost	08-Oct		28-Oct								24-Jul
apply liq dairy manure								30-Sep							Sept 30-132		Sep 30-129
apply compost R1																16-Oct	
flail tops to prevent seed														24-Sep			
disced 2x	24-Sep		08-Oct		08-Oct		08-Oct	03-Sep		03-Sep		Sep3-107,118	03-Sep				Sep 3-129
plant oil radish								22-Sep				Sep3-107,118	03-Sep				Sep 3-129
plant wrye	Sep 24-113		09-Oct		09-Oct					24-Sep							
plant w wheat	Sept 24-112						09-Oct										

* Compost R1	25000kg/ha
* Compost R2	50000kg/ha

Table C- 4. Field activities for Organic Rotation Experiment 2016 all crops.

2016 Crop	Potatoes	Carrots	Squash	Grain Corn	Silage Corn	No-till Soybean	Soybean	Peas	Black Beans	Barley	Spr Wheat	W Wheat	W Rye	Buchwheat	Red Clover	Sorghum Sudangrass	O/P/V
Plot #	130 132	126 127	125	128	129 131	109 113 116	107 114	106	111	110 115	101 105	108 112 117	103	102 104	120 121 124	122 123	118 119
Activity																	
frost seed red clover												Apr 19-117					
mouldboard plow	01-May	01-May	01-May	01-May	01-May												
disc harrow 1x	02-May																
field cultivate 2x	02-May	19-May	19-May	19-May	19-May		19-May	19-May	19-May	19-May	19-May			19-May		19-May	19-May
apply Compost R1*	May 19-132		19-May		May 19-129					19-May		May 5-112,117		05-May			
apply compost R2*	May 20-130										20-May						
disc harrow 2x		12-May	12-May	12-May	12-May		12-May	12-May	12-May	12-May	12-May			12-May		12-May	12-May
Apply Nutri-wave	06-May			06-May								May 6-108	06-May				
row shaped carrot rows		24-May															
plant	10-May	20-Jun	10-Jun	24-May	24-May	07-Jun	26-May	07-Jun	24-May	20-May	20-May			07-Jun		21-Jun	20-May
Apply liq dairy manure					May 11-131											May 11-122	
blind harrow			09-Jun	09-Jun	09-Jun		09-Jun	02-Jun		02-Jun	02-Jun						
blind harrow			30-May	30-May	30-May		30-May		30-May							25-May	25-May
flame	02-Jun	27-Jun															
fingerweed										07-Jun	07-Jun						
seed clover with brillion											07-Jun						
in-row cultivate	16-Jun			16-Jun	16-Jun		16-Jun		16-Jun								
in-row cultivate				12-Jul	12-Jul		12-Jul		12-Jul								
replant		22-Jun		23-Jun	23-Jun											05-Jul	
side-knives on rows		27-Jul															
hand weeded tops of row		07-Jul															
hilled rows	20-Jun	15-Aug															
spray entrust/parasol	05-Jul																
spray K2SIO 2x			Aug 28,sept6														
spray parasol	18-Jul																
spray parasol	27-Jul																
flail	30-Aug														12-Jul	14-Oct	
disc 1x														04-Aug			
Disc 2x														24-Aug			
harvest	07-Sep	09-Nov	05-Oct	31-Oct	17-Oct	07-Oct	07-Oct	07-Sep	07-Oct	24-Aug	07-Sep	24-Aug	24-Aug				28-Jul
apply liq dairy manure								20-Oct							Oct 120-120		Oct 20-119
apply compost R1																20-Oct	
disced 2x	24-Sep		20-Oct				20-Oct	02-Oct		02-Oct			02-Oct				Aug 25-119
plant oil radish														25-Aug			Aug 25-119
plant wrye	22-Sep		20-Oct					05-Oct		05-Oct			05-Oct				
plant w wheat	Sept 24-112						20-Oct										
notill plant w wheat									20-Oct								

* Compost R1	25000kg/ha
* Compost R2	50000kg/ha
Nutri- wave on Potatoes	3500 kg/ha