Irrigated Potato Rotation: Results after 6 Years of Research

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Demand for process potatoes has grown steadily since 1962, with a more rapid rise in the past 10 years (Fig. 1). With limited land base for expansion, there is growing pressure to shorten potato rotations from the traditionally recommended four-year cycle to three- or two-years. In reducing the rotation cycle, there is a corresponding increased risk of tuber yield and quality loss associated with higher incidence of disease and insect pests, and lower soil quality due to wind and water erosion.

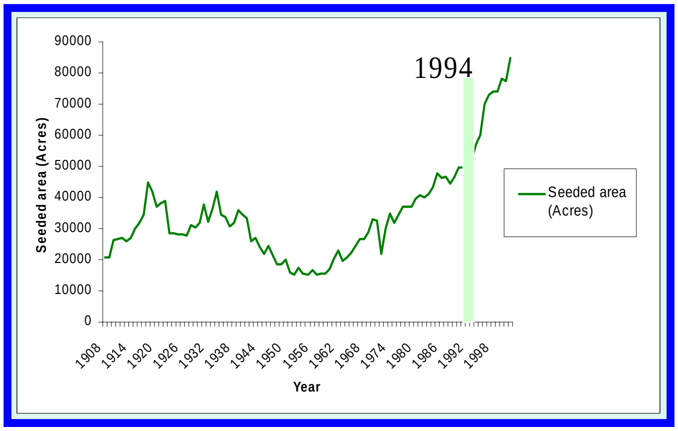

Figure 1. Expansion of irrigated acres in Manitoba (Source: Manitoba Agriculture and Food, 2003)

Potato management is intensive and costly, especially when compared to the crops that it is frequently in rotation with (Table 1). Taking into account the fixed costs associated with land, specialized equipment, irrigation infrastructure and storage, the total cost of producing an acre of potatoes is almost $1,800.00 when operating and fixed costs are combined (Table 2). This translates into a start-up cost of $2.3 million for a 450 acre irrigated operation.

Table 1. Input cost comparison ($/acre) for potato and representative small grains crops.
Source: Manitoba Agriculture and Food, 2003.

Selected Costs / acre	**Potato**	**Wheat**	**Canola**
Fungicide & Insecticide	**180.00**	10.00	25.25
Seed & Seed treatment	**260.55**	17.00	23.38
Fertilizer	**67.10**	29.50	36.35

Producers can ill afford to make poor crop management decisions considering the magnitude of this investment. Unfortunately, there is very little information available to Manitoba potato producers relating to sustainable irrigated potato rotations specific to Manitoba soil and climatic conditions.

The Manitoba Irrigated Potato Rotation Research Project was established to help develop guidelines for sustainable irrigated potato production. Its specific objectives are to identify potato rotations that reduce the risk of yield and quality loss associated with pests and weeds, and to maintain or enhance soil quality, without compromising the profitability of potato production.

Table 2. Fixed and operating costs for potato and representative small grains crops.

Selected Costs / acre	**Potato**	**Wheat**	**Canola**
Total operating cost	**1,285.15**	121.91	156.32
Total fixed cost	**385.78**	55.64	55.64
Total cost of production	**1,758.43**	**192.55**	**229.96**

Source: Manitoba Agriculture and Food, 2003.

Experimental design

In 1997, a 4 ha area was selected on a Wellwood silt loam at MCDC-Carberry (pH: 7.0; EC: 0.24 dS m^{-1}; NO_3^--N: 49.5 kg ha^{-1} to 60 cm; P: 36.1 kg ha^{-1} to 15 cm; K: 585 kg ha^{-1} to 15 cm; $SO_4^=$: 61 kg ha^{-1} to 60 cm). A randomized complete block design (four replicates with 18 treatments/replicate) was established. Plot dimensions were 12.2 m by 24.4 m, with adjacent plots separated by a 2.1 m pathway, and replicates separated by a 6.1 m alleyway. (Plot sizes were subsequently reduced to 21.4 x 12.2 m in 1999 in order to facilitate equipment usage.)

Agronomic management

Uniformity trial (1997): Barley (cv. Bedford) was established across the entire area in 1997. Barley yield, soil properties (including soil texture, pH, EC, macronutrient and micronutrient concentrations), and weed populations were measured in each plot. This information was then used to characterize the site, and to configure the replicates for the rotation study.

Crop Rotation Study (1998 to 2001): In 1998, crop rotation treatments were initiated. Six crop rotations ranging in duration from two to four years, and containing a combination of oilseeds, cereals and legumes, are included in this study (Table 3).

Each phase of each rotation is present each year for a total of 18 treatments per replicate. Each year, crops are established as designated by the rotation treatment.

Potato (cv. Russet Burbank), wheat (cv. AC Barrie), oat (cv. AC Assiniboia), canola (cv. Independence in 1998; Invigor 2163 in 1999; Invigor 2153 in 2000 and 2001) and alfalfa (cv. Centurion) were established from mid May to mid-June. In 1998, annual alfalfa (cv. common) was established in those plots to be seeded to potatoes in 1999.

All crops were managed using best management practices with respect to tillage and seeding operations, nutrient management, and weed, insect and disease control. Spring tillage generally consisted of one pass with a tandem disc followed by one pass with a power harrow prior to potato establishment; for non-potato crops, only those plots following potato were tilled prior to crop establishment. Fall tillage was generally restricted to potato plots. Nitrogen, phosphorus, potassium and sulfur in the form of urea, monoammonium phosphate, potassium chloride and ammonium sulfate were applied at time of seeding as required based on soil analysis. In general, nitrogen and phosphorus were applied to all crops at time of establishment, potassium chloride was applied only to potatoes, and sulphur was applied to canola and sometimes to potato as required based on soil analysis. Recommended herbicides were applied as required to control weeds. For the potato crop, fungicides and insecticides were applied as required to control disease and insect pests including late blight and Colorado potato beetle. Alfalfa, where indicated by treatment, was terminated using a combination of herbicide application and tillage.

Equipment which allowed irrigation of individual potato plots was assembled on the plot area each year.

Table 3. Outline of rotation treatments.

	2 year	3 year	4 year
Cereal	Potato Wheat	Potato Oat Wheat	Potato Wheat Canola Wheat
Oilseed	Canola Wheat	Potato Canola Wheat	
Forage			Potato Alfalfa (Canola) Alfalfa Alfalfa

Soil and plant measurements

Soil characteristics:
In September 2001, soil was sampled in each phase of the rotations. Bulk density was measured (0-15 cm, 15-30 cm, 30-60 cm) using the core method with 3 samples per plot. Soil samples weighing approximately 2.5 kg were sampled (0-5 cm) in at 3 locations in each plot and dry sieved with a rotary sieve (>68.8 mm, 68.8 to 38 mm, 38 to 12.7 mm, 12.7 to 7.2 mm, 7.2 to 2.0 mm, 2.0 to 1.3 mm, 1.3 to 0.5 mm, < 0.5 mm). Crop residue cover (%) was measured in a 144 point grid in a 1 m^2 area from digital images of each plot.

Field saturated hydraulic conductivity was measured with a Guelph permeameter (Reynalds and Topp 1985). Penetration resistance (k Pa, 0 – 50 cm, 5 cm increments) was measured at 5 locations in each plot with a compaction meter (Spectrum Technologies, Inc, Plainfield, Illinois).
Selected treatments were sampled for organic carbon and nitrogen content of soil (0-15 cm, 15-30 cm, 30-60 cm), soil aggregates (1.3-2.0 mm diameter in 0-5 cm depth) in three locations per plot, and flax residues. Organic carbon and total nitrogen were measured with a Carlo Erba 2500 elemental analyser (Thermo Electron Corporation, Milan, Italy).

Three soil samples were collected in each plot for 0-15 cm, 15-30 cm, 30-60 cm depths, after harvest during September, 2001 in all phases of the rotation. Soil nitrate nitrogen (2 M CaCl extract), phosphate phosphorus (CH_3COONH_4 extract) and sulphate sulphur ($CaCl_2$ extract) were determined by colorimetric methods using a Technicon auto-analyzer with procedures described by McKeague (1981). Cation exchange capacity was measured with ammonium acetate extraction and automated colorimetric methods. Soil pH was measured in a 1:2 water ratio.

Statistical analysis was conducted in JMP software version 5.01a (SAS Institute Inc. 2002). Analysis of variance, based on a factorial design with 4 replicates, was used to analyze the effects of crop and rotation. Means were compared with orthogonal contrasts and Tukey's honestly significant difference for effects with a probability less the 5%. Plot averages of bulk density, aggregate size fractions, and penetration resistance were transformed (log base 10) to normalize the distribution of the data.

Plant characteristics:
Weed populations: Seedling and residual weed communities were sampled each year in mid-June and late July, respectively. Weeds were counted by species in 20 quadrats (0.5m x 0.5m) at each time of

assessment. Samples were taken in different locations within plots. Due to difficulties in field identification of species at the seedling stage, prostrate and redroot pigweed were combined as pigweed species and volunteer canola and mustard plus wild mustard were labelled as mustard species.

Disease incidence: Plots were examined throughout the growing seasons for the prevalence of disease. All crops, including potatoes, canola, canola underseeded to alfalfa, alfalfa and oats were rated for disease. Wheat, alfalfa and oat plots were rated around the end of July. Canola and potato plots were rated for diseases mid-August and mid-September, respectively. Wheat, oat and alfalfa ratings were based on approximately 25, 25 and 50 plants/plot, respectively. Canola, potato plant and potato tuber ratings were based on approximately 25, 25 and 50 plants/tubers per plot.

Crop yield and quality: Crop yield and quality was determined each year. Potato yield was subdivided into yield components as follows: marketable yield: tuber with diameter greater than 1.75 inches; main yield: tubers with a diameter 2 inches and greater.; small yield: tubers with diameter 1.75 inches but less than 2 inches, which are further divided into two sub-categories based on length: less than 3” long and greater than 3 inches long; bonus: diameter greater than 2 inches and weigh more than 10 ounces.

Economic analysis

The net return of different crop rotations was compared for irrigated potato production systems. A database, which includes crop inputs (seed, seed treatments, fertilizer, herbicide, insecticide, fungicide), machinery and implements, irrigation equipment, storage, insurance, input and output prices, and crop yield, has been developed to examine the profitability of each rotation. The data were analyzed using a computer model developed for this purpose using Econometric View software. This model produces a net income from each treatment. Because of some inconsistencies of the yield data in 1998, only 1999, 2000 and 2001 data were included in the analysis.

Results and Discussion:

Average yields during 1999 – 2003 for small and bonus tuber yields were about 20% of total yield, while main and marketable yields represented approximately 60 and 80% of total yield, respectively (Figure 2).

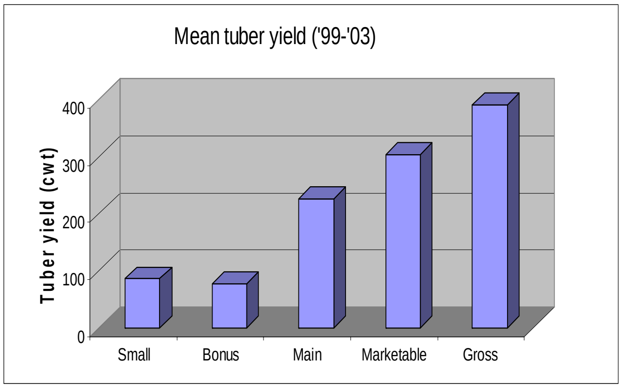

Figure 2. Mean tuber yields of the five main tuber classes from 1999 to 2003.

Change in yields over time

There has been a gradual increase in gross tuber yield over time (Figure 3). This was due to a combined increase in yield of main-grade and bonus tuber yields. Bonus tuber yield increased dramatically in 2003. By comparison, the yield of small tubers has declined since reaching a plateau in 2001.

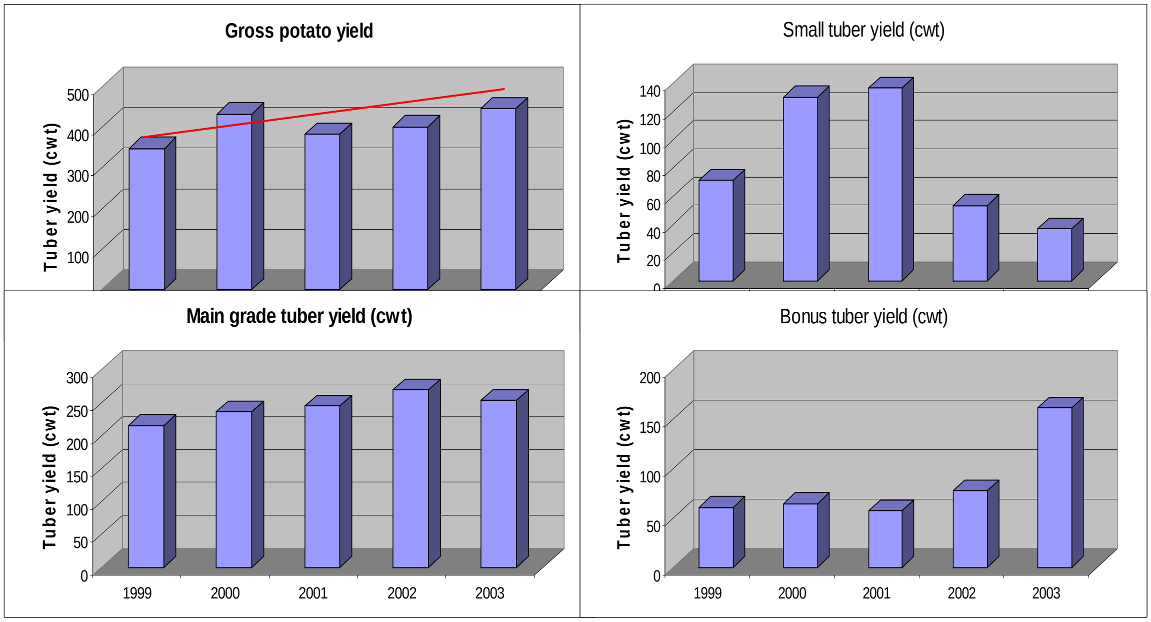

Figure 3. Change in gross, “main”, small, and “bonus” tuber yield over time.

As a result of these effects, except for 2001, marketable yield increased steadily since the beginning of the study.

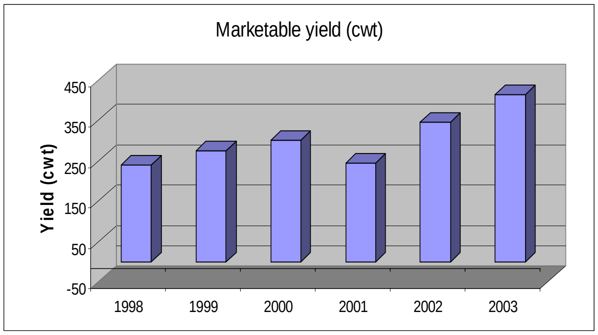

Figure 4. Change in the yield of “marketable” tubers over time.

Rotation effect on tuber yield

Tuber yields were influenced by rotation. Gross tuber yields were highest in the two-year canola (P-C) rotation and lowest in the three-year cereal (P-C) rotation (Fig. 5). This pattern reflected a combined rotation effect on “main” and “bonus” tuber yield. For example, high bonus yield and correspondingly low small tuber yield resulted in the P-C rotation having the highest marketable tuber yields. Similarly good main tuber yields combined with good bonus tuber yields resulted in the four-year alfalfa rotation (P-C-AAA) having the second highest yields. By comparison, while the three-year oilseed/cereal rotation (P-C-W) yielded the highest in terms of main-grade tubers, this rotation had lower bonus tuber yields, and so was amongst the lowest of the rotations in marketable yield.

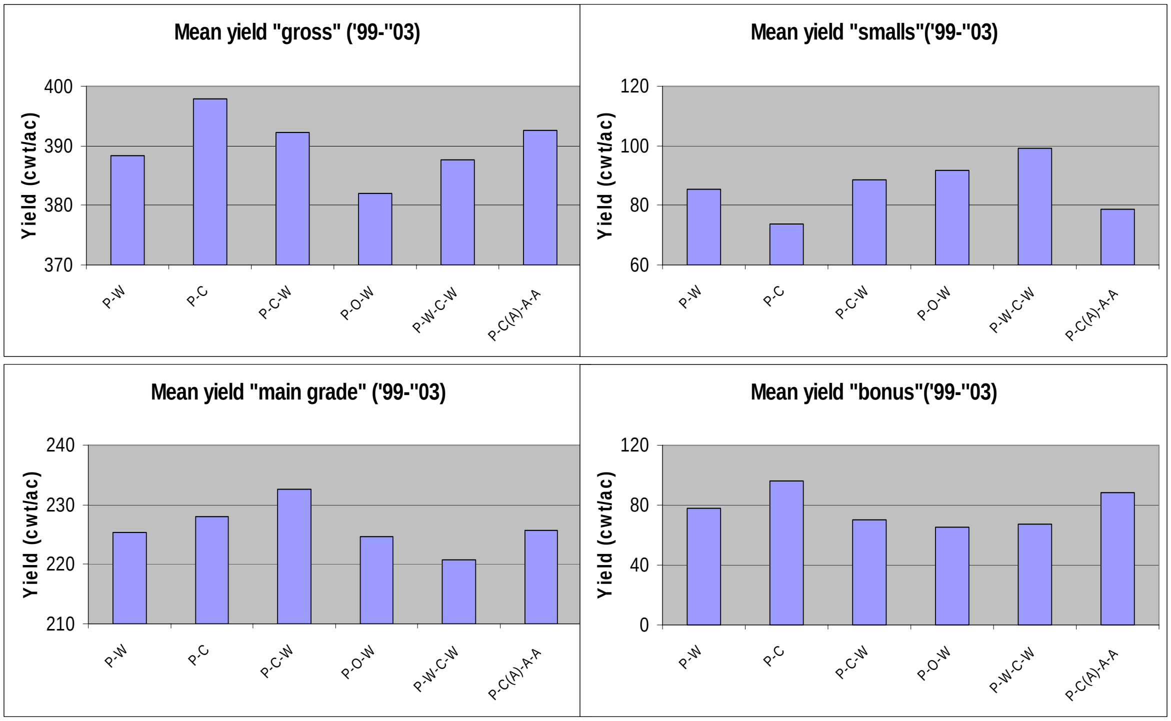

Figure 5. Rotation effect on mean gross, “small”, “main”, and “bonus” tuber yields.

Both the P-O-W rotation and the four-year mixed rotation (P-W-C-W) were the highest in small-tuber yield and the lowest main-tuber yield, and so, had the lowest marketable tuber yields.

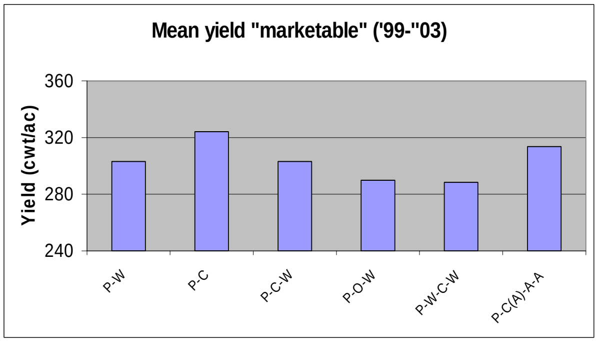

Figure 6. Rotation effect on mean marketable tuber yield.

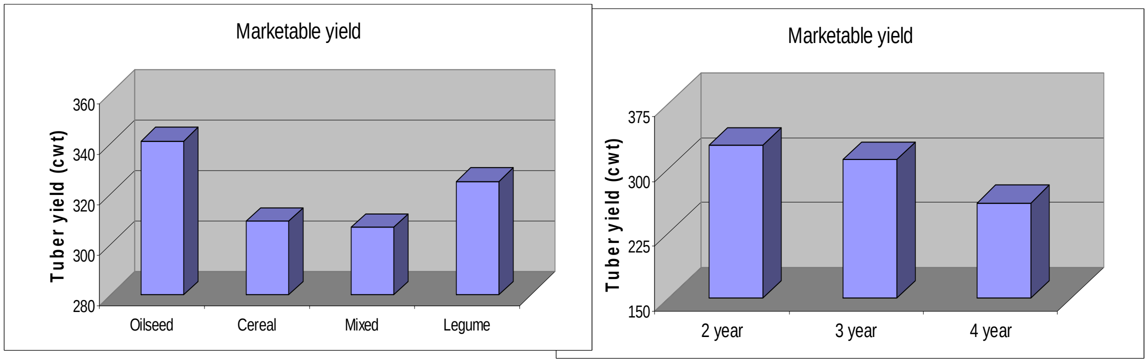
a) b)

Figure 7. Effect of a) crop species and b) rotation length on mean marketable tuber yield.

Effect of crop species and rotation length on tuber yield

Overall, potato rotations that included oilseed were superior in marketable tuber yield (Fig 7a). Both cereal and mixed (oilseed & cereal) rotations produced the lowest marketable yields. The marketable yield of the legume (alfalfa) rotation was intermediate to the other two.

The shorter the rotation, the higher the yield (Figure 7b). However, this observation should be qualified by noting that the four year legume rotation out-yielded the two, three and four-year rotations that included cereals.

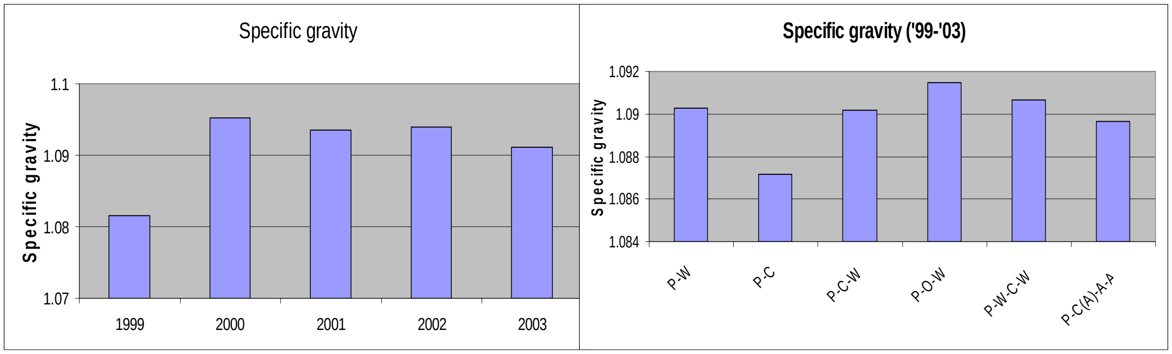

Figure 8. Effect of a) year, and b) rotation on mean tuber specific gravity from 1999 – 2003.

Tuber specific gravity

Tuber specific gravity has generally reflected the yield trends noted above. Specific gravity has stayed above 1.09 since 2000, but has been gradually decreasing since that time, commensurate with the yield increase over time (Fig. 8a). Similarly, lowest specific gravities occurred in the P-C and PC-A-A-A rotations, the two highest yielding rotations. Even the lowest specific gravity has been well above 1.08 (Fig. 8b).

Factors influencing tuber yield.

Weather and climate

It is important to understand not only that there have been changes in yield in response to time and to rotation, but also to know why they have occurred. It is too early, at this stage of the rotation study, to provide conclusive answers as to why yield has been affected by time and by rotation. However, patterns are emerging that help in understanding the variables responsible for treatment effects. It is probable that weather, and more broadly speaking, climate is a root cause for most of the effects. While it is tempting to speculate that the increase in yields observed over time are due to more favourable weather conditions, the weather records do not directly support this (Tables 4 & 5). Between the years 2000 to 2002, there has been increasingly less total

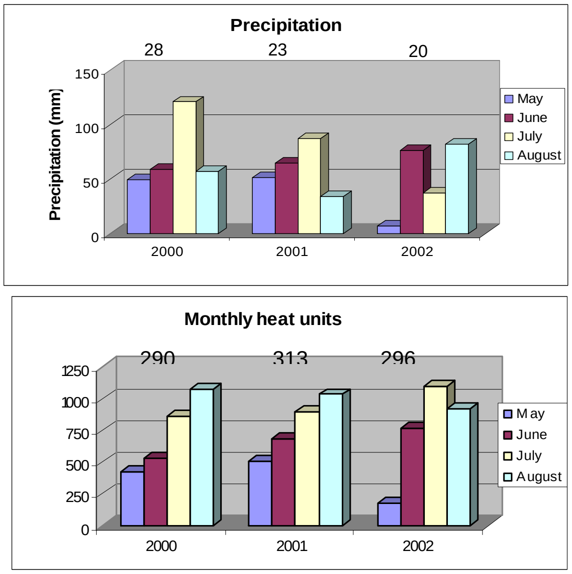

Figure 9. Monthly precipitation and heat units during the 2000 – 2002 growing seasons.

Table 4. Growing season precipitation - 2000-2002, and 30 year average.

	Precipitation (mm)				
	May	June	July	August	Total
2000	53	61	118	59	291
2001	55	122	38	22	237
2002	7.8	75	51	101	234
30 yr average	52	72.1	73.3	72.4	269

Table 5. Growing degree days (Tmin=5 C) from May to August, 2000-2002, and 30year average.

	Growing degree days				
	May	June	July	August	Total
2000	197	243	425	404	1270
2001	239	304	451	440	1436
2002	127	376	470	379	1354
30 yr average	200	328	416	382	1328

growing season precipitation, and there was no clear relationship between total growing season heat units and yield. Warmer weather should favour higher yields, whereas during 2000 – 2002 the highest yields occurred in the cooler years. However monthly trends may be more important than total seasonal trends. For example, higher yields may be associated with the pattern of drier, warmer Julys, coupled with cooler, wetter Augusts. These relationships will be examined in more detail upon completion of the second four-year rotation cycle.

Diseases

With most soil- and stubble-borne diseases, rotation with non-host crops reduces the amount of initial inoculum while continuous cropping can increase the inoculum load.

Black Leg

Blackleg (*Erwinia carotovora*) inoculum is borne on or in seed tubers and will survive for at least a short time in soil. The bacteria may also survive the winter in infected stems or tubers. The disease is most severe under cool, wet conditions at planting followed by high soil temperatures after plant emergence. Rainy weather favours disease development. The incidence of blackleg in the 1999 and 2000 potato plots was low and reflects a low inoculum level and/or environmental conditions not conducive to disease development. Blackleg levels were slightly higher in 2002 and 2003. Notable is a trend toward increasing incidence of Blackleg in the shorter rotations (Fig 10). This relationship has not resulted in yield loss to date.

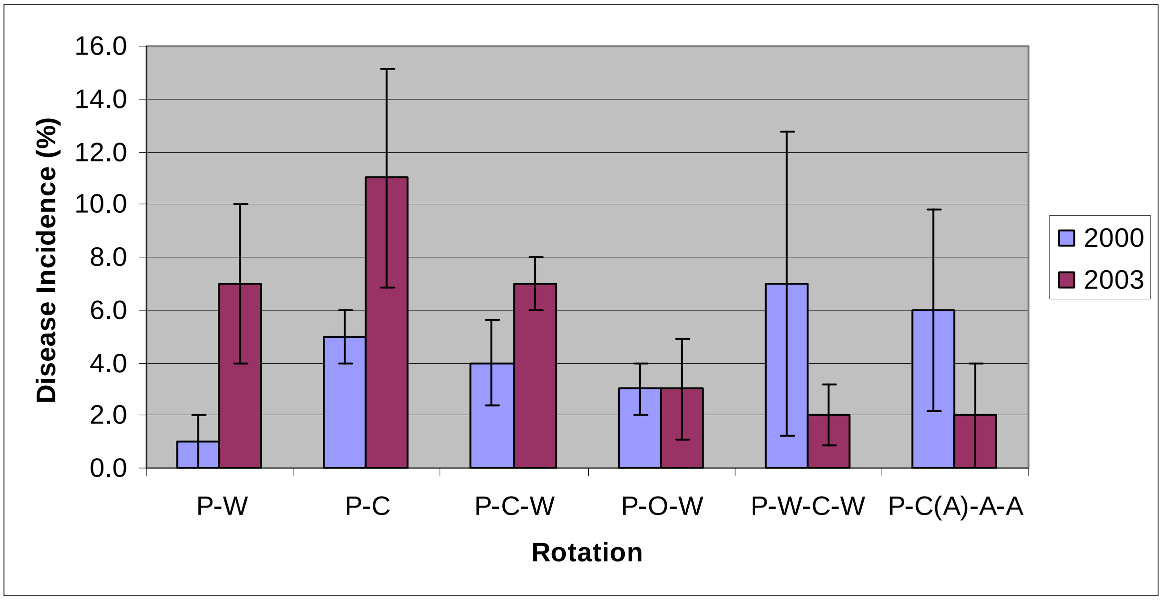

Figure 10. Rotation effect on Blackleg incidence in 2000 and 2003.

Early Blight

Early blight (*Alternaria solani*) is principally a disease of aging plant tissue. Alternating wet and dry conditions are most favourable for spore formation and dispersal. Fungal spores and mycelia overwinter in soil and on plant debris. Disease pressure is greatest with overhead irrigation or when frequent wetting with dew is common. In 2002, levels of early blight were greater than in 2001. Early blight was observed in more plants in the three year rotations than in the two year rotations. Similar results occurred in 1999 where the greatest level of early blight occurred in one of the three year rotations which was followed closely by slightly lower levels in the potato/wheat rotation. Primary infection of leaflets is caused by inoculum that survives in or on soil or plant debris. Spores can move long distances on air currents so that all but the most isolated fields will be exposed to some degree. With this in mind, it is possible that infected debris from other areas may have nullified any rotational benefit due to the presence of inoculum from sources outside the rotation study. Incidence of Early Blight was very low in 2003 (Fig. 11).

Rhizoctonia

Rhizoctonia solani is a ubiquitous fungus found in many soils. Rhizoctonia canker of potato, commonly called black scurf, is present in all potato growing areas and the pathogen, *Rhizoctonia solani*, overwinters as sclerotia on tubers, in soil or as mycelium in plant debris in the soil. In 2000, higher levels of Rhizoctonia were associated with shorter rotations (Fig. 13) In 2002 Rhizoctonia levels increased from those observed in 2001 but levels were generally low with diseased plants observed in all treatments but the P-W-C-W rotation. This trend has continued in 2003, but with low levels of the disease in four-year mixed rotation. The variability in results in any given year may be due to differences in natural inoculum between plots and/or environmental conditions. The generally low levels found recently may be related to unfavorable environmental conditions for the development of the disease. Crop rotation has been reported to reduce soilborne populations of *R. solani* but the length of rotation required varies with the environment. In a warm, dry climate, a one or two year rotation away from potatoes may be adequate whereas in a cool, wet climate, a longer rotation may be required.

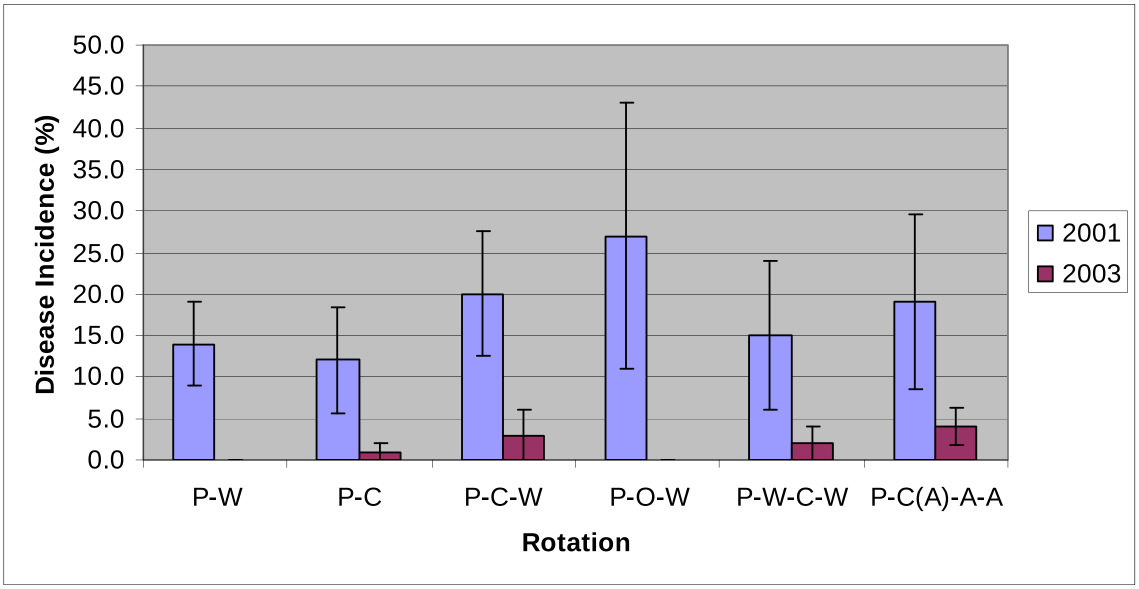

Figure 11. Rotation effects on incidence of Early Blight in 2001 and 2003.

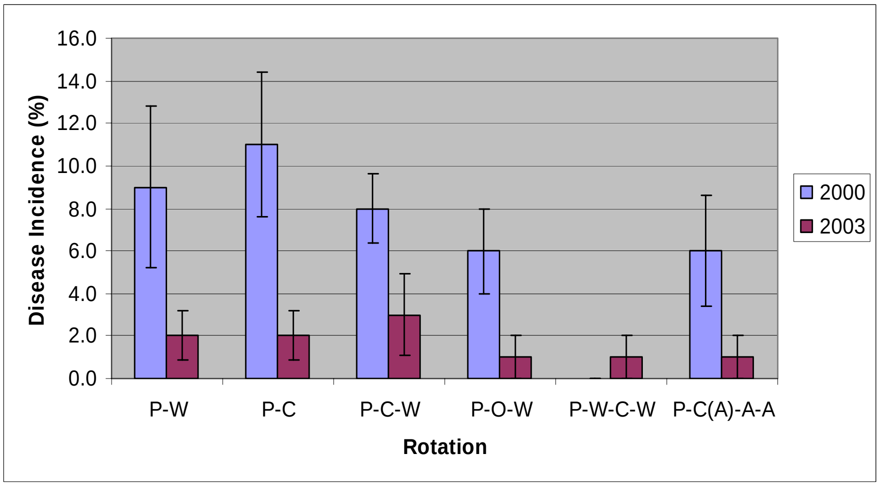

Figure 12. Effect of rotation on incidence of rhizoctonia in 2000 and 2003.

Fusarium Dry Rot

Fusarium fungal spores survive in decayed plant tissue in the soil. Sources of inoculum are infected and contaminated seed tubers and infested soil. Pathogen can survive for several years in soil. Long crop rotations can partially control disease. Disease incidence was highest in longer rotations during the early years of the rotation (Figure 13). In 2003, the incidence of Fusarium dry rot has decreased and is evenly spread among the rotations. There was less fusarium dry rot was observed in both years in the potato-oat-wheat rotation than in the potato-canola-wheat rotation.

In general the incidence of disease is lower in 2003 than in previous years. The dry, warm weather conditions in 2003 may have resulted in conditions less conducive to disease development. Further data collected from the Carberry site over the next few years will help to determine the impact of crop rotation on the incidence and severity of diseases in potatoes and in rotational crops in subsequent years.

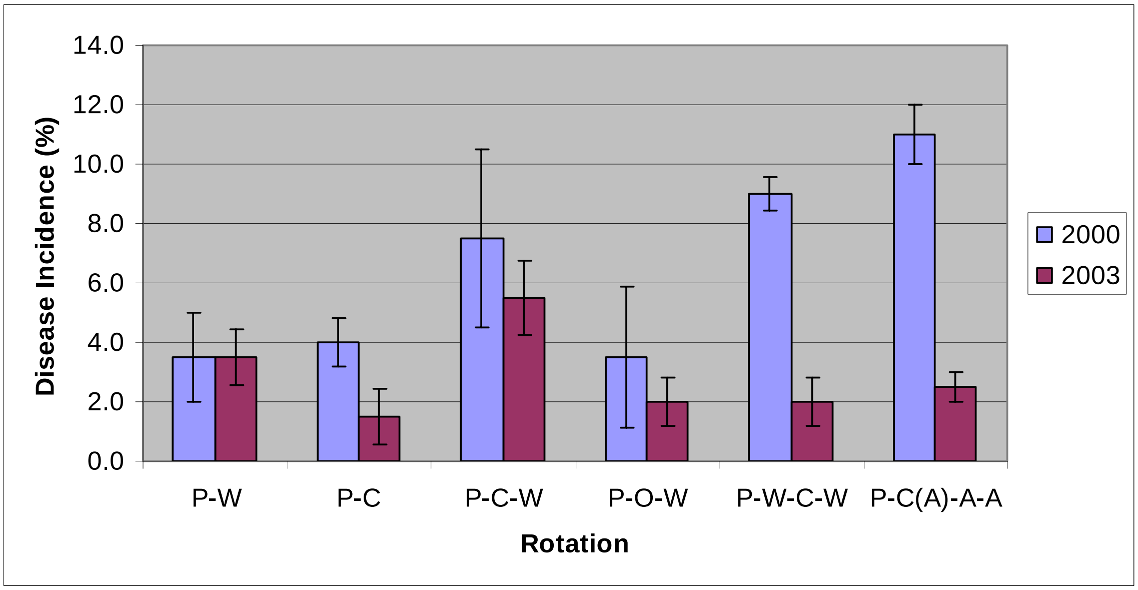

Figure 13. Rotation effect on incidence of Fusarium dry rot in 2000 and 2003.

Impact of weed populations

Weed density has tended to decrease over time when averaged over all rotations (Fig. 14). Longer rotations have tended to have lower weed populations, owing largely to a minimum tillage strategy in non-potato years. In the year of tillage, weed populations have exploded, emphasizing the need to develop effective weed control measures during the potato year. Lower weed populations associated with specific crops, eg., canola, may reflect the competitiveness of the crop or agronomic practices used in its management. There was considerable variation in potato weediness among rotations. For example, in 2001, while potatoes in the P-O-W rotations had an average weed density of 136 m^{-2}, potatoes in the potato-canola rotation had an average weed density of 16 m^{-2}.

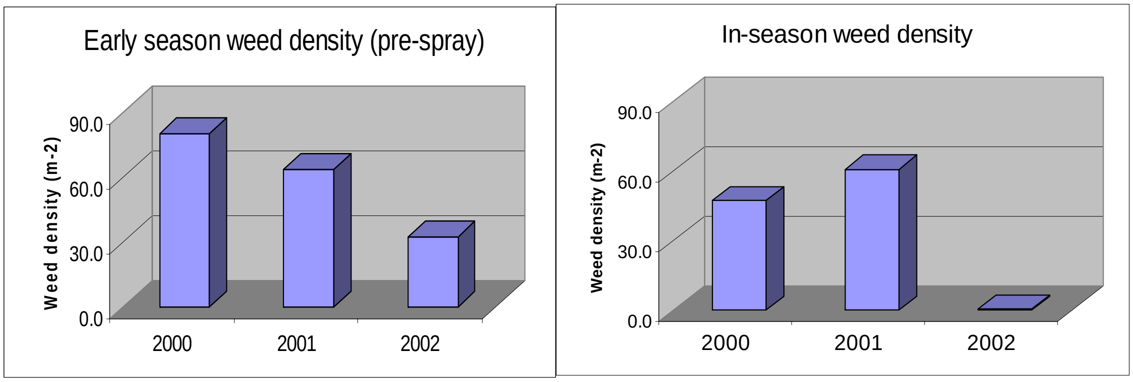

Figure 14. Change in a) early, and b) in-season weed densities in the potato year over time.

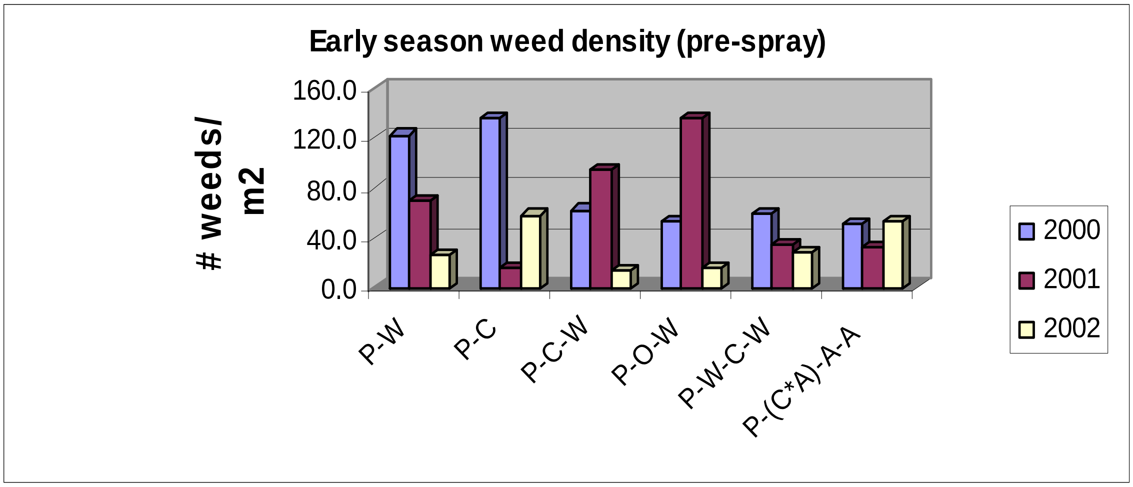

Figure 15. Rotation effects on early-season weed density in the potato year from 2000-2002.

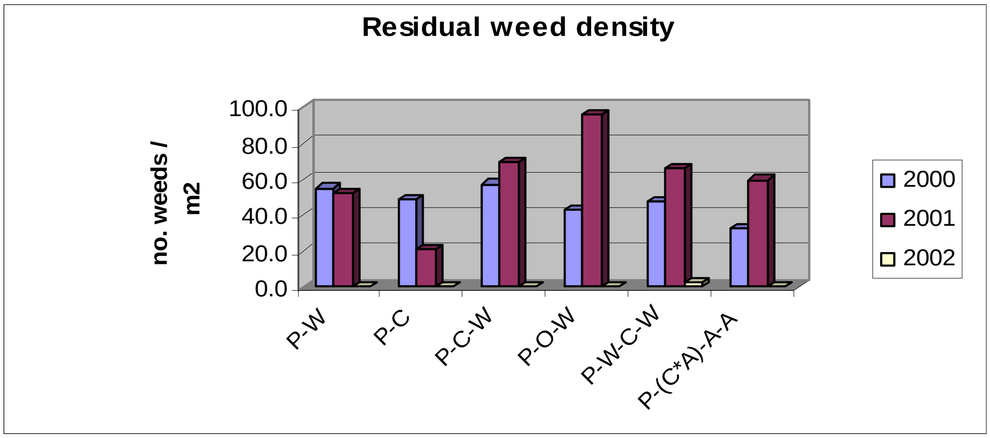

Figure 16. Rotation effect on in-season weed density in the potato year from 2000-2002.

The pattern of weed density in 2001 reflected 2001 yields, suggesting that weed density was responsible for yield variation. However, subsequent years have not indicated a similar trend.

Effect of potato rotations on soil quality

Residue Cover

Residue cover (%) in spring 2001 was near 100% for all treatments except potatoes where values ranged from 1 to 14%.

Aggregate Size Distribution

Dry-sieved aggregates <0.5 mm and 0.5-1.3 mm in diameter (%) were significantly higher in the potato phase of the potato-canola (alfalfa)-alfalfa-alfalfa rotations in 2001. Conversely aggregates 38 to 12.7 mm and 12.7 to 7.2 mm in diameter were significantly lower in the same phase and rotation. Soil moisture, at the time aggregates were sampled, was also lower in the potato phase of the potato-canola (alfalfa)-alfalfa-alfalfa rotations. The aggregate fraction < 0.5 mm (%) was significantly negatively correlated (r = - 0.67) with soil moisture across all phases of all rotations.

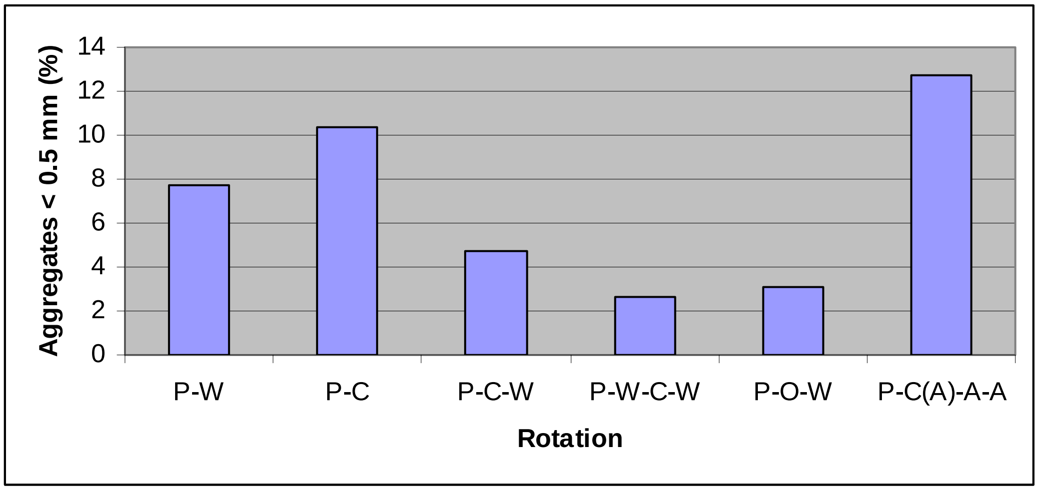

Figure 17. Aggregates less than 0.5 mm diameter (%) in potato phase of rotations.

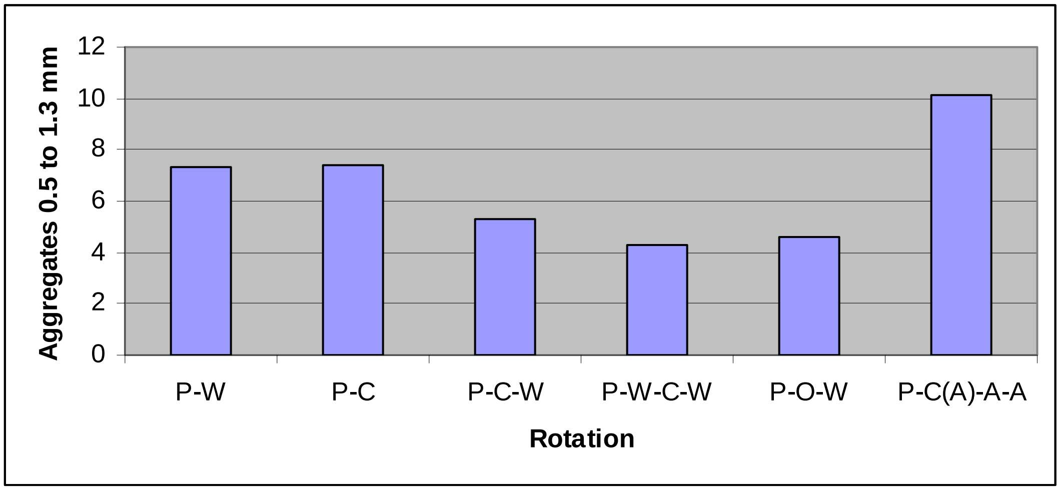

Figure 18. Aggregates 0.5 to 1.3 mm diameter (%) in potato phase of rotations.

Field-saturated hydraulic conductivity

No significant differences were observed for field-saturated hydraulic conductivity (cm s^{-1}) between rotations in June, 2001. Field-saturated hydraulic conductivity ranged from 0.89 $*10^{-2}$ cm s^{-1} to 2.7 $*10^{-2}$ cm s^{-1} for the potato phase of the rotations.

Penetration Resistance

Lower penetration resistances (kPa) in the potato year were observed at 5-10 cm for two year rotations compared to 3 and 4 year rotations (Figure 19). This is attributed to tillage associated with potatoes in rotation.

Soil Moisture

No significant differences were observed in fall soil moisture (% gravimetric) between rotations for the 0-15 cm increment with the exception of the potato-canola (alfalfa)- alfalfa- alfalfa rotation. Soil moisture was significantly higher in the wheat phase of the potato-wheat rotation at the 30-60 and 60-90 cm depths. Levels were significantly reduced in the third phase (alfalfa) of the potato-canola(alfalfa)- alfalfa- alfalfa rotation. The treatment effect was consistent throughout the soil profile for this phase. Fall soil moisture was significantly lower throughout the profile in 2001 in the fourth year of the potato-canola(alfalfa)-

alfalfa-alfalfa year. This is attributed to water use by alfalfa. There was significantly less soil moisture in the 30-60 cm depth increment during spring in the potato year following alfalfa.

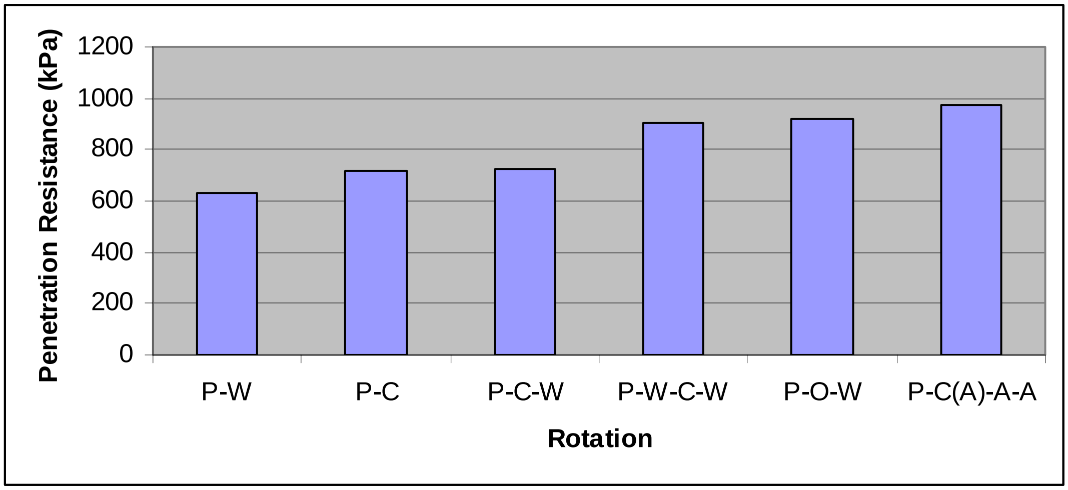

Figure 19. Penetration resistance (kPa) in potato phase of rotations.

Bulk Density

No significant differences were observed in bulk density (Mg m^{-3}) between rotations in May, 2001. Bulk density ranged between 1.0 to 1.2 Mg m^{-3} for the 0-15 cm depth increment.

Soil Organic Carbon

Soil organic carbon was significantly higher in the potato phase of the potato-oat-wheat phase for the 30-60 cm depth. No significant differences were observed between rotations for inorganic carbon.

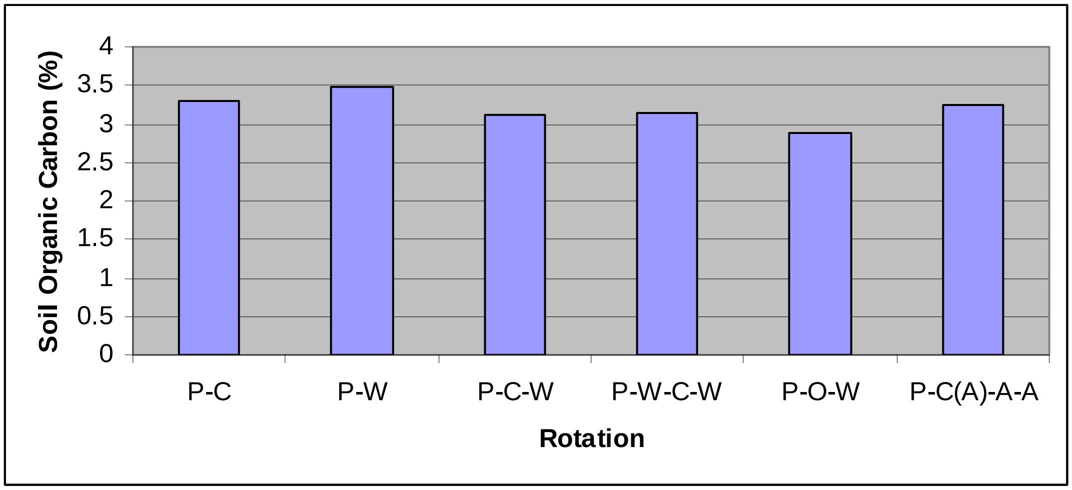

Figure 20. Soil organic carbon (%) in potato phase of rotations.

Soil Total Nitrogen

Relative to other rotations, total soil nitrogen was highest in the fourth alfalfa phases of the potato-canola(alfalfa)-alfalfa-alfalfa rotation for the 0-15 and 60-90 cm depths.

Soil Cation Exchange Capacity and pH

No significant differences were observed between rotations for cation-exchange capacity. Soil pH was higher in the fourth wheat phase of potato-wheat-canola-wheat compared to the fourth alfalfa phase of the potato-canola (alfalfa)-alfalfa-alfalfa rotation.

Nitrate Nitrogen

Nitrate nitrogen (kg ha^{-1}) was significantly higher in fall soil samples on potato residue (Phase 1) following canola for the 0-15 cm depth increment. In addition the same effect was observed for total nitrate nitrogen for the 0-120 cm depth increment. High levels of nitrate-N in phase 1 may be residues from 2000 for phase 2.

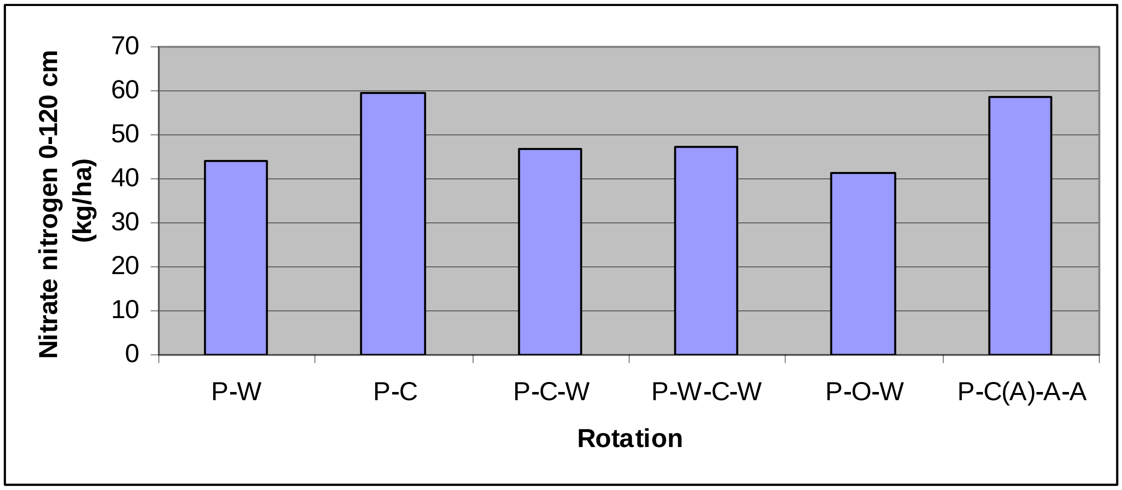

Figure 21. Nitrate nitrogen (kg ha^{-1}) in potato phase of rotations.

Phosphate-Phosphorus

Phosphorus was significantly higher in the potato phase of the potato-canola rotations relative to the potato-canola(alfalfa)-alfalfa-alfalfa rotation which was the lowest.

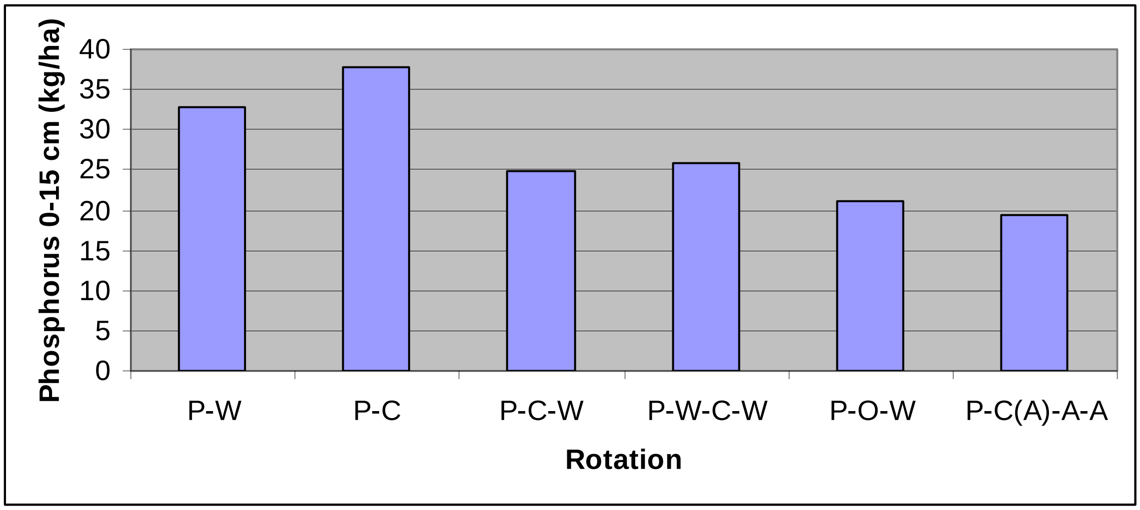

Figure 22. Phosphate phosphorus (kg ha^{-1}) in potato phase of rotations.

Potassium
Potassium was significantly higher in the potato phase of the potato-canola rotation at 0-15 cm.

Sulphur
Sulphate sulphur was significantly higher in the potato phase of the potato-canola rotation for the 15-30, 30-60, 60-90 cm depth increments, and the canola phase of the same rotation for the 0-15 cm depth increment.

Over the short-term of this study there was significant potential for wind erosion due to low residue cover in the spring following potatoes in rotation. However the proportion of aggregates in the erodible fraction was low relative to critical levels for wind erosion. Wind erosion can be significant for fields in potato stubble if aggregates are influenced by dry conditions and wind blown erodible material.

Low penetration resistance in short term rotations did not result in negative environmental impacts, and was not correlated with hydraulic conductivity or bulk density. No evidence of compaction was observed in the study. Further research is required to determine the effect of rotation on soil physical properties in the study.

High levels of soil organic carbon and cation exchange capacity are indicators of good soil quality. Changes in these soil properties are expected to occur over the long term, due to variable inputs of carbon and nitrogen as crop residue and roots from crops in rotation. Total soil nitrogen increased in rotations with alfalfa, though further research is required to confirm this trend.

Fertilizer management of potato rotations with canola may require adjustments to reduce accumulation of nitrogen and sulphur. Similar adjustments may be required where nitrogen accumulates in the rotation with alfalfa, due to fixation and subsequent mineralization. Further research is required to determine the impact of rotation on soil fertility.

Economic analysis

Net income from six different potato crop rotations: 1999 – 2001
Based on the total marketable potatoes produced from this experiment, the aggregate net income from six different potato crop rotations from 1999 – 2001 was computed (Fig. 23).

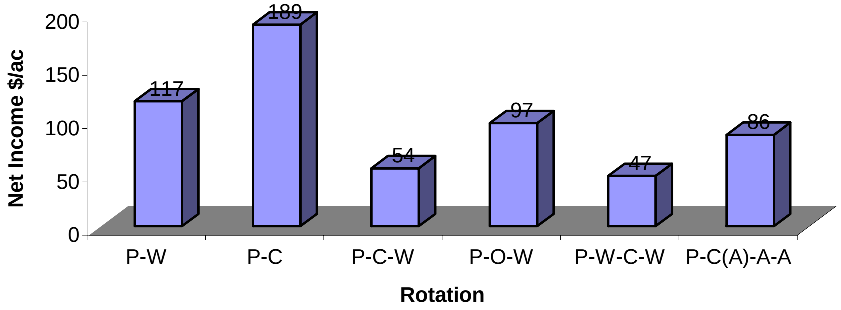

Figure 23. Effect of rotation on aggregate net income.

On average, based on data from 1999-2001, potato-canola (P-C) rotation generated the highest net income ($292/ac) while potato-canola-wheat (P-C-W) ($123/ac) and potato-wheat (P-W) ($119/year) rotations have generated the second and third highest net income. The lowest net income of $48 per acre was generated from the potato-wheat-canola-wheat (P-W-C-W) rotation. This rotation, however, produced the highest potato gross yield of 400 cwt./ac. It is worthwhile to note that the highest net income of potato-canola (P-C) rotation was due to the highest marketable yield ('main' category) recorded for potato crop but not the canola yield. Canola consistently produced the lowest net income from all six rotations. A three-year average marketable ('main' category) yield of potato from potato-canola rotation was 303 cwt./ac, which is about 13% higher than the average marketable potato yield (main) of the other five rotations (268 cwt./ac).

In essence, potato in potato-canola (P-C) rotation produced the highest percentage of marketable yield while the lowest percentage of marketable potato was recorded in potato-wheat-canola-wheat (P-W-C-W) rotation. The average net income of these six rotations varied between $48 to $292 per acre. The potato-canola rotation generated the highest net income while potato-wheat-canola-wheat rotation generating the lowest net income, which displays similar patterns as for marketable potato. Results indicated that potato was the key determinant of net income or profitability of all these rotations.

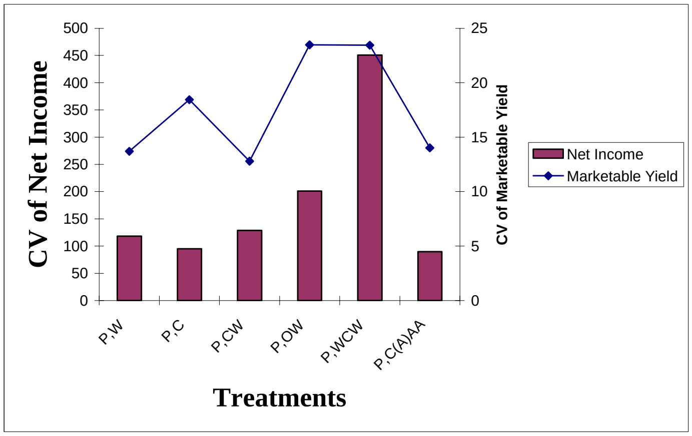

Figure 24. Effect of rotation on income variability from 1999 – 2001.

The coefficient of variation (CV) was used to measure relative variability of yield and net income or relative riskiness of potato in each treatment (Figure 24). The CV computed for potato yield of each treatment indicated that there was generally lower potato yield variability associated with two years and four year potato/alfalfa rotations. This coefficient is the lowest for potato in two year canola and four year alfalfa rotations. The CV computed for net income of potato displays a similar pattern except it is a little bit higher for two year potato rotation with canola.

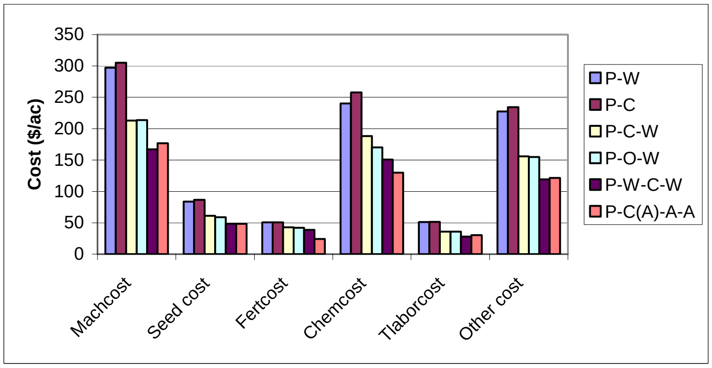

Figure 25. Effect of rotation on input costs.

Distribution of total input costs indicated that machinery (30-34%) was the highest cost in each treatment, followed by chemical (18-27%), seed (9-10%), and fertilizer cost (5-7%) (Figure 25). As expected, each of these costs was highest for two year rotations and lowest for four year rotations.

Conclusion

Development of agronomically and economically viable cropping systems for irrigated potato production is key to the processing potato industry in Manitoba. Clear patterns are beginning to emerge with respect to the impact of rotations on yield and quality parameters. It will be important that the key variables determining potato performance are identified within the rotation context, as well as to understand the nature of their impact.

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