

Lessons from the Carberry Potato Rotation Study

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Abstract

Rapid expansion of the processing potato industry has contributed to a significant increase in irrigated potato production in Manitoba. However, information is lacking regarding optimum rotations for local conditions. In 1998, a crop rotation study was initiated on a Wellwood silt loam near Carberry to identify crop rotations that optimized crop yield and quality while maintaining soil quality. In this ongoing study, treatments consist of two 2-year, two 3-year, and two 4-year rotations of potato-canola (PC), potato-wheat (PW), potato-canola-wheat (PCW), potato-oat-wheat (POW), potato-wheat-canola-wheat (PWCW), and potato-canola(underseeded to alfalfa)-alfalfa-alfalfa (PCAA). Crop yield and quality, diseases, weeds, soil parameters, economics and wireworms are assessed on an ongoing basis. This paper will focus on potato yield, select tuber quality factors, and select potato diseases.

Differences among rotations have begun to emerge as the study has matured. While no single rotation consistently out-performed the other rotations in terms of potato yield, a descriptive grouping methodology developed by Francis and Kannenberg (1978) placed PC, PCAA and PCW in the higher-yielding group in terms of marketable (>2") yield based on average yield for the period 1998 through 2006. Rotations predominated by cereals fell into the lower-yielding group for this period. While data collected during the initial nine years of the rotation study suggested greater potential for blackleg, rhizoctonia and vascular disease in potato in the 2-year rotations, consistent effects on yield were not evident.

In 2007, however, the PC rotation had a significantly lower total tuber yield (339 cwt/ac) than the other rotations (average of 424 cwt/ac). The yield of tubers >2" was also lower in the PC rotation than in the 3- and 4-year rotations, but similar to the PW rotation. Disease assessments revealed that more than 75% of potato plants in the PC rotation were affected by vascular wilt and that the most severe symptoms were almost exclusively associated with that rotation, suggesting that disease may have contributed to reduced yields in 2007. The PW rotation showed the next highest level of vascular wilt at 18% of surveyed plants. These preliminary findings from 2007 suggest that 2-year rotations may not be sustainable in the longer-term due to increasing disease pressure. Monitoring of this study will continue for 12 cycles of the rotation, until 2009, to determine whether observed trends will continue in the longer term.

Introduction

Rapid expansion of the processing potato industry in Manitoba has significantly increased irrigated potato production in this province. However, much of the agronomic information currently available to growers is based on research conducted in traditional potato-growing areas that differ from southern Manitoba in terms of climate, soil conditions and, in some cases, agricultural practices.

Crop rotation is one management tool that has the potential to alter a host of factors that may influence crop yield and quality, including disease incidence, weed populations, and soil characteristics and functioning. Questions exist as to the relative agronomic and economic viability of two-year versus three-year versus four-year rotations for irrigated potato under Manitoba conditions. Shortening the rotation cycle could potentially increase the risk of tuber yield and quality losses that may be associated with factors such as increased disease and insect pressure as well as reduced soil quality. Selection of crop species and their sequence in rotation with potato might also influence the overall productivity of a given rotation.

In order to ensure the long-term viability and sustainability of irrigated potato production, management strategies which maintain or enhance potato yield and quality, as well as soil and water quality, must be identified for Manitoba conditions.

Methods

In 1997, a 4 ha area was selected on a Wellwood silt loam at MCD-Carberry (pH: 7.0; EC: 0.24 dS m⁻¹; NO₃⁻-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; SO₄⁼: 61 kg ha⁻¹ to 60 cm). A randomized complete block design (four replicates with 18 treatments per 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.)

In 1997, barley (cv. Bedford) was seeded across the entire experimental area. Grain yield, soil properties (including soil texture, pH, EC, macro- 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.

In 1998, crop rotation treatments were initiated. Six crop rotation treatments were established: potato-canola (PC), potato-wheat (PW), potato-canola-wheat (PCW), potato-oat-wheat (POW), potato-wheat-canola-wheat (PWCW), and potato-canola(underseeded to alfalfa)-alfalfa-alfalfa (PCAA). Each phase of each rotation is present in each year for a total of 18 treatments per replicate.

Cultivars grown included: potato (cv. Russet Burbank), wheat (cv. AC Barrie from 1998 through 2001; AC Cora from 2002 through 2007), oat (cv. AC Assiniboia), canola (cv. Independence in 1998; Invigor 2163 in 1999; Invigor 2153 in 2000 and 2001; Invigor 3640 from 2002 through 2005; 5020 in 2006 and 2007) and alfalfa (cv. Centurion).

All crops were managed using best management practices with respect to tillage and seeding operations, nutrient management, and weed, insect and disease control. The majority of tillage was conducted immediately before, during and after the potato crop, while crops following non-potato crops were grown using zero-tillage practices. 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. Recommended herbicides, fungicides and pesticides were applied as required to control weeds, diseases and insects. Potatoes were irrigated as required.

Management practices were reviewed periodically throughout the course of the study and

altered as necessary to update cultivars and pesticides, improve management practices, etc. However, to the greatest extent possible, efforts were made to maintain similar management practices throughout the course of the study in order to avoid introducing year-to-year differences in rotation functioning that were due, not to rotation *per se*, but to changes in crop management.

Information collected over the course of the study has included: crop yield and quality, disease incidence, weed populations, soil chemical, physical and biological properties, economic analysis, and wireworm damage. This paper will focus on potato yield and select quality factors, and on select potato diseases.

Tuber Yield and Quality

Potato plots were typically harvested for yield determination in late September following desiccation of potato tops by Reglone. An approximate 14 m length of the two centre rows of each plot was harvested using a 1-row digger.

Following harvest, a subsample of potato tubers from each plot was graded. Although specific grading criteria varied slightly among years, tuber size distribution, tuber defects and specific gravity were assessed in all years.

Several statistical analyses have been employed. Preliminary statistical analysis by analysis of variance has been conducted for each year. For select parameters, data were analyzed across sites (1998-2006, inclusive) using a mixed model (SAS Institute 1999). A descriptive grouping methodology (Francis and Kannenberg 1978) was also used to classify rotations with regard to marketable yield.

Plant Pathology

During each growing season, all plots were examined on a weekly basis for the appearance and development of diseases. Disease ratings on foliage and stems were conducted during the season and tuber assessments were made following 3 months in storage. Tubers were collected and bagged by plot in the field at harvest and were then stored at 12°C prior to rating. Ratings were done on 50 tubers that were selected randomly from each plot. Each tuber was cut at a cross section near the stem end and again longitudinally to assess for internal damage. Incidence ratings were done for the following diseases: Fusarium dry rot, vascular discoloration (brown discoloration of the vascular tissue; excluding ring rot), net necrosis (phloem discoloration due to Potato Leafroll Virus), tuber soft rot, blackleg, late blight, sclerotinia, rhizoctonia, silver scurf, and scab. Physiological disorders including hollow heart, brown center and black heart and were also noted. In preparing tubers for assessment, soil was removed but the tubers were not washed. This may have impeded assessment of tubers for rhizoctonia, silver scurf, and scab.

Diseased plants were noted during the season but final plant foliar ratings were conducted just prior to desiccation. Ratings were done on 25 plants (12 or 13 plants in series for 2 rows for a total of 25). Incidence ratings were done for the following diseases: early blight, blackleg, aerial soft rot, rhizoctonia, vascular wilts, and sclerotinia. The presence of other diseases such as late blight, aster yellows, potato virus Y (PVY) and potato leafroll virus (PLRV), that would not be impacted by rotation, was also noted.

Blackleg, rhizoctonia stem canker, fusarium dry rot, and vascular wilts of potato are discussed in this paper.

Results and Discussion

Tuber Yield and Quality

1998 - 2006

Rotation had little effect on total tuber yield or the yield of marketable tubers (>2" diameter) during the initial three to four years after the rotations were established (Figure 1). As the study continued, yield differences among rotations were observed with increasing frequency although no single rotation consistently and substantially outperformed the others. The time lag between establishment of the rotations and the occurrence of yield differences among rotations suggests that effects of rotation emerged over time as rotations begin to impact the plant-soil system. These results suggest that the performance of crop rotations may change as rotations mature.

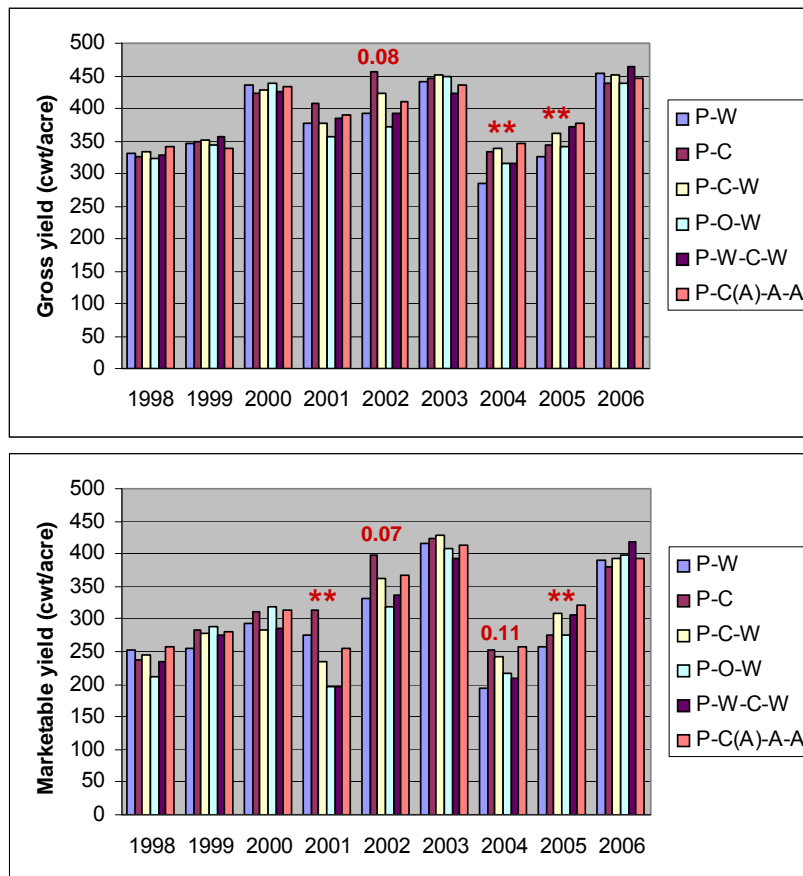


Figure 1. Gross and marketable yield of irrigated Russet Burbank potato as affected by crop rotation (1998 – 2006). ** indicates $P \leq 0.01$; where $0.05 < P \leq 0.11$ the value is reported.

Large year-to-year variations in marketable and total yield were evident suggesting that environmental conditions may have had a significant impact on potato yield (Figure 1). Average annual total yields ranged from 322 cwt ac⁻¹ in 2004 to 448 cwt ac⁻¹ in 2006. In all years of the study, the variety Russet Burbank was grown under irrigation, on the same soil type and in the same geographic location, using similar management practices. As such, these factors were unlikely to have contributed substantially to the large year-to-year variations in yield observed.

In order to assess the production risk associated with each rotation, the mean marketable yield (1998-2006) of each rotation was assessed. A descriptive grouping methodology (Francis and

Kannenbergs 1978) was used to classify responses into four categories: Group I: high mean, low variability, Group II: high mean, high variability, Group III: low mean, high variability, Group IV: low mean, low variability. Based on this analysis, PC, PCAA and PCW fell into groups I and II, and were considered among the rotations with a comparatively higher marketable yield. Of these rotations, PC and PCAA had numerically higher yields than PCW. In contrast, those rotations predominated by cereals (i.e. PW, POW, PWCW) fell into groups III and IV and were considered among the rotations with a comparatively lower marketable yield. Of the higher-yielding rotations, marketable yield in the PC rotation (Group II) was comparatively more variable than in PCAA (Group I), while PCW was intermediate.

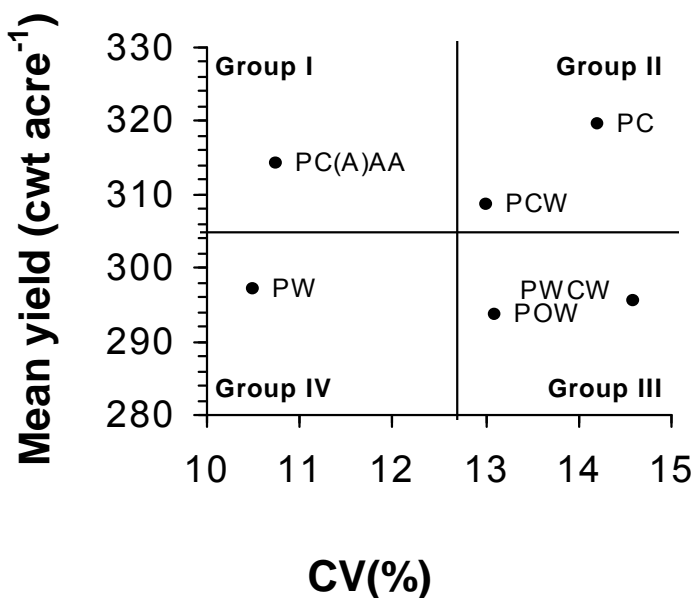


Figure 2. Mean marketable yield (1998-2006) and coefficient of variation (CV%) as affected by crop rotation. Groups are classified as follows: I: high mean, low variability, II: high mean, high variability, III: low mean, high variability, IV: low mean, low variability.

Specific gravity was assessed annually (Figure 3). In most years, specific gravity in most rotations exceeded the range that would result in the highest price premium. Differences among rotations were evident in 5 of 6 years from 2001 through 2006. Averaged across all years, the PC rotation produced a significantly lower specific gravity than the other rotations, but remained within acceptable limits for processing. Specific gravity in the PCAA rotation, while numerically lower than most of the remaining rotations, was significantly lower than the POW rotation only.

Averaged across all years (1998-2006), rotation did not affect the probability of hollow heart / brown centre occurring (data not presented).

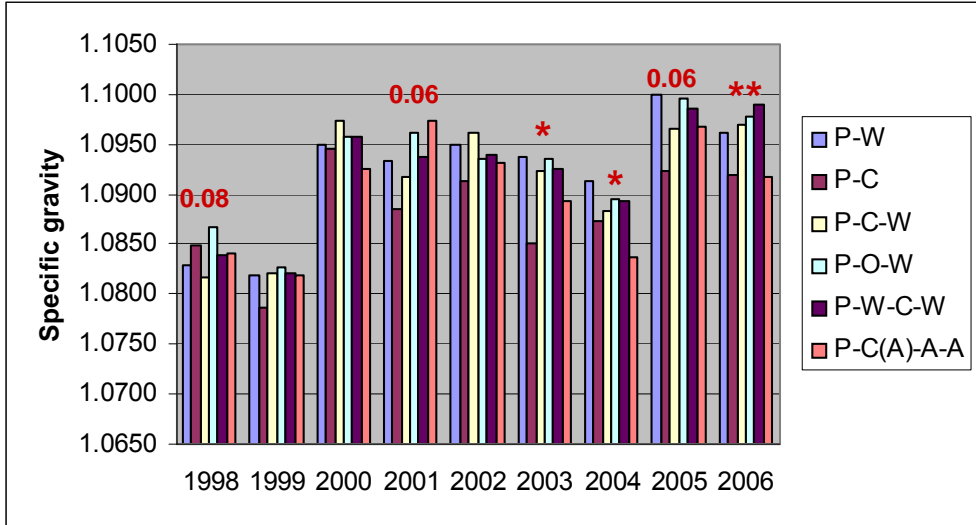


Figure 3. Specific gravity as affected by crop rotation (1998 – 2006). * indicates $P \leq 0.05$; where $0.05 < P \leq 0.10$ the value is reported.

2007

In 2007, rotation had a marked effect on marketable yield ($P=0.03$) and total yield ($P=0.002$) (Figure 4). In contrast with previous years, preliminary data revealed a significantly lower marketable yield in the PC rotation than in the 3- and 4-year rotations. The PW rotation was intermediate. Marketable yield in PC averaged 263 cwt ac^{-1} , which was 95 cwt ac^{-1} less than the average yield of the 3- and 4-year rotations. Similarly, total yield in the PC rotation was significantly lower than all other rotations in 2007. Observed yield declines in the 2-year rotations, particularly the PC rotation, appeared to be due at least in part to increased levels of vascular wilt in these rotations. Given the high value of the potato crops, the observed yield reductions would represent a significant economic loss.

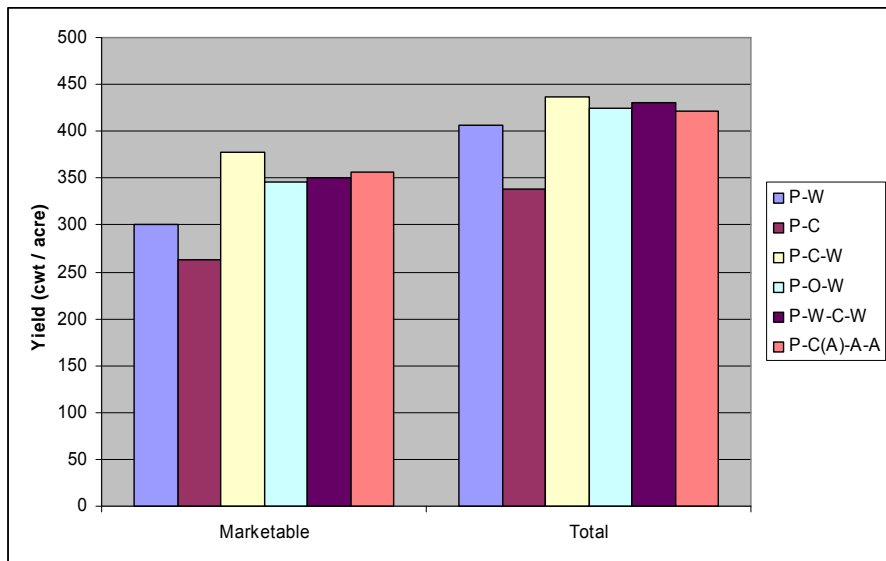


Figure 4. Effect of crop rotation on marketable and total yield of potato in 2007.

Plant Pathology

The effect of crop rotation on disease incidence is determined by the ability of pathogens to disseminate inoculum, to overwinter, and to infect alternate crops. 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. Many bacteria and fungi that survive on crop debris eventually die if residues decay before the next susceptible crop is planted. Specific objectives of the plant pathology component of this study are to evaluate management of plant diseases through manipulation of host factors such as crop type, and interruption of disease cycles through crop rotation.

Blackleg

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 (Figure 5). This relationship did not result in a yield loss. In 2004, blackleg levels were higher in most treatments than observed in the previous two years and this was most likely due to the cool, wet environmental conditions that prevailed during this field season. Under conditions conducive to the development of blackleg, the greatest level of disease was noted in the short rotation of potato-wheat. In 2005, less blackleg was observed than in 2004 as environmental conditions were not as favourable for disease development. However, diseased plants were observed in the shorter rotations (P-W, P-C and P-O-W). The 2006 field season was a hot dry one, and very little disease was observed in many crops. In this study, no plants with blackleg were observed in 2006. Analysis of 2007 samples is underway.

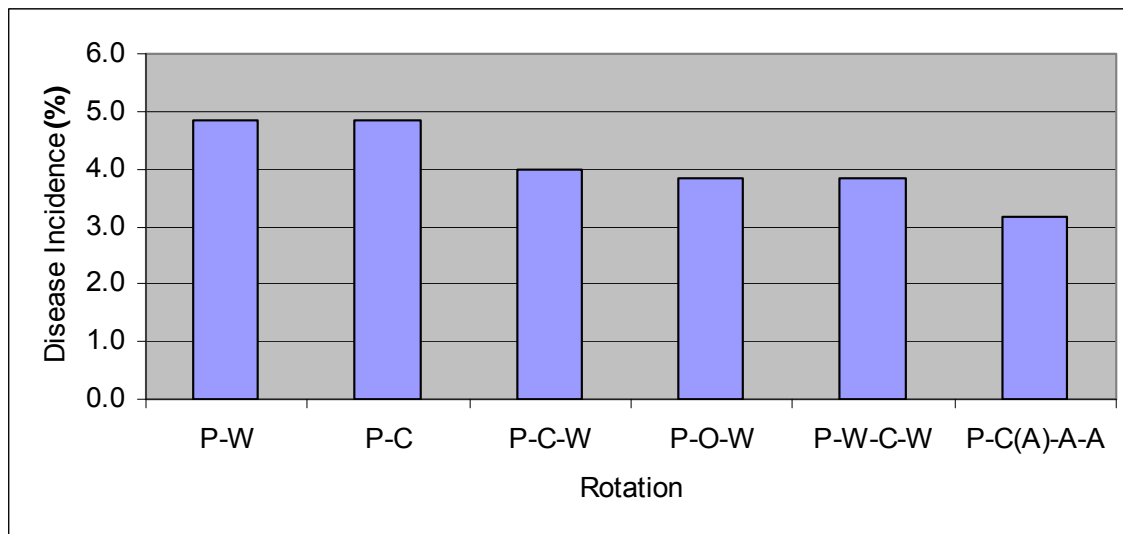


Figure 5. Mean blackleg incidence in potato (2000-2005) as affected by crop rotation.

Rhizoctonia

Rhizoctonia solani is a ubiquitous fungus found in many soils. Rhizoctonia stem canker and black scurf occur wherever potatoes are grown. The pathogen, *R. solani*, overwinters as sclerotia on tubers, in soil or as mycelium in plant debris in the soil. Cooler conditions at planting favour disease development. Under humid conditions, a white cottony growth occurs on the lower stems of infected plants.

Rhizoctonia solani is divided into a number of subgroups known as AG groups. The subgroup *R. solani* AG-3 causes considerable yield loss in potato fields in eastern Canada, and likely AG-3 is also found in potato in Manitoba. A report in the literature indicates that AG-3 is also weakly virulent on canola and it has been isolated from alfalfa

In 2000, higher levels of rhizoctonia were associated with shorter rotations (Figure 6). In 2002, disease 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 continued in 2003 but with low levels of disease in the four-year mixed rotation. No rhizoctonia was observed in 2004 and only 1% of plants in the P-C-W rotation had stem canker in 2005. In 2006, levels of rhizoctonia were again low, with only 6 infected plants observed, one in each of the P-O-W and P-W-C-W rotations and 4 in the tight P-W rotation. The generally low levels of disease found in recent years may be related to unfavourable environmental conditions for the development of this disease. Crop rotation has been reported to reduce the soilborne populations of *R. solani*, but the impact of rotation length can vary 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.

In contrast to previous years, rhizoctonia levels were lower in shorter rotations in 2007. While the development of this disease in the longer rotations may be a reflection of the crops within the rotation and the increase of inoculum over time, higher levels of rhizocontia had been expected in the two short rotations. Possibly, because these two-year rotations have the most vascular wilt, there may be some antagonistic effects produced in the soil that affect the relative competitive advantage of *R. solani* thereby reducing the efficacy of this pathogen in causing stem canker.

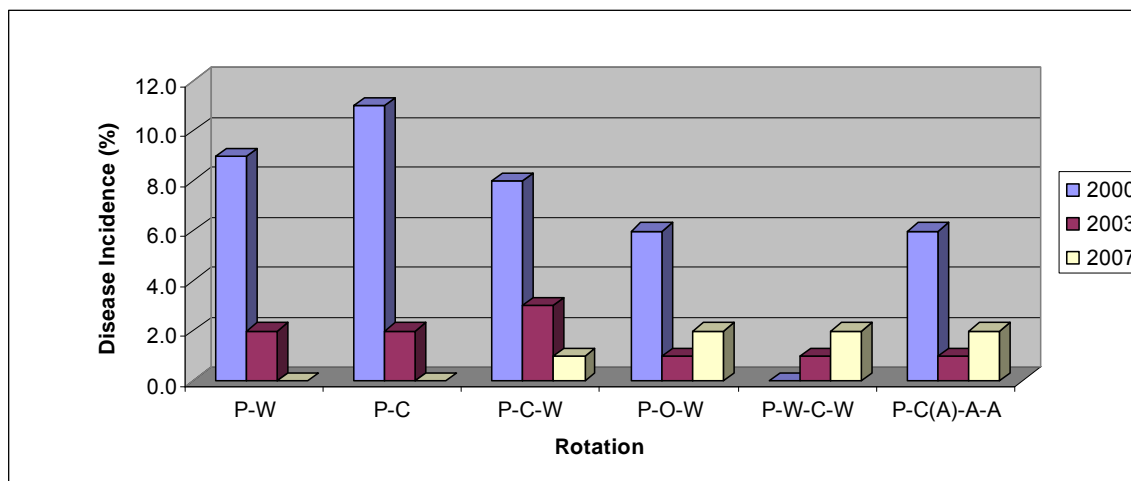


Figure 6. Incidence of *Rhizoctonia* stem canker as influenced by crop rotation.

Fusarium Dry Rot

Fusarium dry rot is one of the most important postharvest diseases of potato. Sources of inoculum are contaminated and infested seed pieces and infested soil. Decaying seed pieces and infected seed tubers infest the surrounding soil, where the pathogen can survive for several years. Long crop rotations and use of clean seed have been known to partially control disease. In the current study, disease incidence was highest in longer rotations during the early years (2000-02) of the rotation study (Figure 7). In 2003 and 2004, the incidence of dry rot was generally evenly spread among rotations. In 2005, levels of fusarium dry rot were the highest of all years of the study with the most diseased tubers observed in the short rotation of potato-wheat. Levels of fusarium dry rot were low in 2006, and assessment of 2007 samples is underway.

Interestingly, mean levels of fusarium dry rot (2000-05) were less in the P-C rotation than in any other rotation. Canola has been known to suppress some soilborne pathogens by toxic compounds released from decaying roots, but it is unclear at present if this is a factor contributing to reduced disease levels in the P-C rotation. Increased levels of fusarium dry rot is a concern in the PW rotation as *Fusarium graminearum*, the causal agent of fusarium head blight in wheat, has now been isolated from potato as a dry rot pathogen.

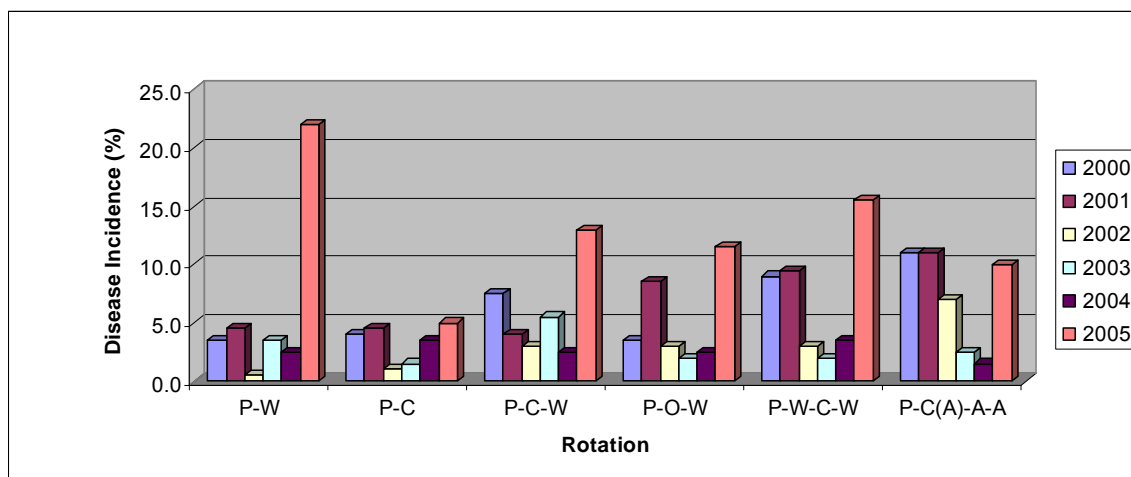


Figure 7. Fusarium dry rot in potato as influenced by crop rotation.

Vascular Wilt Diseases in Potato

The vascular wilt diseases are common and destructive to potatoes in many production regions throughout the world. Wilts are usually associated with the fungi *Verticillium* and *Fusarium*. Black dot infects the roots of the potato causing them to rot and it is also capable of invading the vascular tissue causing wilt. When black dot is present, the plant wilts and dies much more rapidly than with other diseases. Black dot can be difficult to detect because the symptoms are similar to more common potato diseases. In the potato rotation research study, vascular wilt was noted and incidence recorded. Data is not presented in years when no wilt or <5 wilted plants were observed. The highest levels of vascular wilt were associated with the tight rotations of P-C and P-W (Figure 8). In 2007, disease assessments revealed that more than 75% of potato plants in the PC rotation were affected by vascular wilt and that the most severe symptoms were almost exclusively associated with that rotation, suggesting that disease may have contributed to reduced yields in 2007. The PW rotation showed the next highest level of

vascular wilt at 18% of surveyed plants. The vascular wilt pathogens can overwinter in the field and crop rotation has been reported to provide some control of these diseases.

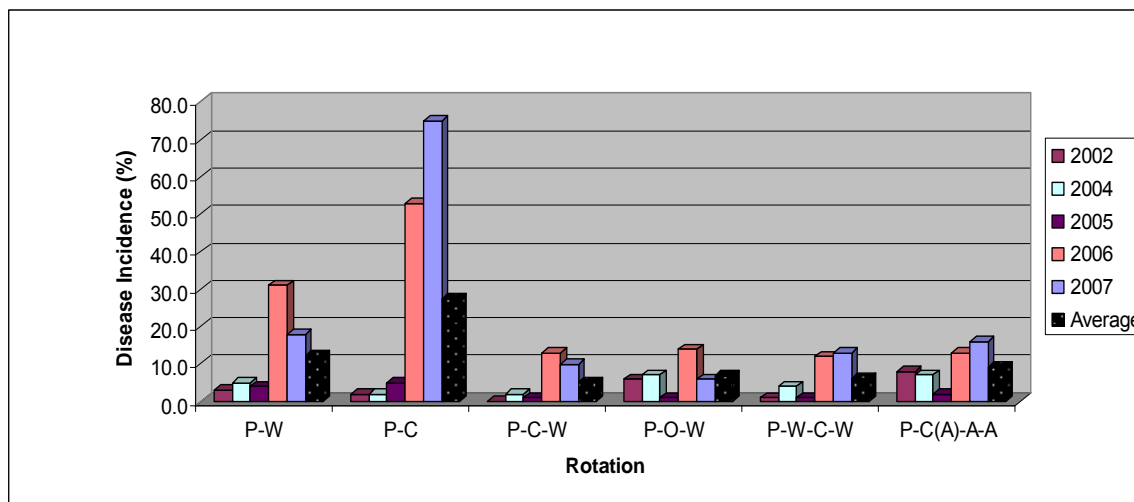


Figure 8. Incidence of vascular wilt disease in potato as affected by crop rotation.

Summary

As of 2007, the irrigated Potato Rotation Study at Carberry had been in place for ten field seasons, equivalent to five cycles of the 2-year rotation and 2.5 cycles of the 4-year rotation. While rotation had no effect on marketable or total tuber yield during initial years of the study, effects of rotation became evident as rotations matured. Although no single rotation consistently outperformed the rest in terms of yield during the initial nine years of the study, a descriptive grouping methodology based on average marketable yield (1998-2006), indicated that the PC, PCAA and PCW rotations tended to be among the higher-yielding rotations while rotations predominated by cereals tended to be among the lower-yielding rotations. Despite evidence of increased potential for blackleg, rhizoctonia stem canker and vascular wilt in the shorter rotations during the first nine years of the study, consistent effects on yield were not evident.

In 2007, however, high levels of vascular wilt appeared in the PC rotation (75% of plants diseased, many with severe symptoms), and the PC rotation produced a lower total tuber yield than any other rotation. Marketable yield in the PC rotation was also significantly lower (by ~95 cwt ac⁻¹) than the three- and four-year rotations. The other 2-year rotation, PW, had the second highest level of vascular wilt but only 18% of plants were affected. These preliminary findings from 2007 suggest that 2-year rotations may not be sustainable in the longer-term due to increasing disease pressure. However, continued monitoring of this study until 2009 is planned in order to better understand the longer-term impacts of rotation on the plant-soil system, and to determine whether trends observed in 2007 will continue.

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