MANITOBA CROP DIVERSIFICATION CENTRE

2003 ANNUAL REPORT

Manitoba Crop Diversification Centre
P.O. Box 309
Carberry, Manitoba
R0K 0H0
(204) 834-6000
(204) 834-3777
www.agr.gc.ca/pfra/mcdc/mcdc_e.htm

Canada MHPEC Inc. Manitoba

Contents

Potato Projects

Other Crops and Projects

Introduction

On behalf of the partners in the Manitoba Crop Diversification Centre, it is my pleasure to present the **2003 Annual Report**. It is primarily a technical report on most of the MCDC projects conducted in 2003 by Centre staff and cooperating agencies. Thank-you to the individuals from those agencies who helped by providing material for many of the sections. This Report represents one of the several means by which the Centre and its research partners extend information on Centre projects and activities. You may also be familiar with our newsletter (*The Rainbow*), or have attended our field extension events, visited with us at our booth at trade shows, or took in our presentations on these projects by our research partners and staff at various conferences and meetings.

MCDC continues to be a model of **partnership** among governments and industry. The *Agreement* under which the Centre operated in 2003 included on-going equal annual commitments from each of the three parties - **Canada** (through Agriculture and Agri-Food Canada), **Manitoba** (through MB Agriculture and Food, MB Conservation, and MB Intergovernmental Affairs), and **MHPEC** (Manitoba Horticulture Productivity Enhancement Centre Inc.). MHPEC is a consortium of Manitoba potato processors (Midwest Foods Products Inc. and McCain Foods [Canada] Ltd.) and the processing potatoes growers association (Keystone Vegetable Producers Association). The Centre Overview following provides operational details. All parties to the *Agreement* continued to support the Centre in 2003, and were actively involved in directing the Centre's management and activities.

Most of the Centre's projects are coordinated and carried out in **cooperation** with a wide range of industry, government, and individual partners. Industry and producers have also generously supported our programs through contributions of inputs, study sites, and other donations, and their time at meetings and consultations.

Notable **new initiatives** in 2003 included changes in format for our Carberry site field extension events (including a very successful evening horticultural tour), and some new field demonstrations and potato fertility trials. The Potato Diagnostic School initiated in 2002 was held again, as was the Manitoba Potato Research Coordination meeting last held in 2001; both were well-attended and well-received. Staff continued active involvement in the Assiniboine Delta Aquifer Management Planning Process, providing technical input and representing MHPEC at several meetings of the Round Table of stakeholder groups. Facility upgrades included major building renovations at the Portage la Prairie site, potato storage and fry-colour equipment at the Carberry site, and three new vehicles (with incremental support from our Federal partner).

MCDC **Program Renewal** discussions continued, to near completion by year-end. The original *Agreement* was extended to April 2004, when a similar new partnership agreement will take effect.

2003 was another **successful year** operationally for field and plot activities, with good crop yields despite an extended mid-summer drought. Our staff is credited for meeting the frequent weather-related challenges inherent in agricultural production and research.

Visitors are always welcome at all the MCDC sites. Planned events provide opportunities to hear from our cooperators and visit with other producers, as well as with Centre staff. Call us or drop in for more information on anything in this report, or any of our programs and activities.

Dale J. Tomasiewicz
Centre Manager, MCDC

Overview of the Manitoba Crop Diversification Centre - 2003

Background and Partners

The Manitoba Crop Diversification Centre (MCDC) was established in 1993 under a ten-year agreement among the Government of Canada, the Government of Manitoba, and Manitoba Horticulture Productivity Enhancement Centre Inc. (MHPEC). The goal was to develop and operate "a Centre through which crop diversification and production enhancing technologies can be investigated and demonstrated for the benefit of the agricultural industry in Manitoba." Since April 2003, the Centre has operated under a one-year an extension to the original agreement.

Each of the three parties to the Agreement committed to annual contributions of equal value to the Centre operation. Most of the development and infrastructure costs, and a portion of the operating costs for the first few years, were provided for by Western Economic Diversification (WED) Canada through MHPEC.

Canada's support, provided by Agriculture and Agri-Food Canada (AAFC), includes four staff positions, infrastructure support, and support services. **Manitoba**'s commitment is met through provision of several full and part-time staff positions and related support costs, mostly in the technology transfer area.

MHPEC is a consortium formed by the two Manitoba French-fry processors (Midwest Food Products Inc., and McCain Foods [Canada] Ltd.), and Keystone Vegetable Producers Association (the processing potato growers association). The MHPEC members provide their support mostly as direct cash contributions.

All three partners in MCDC actively participate in the Centre management and program advisory function committees. Input from other industry and stakeholder representatives is also obtained at annual program advisory meetings.

Infrastructure

The Centre operates sites at Carberry (headquarters), Portage la Prairie, and Winkler.

The **Carberry site** is located on a half section of excellent agricultural land (mostly Wellwood and Ramada clay loam and loam) at the junction of Highways #1 and 5. Buildings include an office-lab-classroom complex, a building for sample processing, shop work and storage, chemical storage and handling buildings, grain bins, and a new machine storage building. Equipment for most operations is owned, while some field and research operations are contracted out or conducted by project cooperators. Advanced irrigation systems permit irrigation of approximately 70 ha of land, using three pivot irrigators and two linear-move systems well-adapted to meet the needs of irrigation research trials. This capability is unique to MCDC in Manitoba, so the Centre attracts most research in Manitoba requiring good irrigation control.

The **Portage la Prairie site** was previously an Agriculture and Agri-Food Canada Research Branch sub-station. It has an office-lab-workshop building, a chemical storage and handling building, and a small greenhouse. Two linear-move field irrigators and an irrigation water supply system were set up to irrigate much of the land base of over one-quarter section, mostly good quality clay loam.

The **Winkler site** consists of approximately 16 ha of sandy loam land under a linear-move field irrigator. There are no buildings or full-time staff on-site. Most field and plot operations are carried out by a local seasonal technician and staff from the Portage la Prairie site; other services are contracted locally.

The three MCDC sites are strategically located in three areas of Manitoba with high-value crop production potential (including irrigation) and a range of representative soils.

Staff

AAFC provides four staff positions dedicated full-time to MCDC - the Centre Manager, Office Administrator, Receptionist/Secretary, and Portage Site Supervisor. AAFC also dedicates a portion of the time of an off-site Research Economist to MCDC programs.

Manitoba provides or supports three full-time on-site positions at Carberry - Water Resource Specialist, Agri-Water technologist, and Centre Agronomist. Manitoba also dedicates portions of off-site Provincial Specialists time to MCDC programs.

MHPEC provides one full-time staff position (Carberry Site Farm Supervisor) and up to fifteen seasonal support staff.

Project Partnerships

Most of the centre's programs and projects are carried out under some type of partnership with other public or private agencies. The nature of the cooperative arrangements are almost as numerous as the projects themselves; i.e. whatever is required to get the job done by using the resources of both parties efficiently in support of the common objectives. Through this type of cooperation, MCDC projects can take advantage of the research knowledge, expertise, and large resources of other agencies, both public (e.g. Universities, AAFC, MB government) and private (e.g. consultants).

Extension

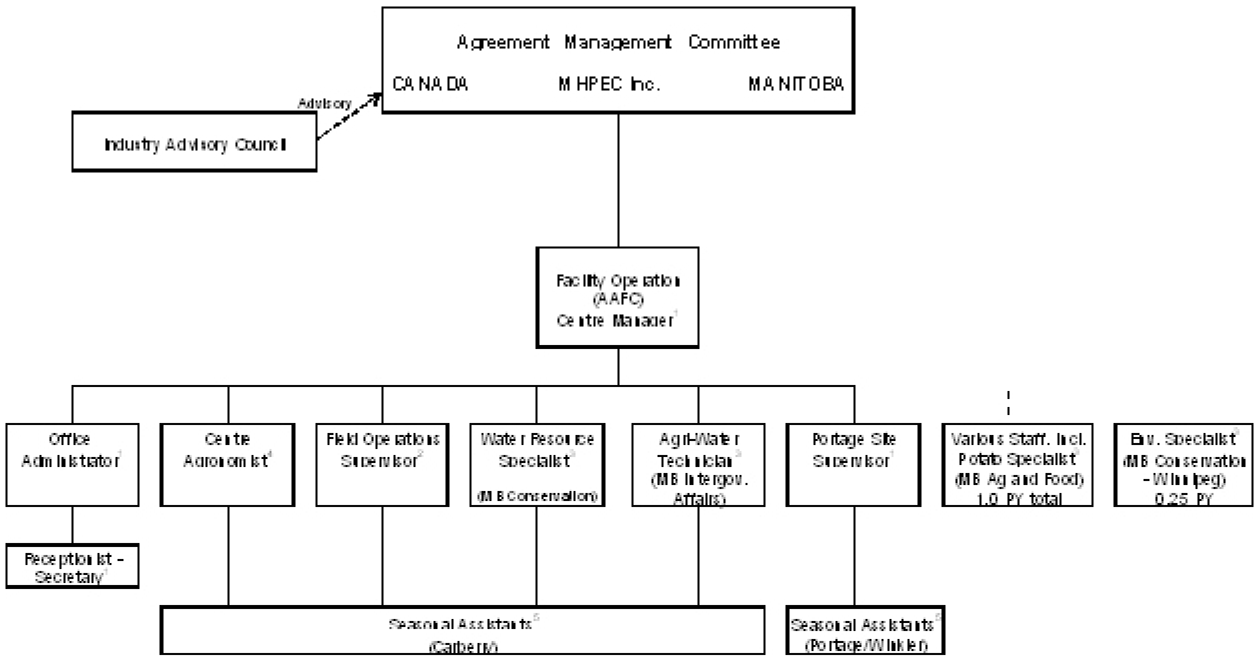
Results of MCDC programs, and general information on agricultural diversification, potato production, irrigation, and environmentally responsible agriculture, are extended to the industry and the public by several means. The Centre's Annual Report and Newsletter (*The Rainbow*) are widely distributed. Staff take part in trade shows and seminars (e.g. Ag Days, Potato Production Days), organize extension meetings, host annual events at each site, and respond to office and telephone inquiries. As most projects are cooperative, the cooperating agencies also transfer information from their projects through their established contacts and mechanisms.

Results, the Future

The value of diversification of the agricultural and rural economies is widely accepted, and highlighted at times of poor market returns to some of our standard agricultural products. The production of high-value crops facilitated by the Centre typically have farmgate values per acre in excess of ten times those of our standard grains and oilseeds. The Centre also plays a role in monitoring and promoting the environmental sustainability of intensive field agriculture.

MCDC completed its tenth field season in 2003. Its mission statement, adopted after a strategic planning initiative which was completed in 2000, reads: *To develop agronomic solutions to enhance crop diversification and support sustainable water management*. A renewed agreement for operation of the Centre beyond its current term is near completion. Partners and stakeholders expect to see it continue to play a meaningful role in the development of sustainable intensive agriculture in Manitoba.

MCDC Management/Staff Organizational Structure - 2003



[1] Agriculture and Agri-Food Canada (AAFC) staff

[2] Manitoba Horticulture Productivity Enhancement Centre Inc. (MHPEC) staff

[3] Manitoba Provincial Government staff (reporting also to indicated MB Government Department); staff committed part-time to MCDC work out of their regular Manitoba Government office locations. Manitoba Government re-organization in late 2003 (not shown here) changed department names and sources for the provincial commitments, but not the actual commitments.

[4] MHPEC staff (position supported by MB Intergovernmental Affairs under Rural Economic Development Initiative)

[5] MHPEC staff, and AAFC staff supported by MHPEC

MCDC Staff - 2003-2004

Carberry Site

Full time

Name	Supporting MCDC Partner	Position
Lorry Broatch	Manitoba Conservation	Water Resource Specialist
Clayton Jackson	MHPEC[1]	Farm Supervisor
Linda McLaughlin	AAFC[2]	Office Administrator
Les Mitchell	Manitoba Intergovernmental Affairs/MHPEC[3]	Centre Agronomist
Sherree Olmstead	AAFC	Receptionist/Secretary
Bob Toma	Manitoba Intergovernmental Affairs	Agri-Water Technologist
Dale Tomasiewicz	AAFC	Centre Manager

Seasonal

Sharon Ardron	MHPEC	Research Assistant
Bernie Brecknell	MHPEC/AAFC	Field Research Assistant
Eric Claeys	MHPEC	Field Operations Assistant
Kevin Evans	MHPEC	Summer Student Assistant
Jarret McKee	MHPEC	Summer Student Assistant

Portage la Prairie Site

Full time

Gerald Loeppky	AAFC	Portage Site Supervisor

Seasonal

Pam Allen	MHPEC	Summer Student Assistant
Dan Bouchard	MHPEC	Field Operations Assistant
Brad Boyd	MHPEC	Summer Student Assistant
Jeff Clarkson	MHPEC	Summer Student Assistant
Harvey Klippenstein	MHPEC	Field Operations Assistant
John Lapawchuk	MHPEC/AAFC	Field Research Assistant
Keith Maxwell	MHPEC/AAFC	Operator and Maintenance Assistant
Henry Wolfe	MHPEC	Plot Labourer (Winkler site)

Off-Site Staff with Part-time MCDC Program Commitments

Various Manitoba Agriculture and Food Staff, including Bill Moons, Potato Specialist (Carman)

[1] Manitoba Horticulture Productivity Enhancement Centre Inc.
[2] Agriculture and Agri-Food Canada
[3] MHPEC position funded through the Rural Economic Development Initiative of Manitoba Intergovernmental Affairs

MCDC Site Infrared Aerial Photos

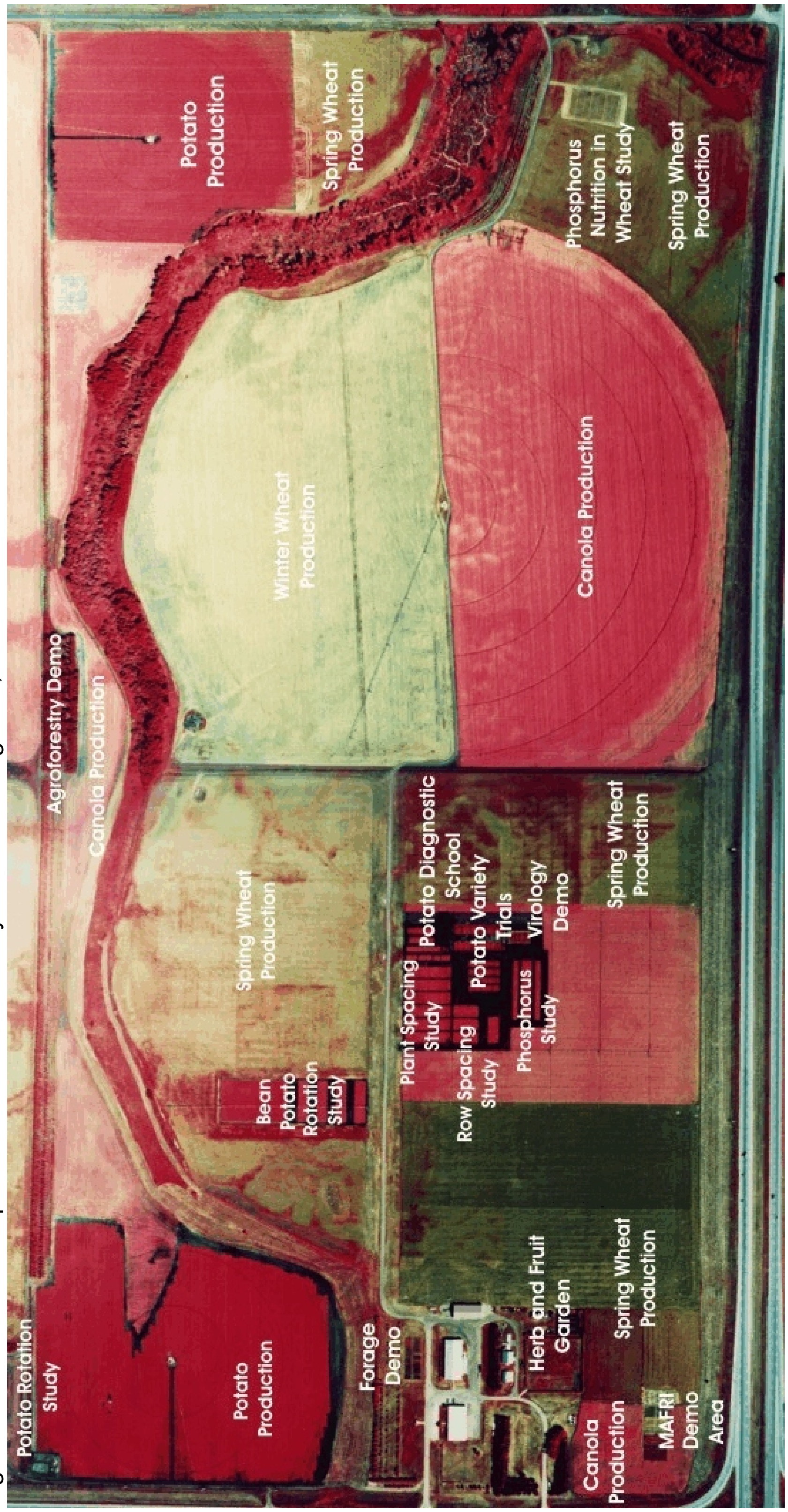
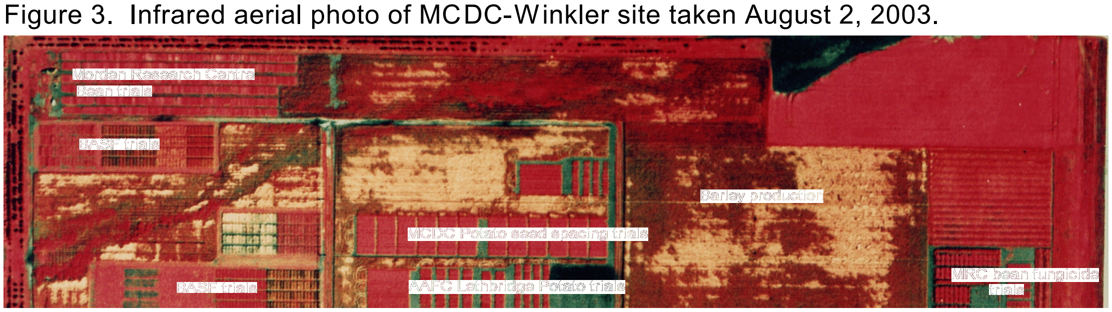


Figure 1. Infrared aerial photo of MCDC-Carberry site taken August 2, 2003.

Figure 2. Infrared aerial photo of MCDC-Portage la Prairie site taken August 2, 2003.

Figure 3. Infrared aerial photo of MCDC-Winkler site taken August 2, 2003.



Meteorological Data for MCDC Locations

Figure 1. Growing season temperature at MCDC-Carberry.

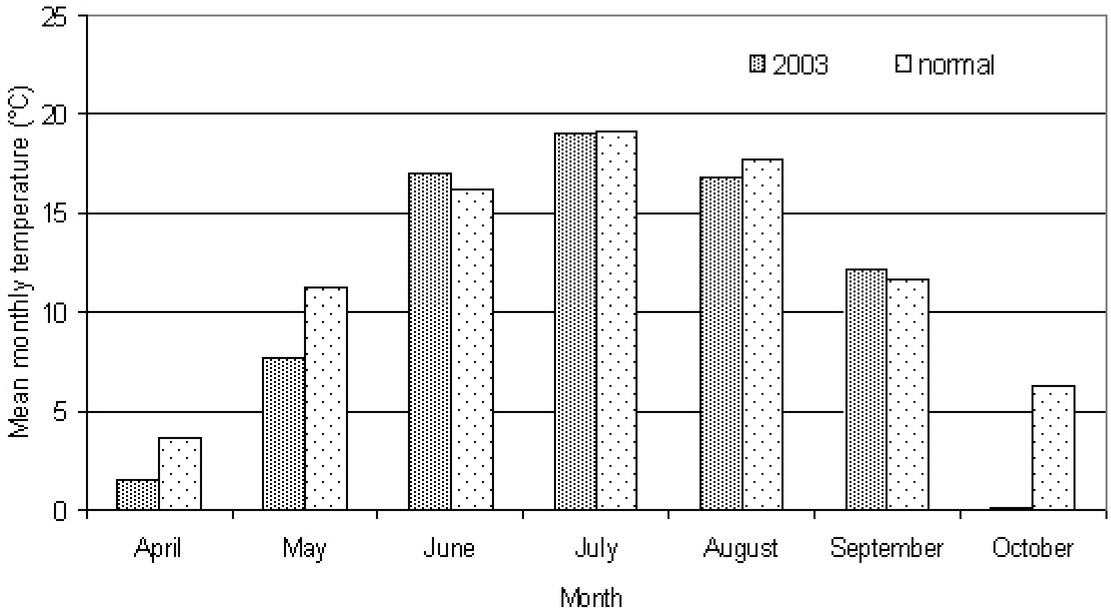


Figure 2. Growing season precipitation at MCDC-Carberry.

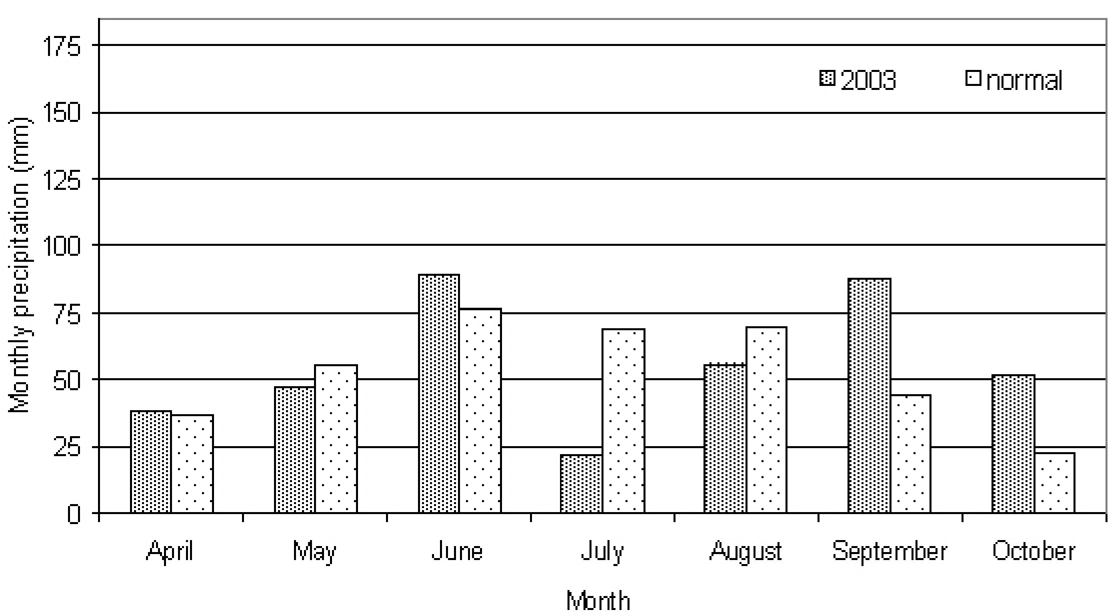


Figure 3. Growing season temperature at Portage la Prairie.

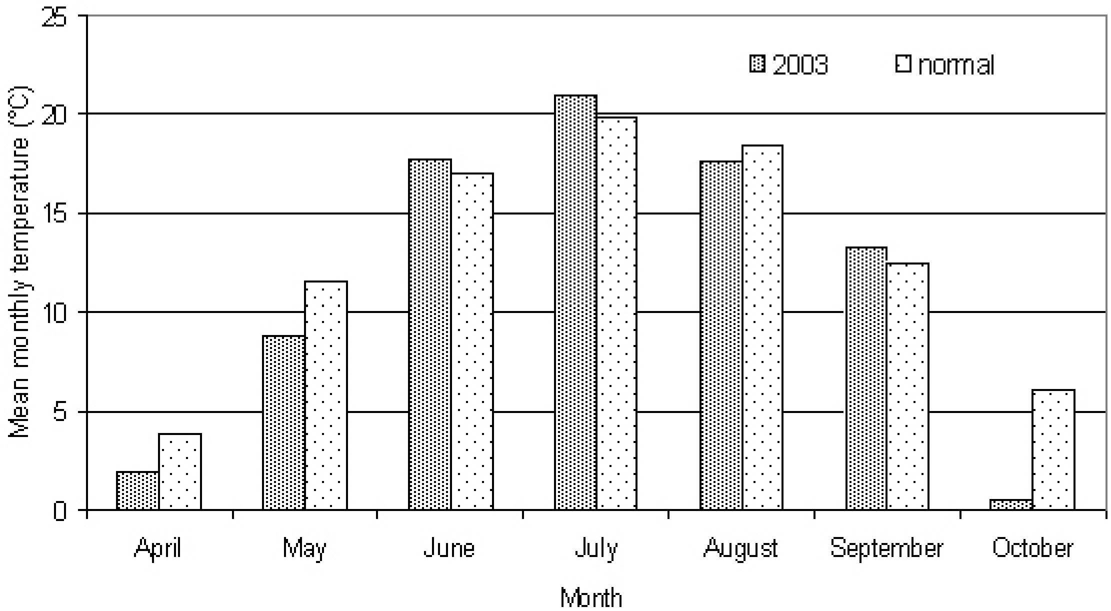


Figure 4. Growing season precipitation at MCDC-Portage la Prairie.

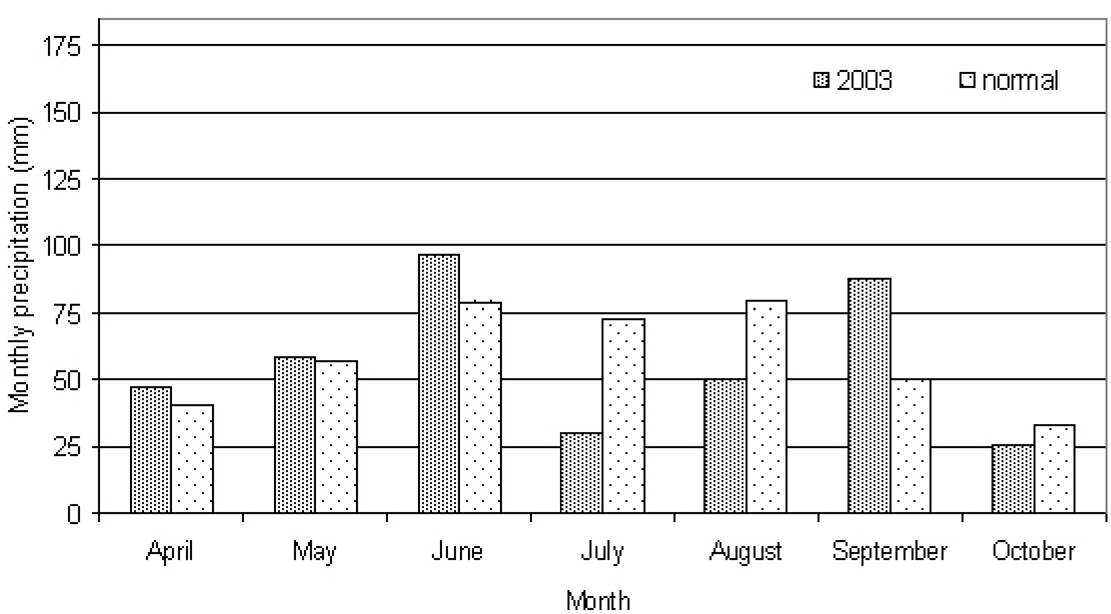


Figure 5. Growing season temperature at Morden (for MCDC-Winkler site).

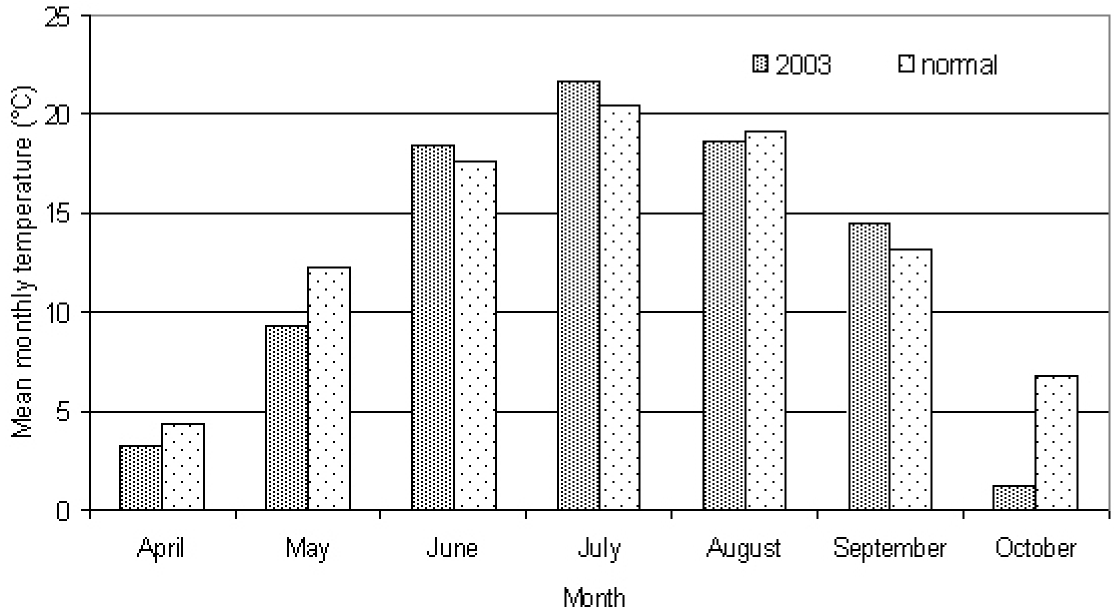
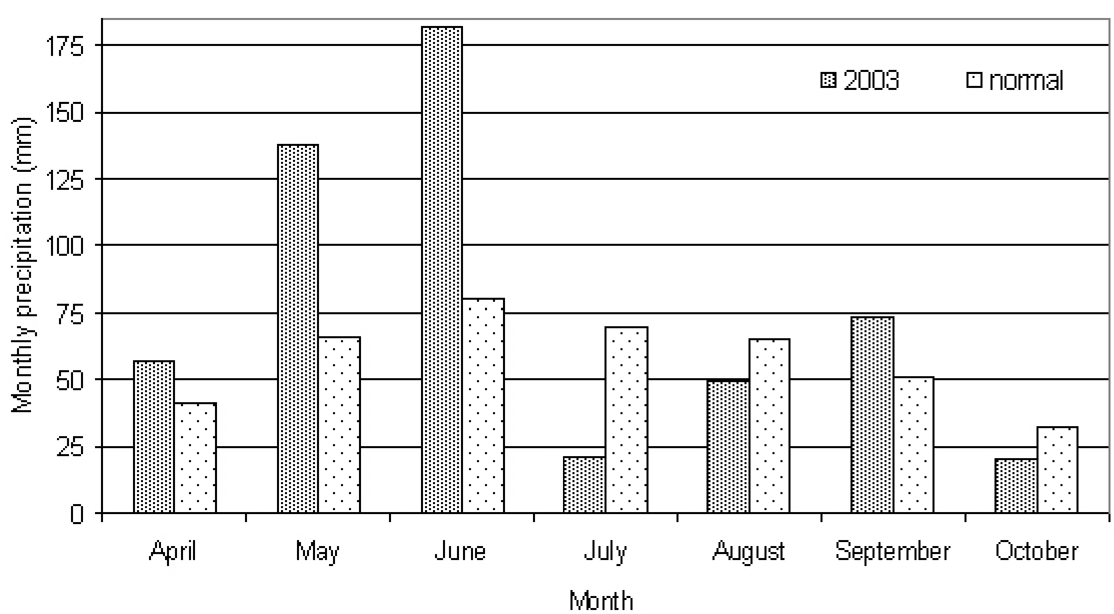


Figure 6. Growing season precipitation at Morden (for MCDC-Winkler site).



Potato Projects

Potato Rotation Study

Principal Investigators: K.M. Volkmar, R.M. Mohr, A. Moulin, D. McLaren, M. Khakbazan, and M. Monreal, AAFC-Brandon Research Centre

Co-investigators: D.J. Tomasiewicz and L.G. Mitchell, MCDC

Funding: MCDC, AAFC (Matching Investment Initiative)

Progress: Seventh year of ongoing research program (year six under MII); sixth year of rotation

Objective: To identify crop management strategies that maintain or enhance potato yield and quality, as well as soil and water quality, to ensure the long-term viability and sustainability of irrigated potato production in Manitoba

Abstract

Rapid expansion of the processing potato industry in Manitoba has increased irrigated potato production in this province. However, much of the agronomic information currently available to producers is based on research conducted under environmental conditions unlike those in southern Manitoba.

In 1997, the Manitoba Crop Diversification Centre (MCDC) and the Brandon Research Centre (BRC), Agriculture and Agri-Food Canada (AAFC), initiated a research project to define viable potato rotations that ensure sustainable land management during industry expansion. This research program is unique in that it examines six different potato crop rotation systems located at one site and covers almost every aspect of crop management, as well as economic analysis of the rotations. No other potato rotation study is being conducted in Canada at this large scale.

Research by MCDC and BRC focuses on the impact of crop rotation on plant development and crop yield, weed populations, disease incidence and severity, and soil characteristics, and on net returns. The MCDC-BRC collaboration is targeted towards identifying viable potato rotations that minimize yield and quality losses due to diseases and weeds, and that maintain soil quality.

As of 2001, crop rotation treatments had been in place for four field seasons, which is equivalent to one cycle of the 4-year rotation and two cycles of the 2-year rotation. Differences among rotations in soil characteristics, weed populations, disease levels, yield and net returns have been identified in some cases. However, variability in responses within treatments and among years suggests that the effect of rotation may not have been fully expressed during the initial four-year period. In part, the plant-soil system within each rotation may not yet have stabilized. As such, additional data will continue to be collected in future years to identify the effects of rotation.

Introduction

Demand for process potatoes has grown steadily since 1962, with a more rapid rise in the past ten years (Figure 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.

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.

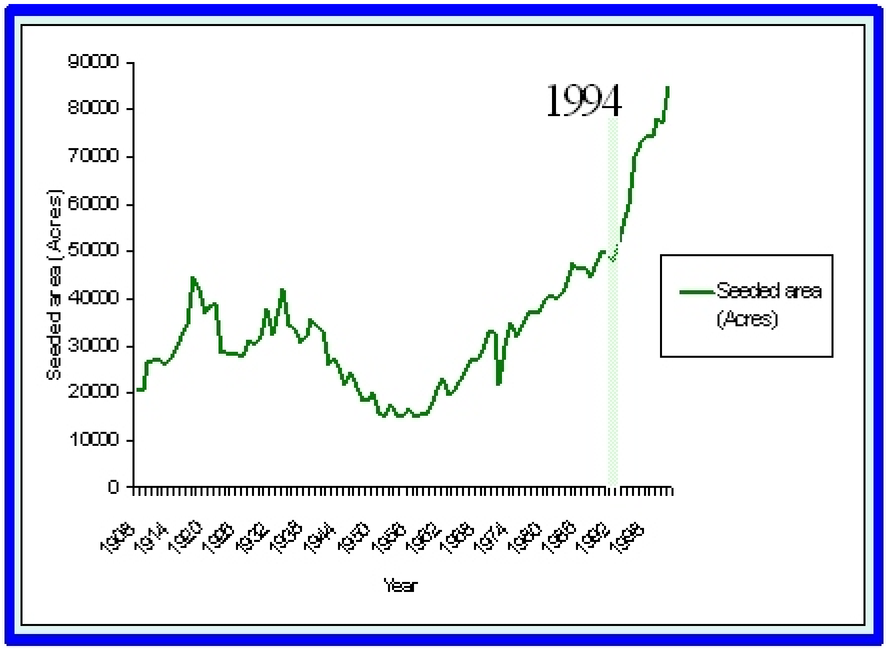


Figure 1. Expansion of irrigated acres in Manitoba (Source: Manitoba Agriculture and Food, 2003)

Table 1. Input cost comparison for potato and representative small grains crops.

	Input costs		
Inputs	**Potato**	**Wheat**	**Canola**
	----------------	$ ac^{-1}	----------------
Fungicide and insecticide	180.00	10.00	25.25
Seed and seed treatment	260.55	17.00	23.38
Fertilizer	67.10	29.50	36.35

Source: Manitoba Agriculture and Food, 2003.

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

	Cost		
Cost category	**Potato**	**Wheat**	**Canola**
	----------------	$ ac^{-1}	----------------
Total operating cost	1285.15	121.91	165.32
Total fixed cost	385.78	55.64	55.64
Total cost of production	1758.43	192.55	229.96

Source: Manitoba Agriculture and Food, 2003.

Producers cannot afford to make poor crop management decisions considering the magnitude of this investment. There is very little information available to Manitoba potato with regard 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.

Experimental Design and Agronomic Management

In 1998, crop rotation treatments were initiated, with six crop rotations ranging in duration from two to four years, and containing a combination of oilseeds, cereals and legumes:

Potato-canola
Potato-wheat
Potato-canola-wheat
Potato-oat-wheat
Potato-wheat-canola-wheat

Each phase of each rotation is present each year for a total of 18 treatments per replicate. The study follows a randomized complete block design (four replicates with 18 treatments/replicate). Plot dimensions are 21.4 x 12.2 m. See previous MCDC Annual Reports for details on crops, agronomics, and measurements.

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).

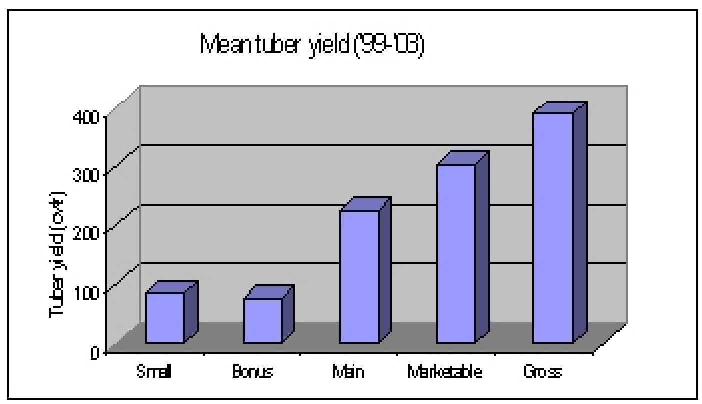


Figure 2. Mean tuber yields of the five main tuber classes from 1999 to 2003.

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, yield of small tubers has declined since reaching a plateau in 2001. As a result of these effects, except for 2001, marketable yield increased steadily since the beginning of the study (Fig. 4).

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

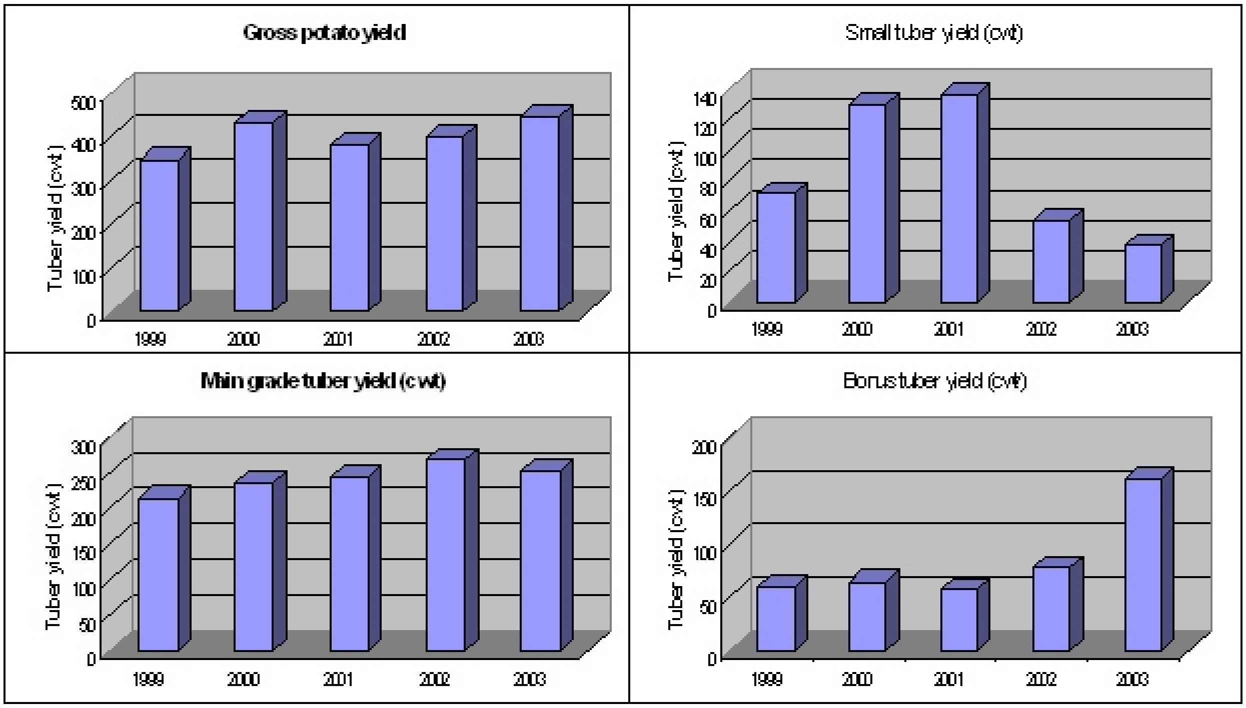


Figure 3. Change in gross, "main", small, and "bonus" tuber yield over time.

rotation had lower bonus tuber yields, and so was amongst the lowest in marketable yield.

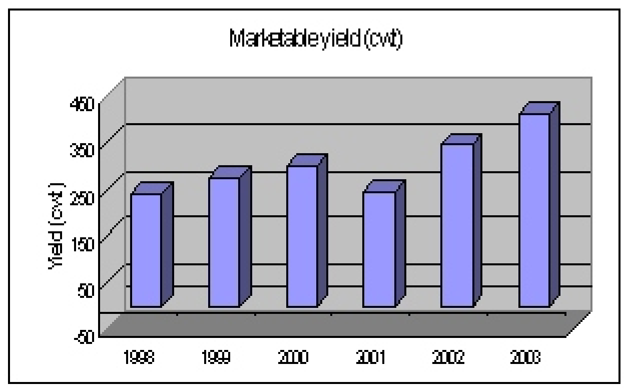


Figure 4. Change in the yield of "marketable" tubers over time.

Both the P-O-W rotation and the four-year mixed rotation (P-W-C-W) were the highest in small-tuber yield and lowest main-tuber yield, and so, had the lowest marketable tuber yields (Fig. 6).

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.

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 P-C-A-A-A rotations, the two highest yielding rotations. Even the lowest specific gravity has been well above 1.08 (Fig. 8b).

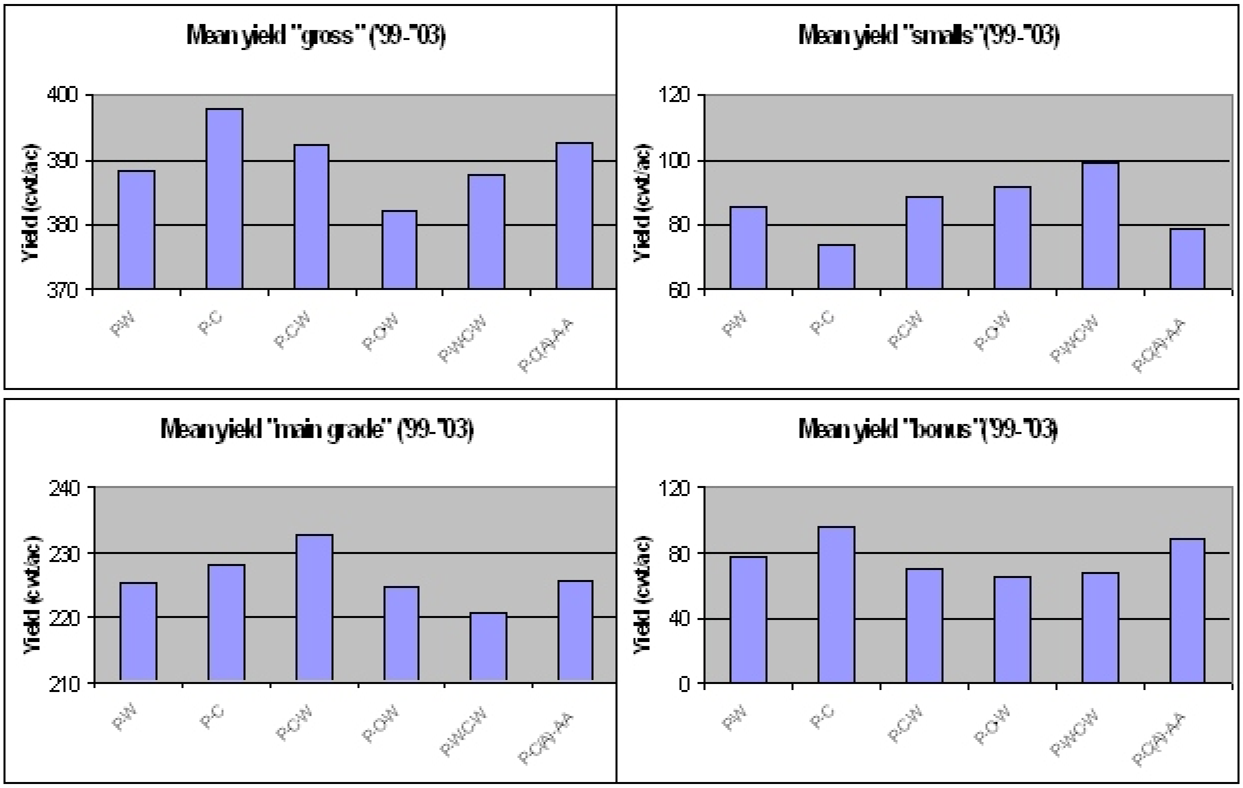


Figure 5. Rotation effect on mean gross, "small", "main", and "bonus" tuber yields.

Factors influencing tuber yield

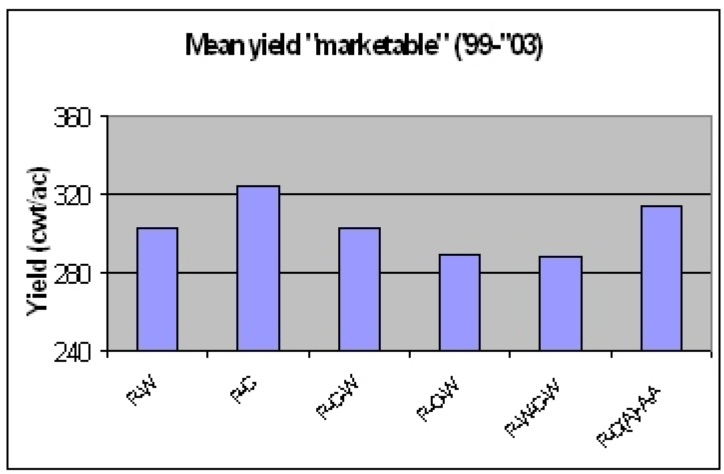


Figure 6. Rotation effect on mean marketable tuber yield.

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. Between the years 2000 to 2002, there has been increasingly less total 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.

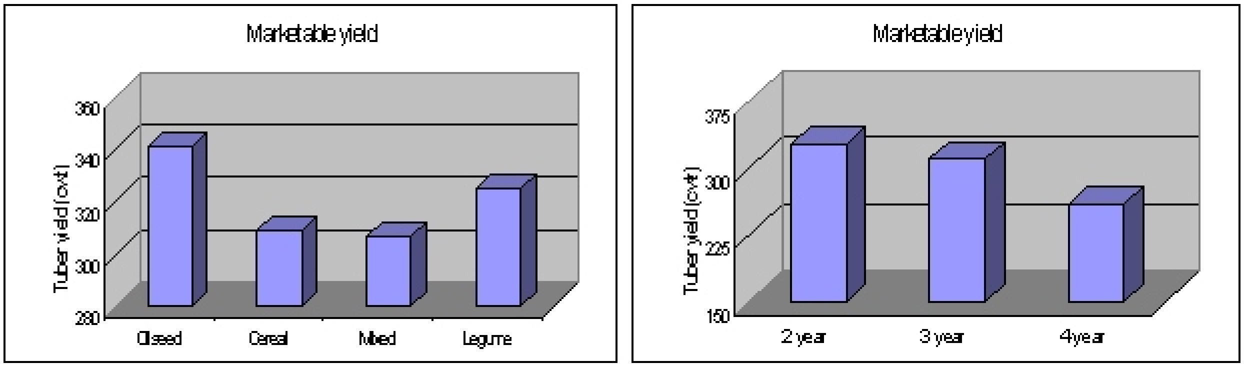


Figure 7. Effect of a) crop species and b) rotation length on mean marketable tuber yield.

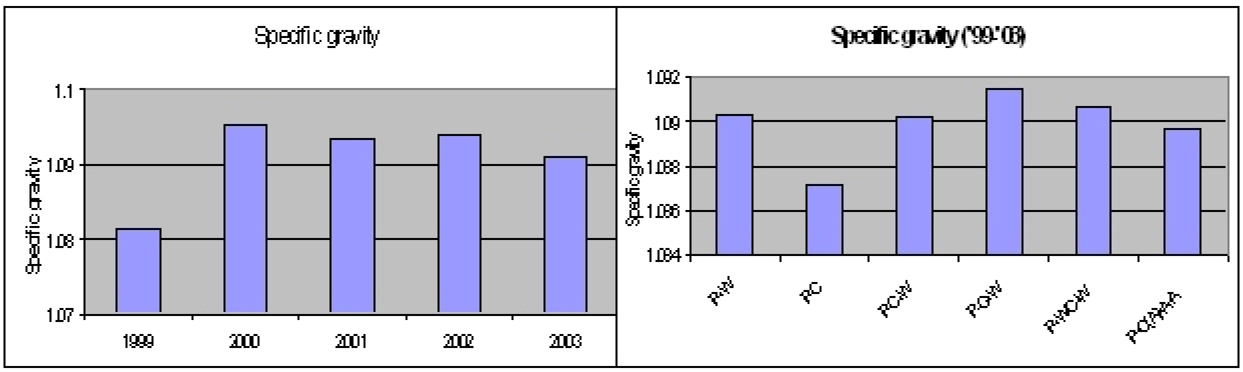


Figure 8. Effect of a) year, and b) rotation on mean tuber specific gravity from 1999 - 2003.

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.

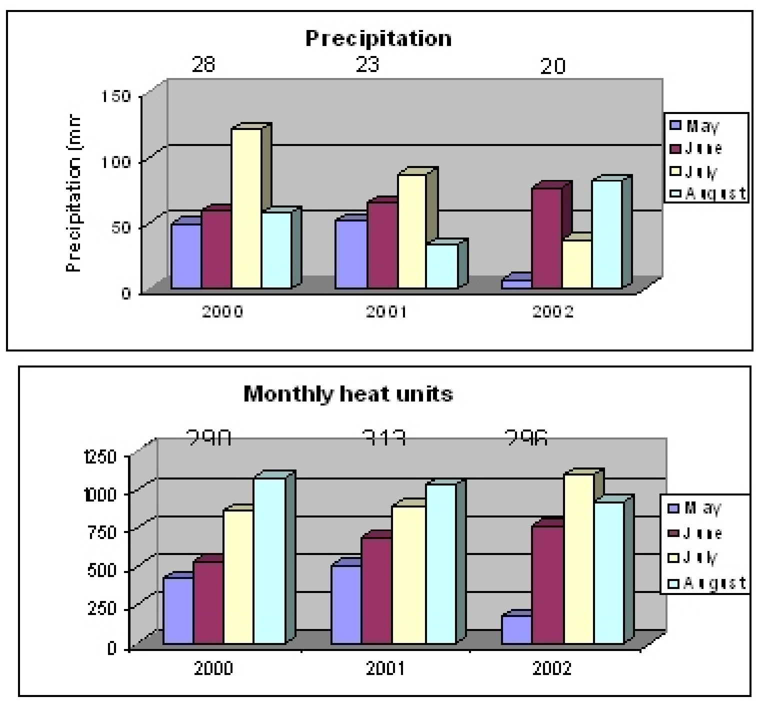


Figure 9. Monthly precipitation and heat units 2000 - 2002 growing seasons.

Early Blight

Early blight (*Alternaria solani*) is principally a disease of aging plant tissue. Alternating wet and dry conditions 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).

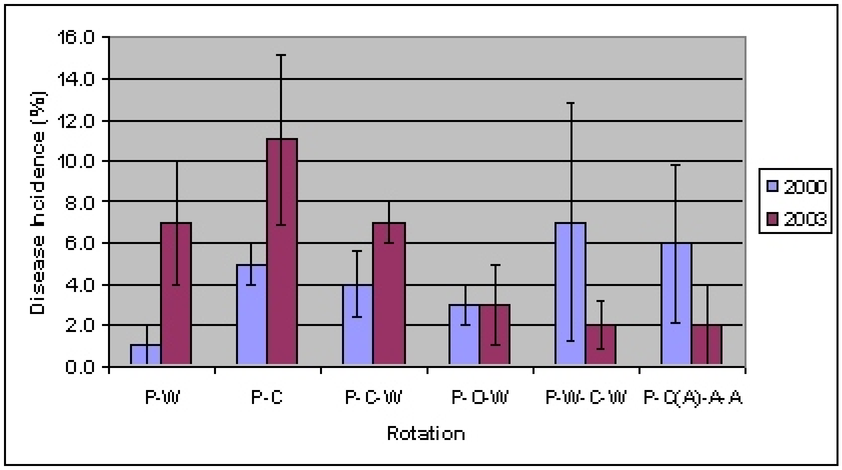


Figure 10. Rotation effect on Blackleg incidence in 2000 and 2003.

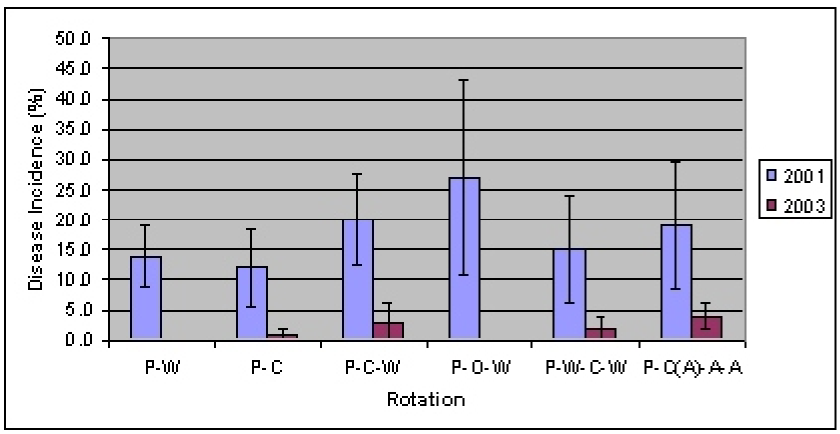


Figure 11. Rotation effects on incidence of Early Blight in 2001 and 2003.

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. 12). In 2002 Rhizoctonia levels increased from those observed in 2001, but levels were

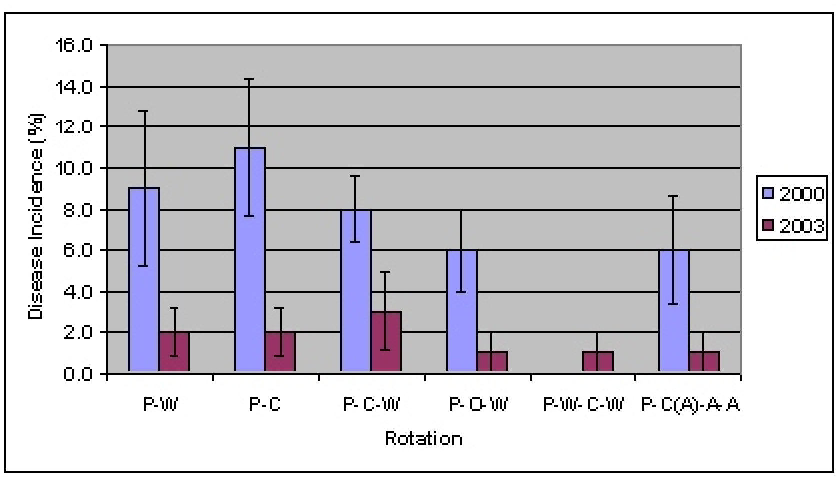


Figure 12. Effect of rotation on Rhizoctonia incidence in 2000 and 2003.

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 unfavourable 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.

<u>Fusarium Dry Rot</u>

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.

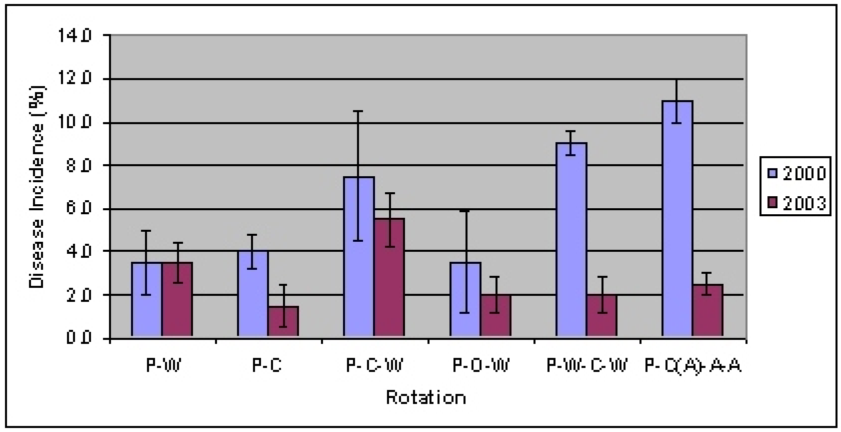


Figure 13. Rotation effect on incidence of Fusarium dry rot in 2000 and 2003.

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.

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

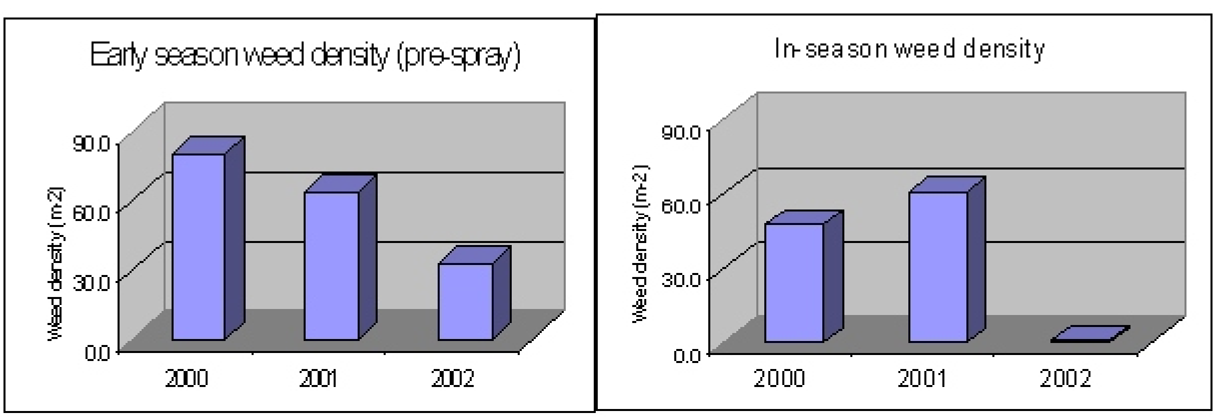


Figure 14. Change in a) early, and b) in-season weed densities in the potato year over time.

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, e.g. 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}.

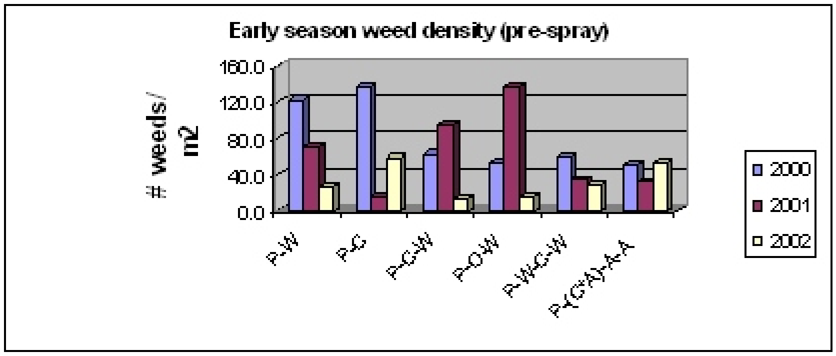


Figure 15. Rotation effects on early-season weed density in the potato year from 2000-2002.

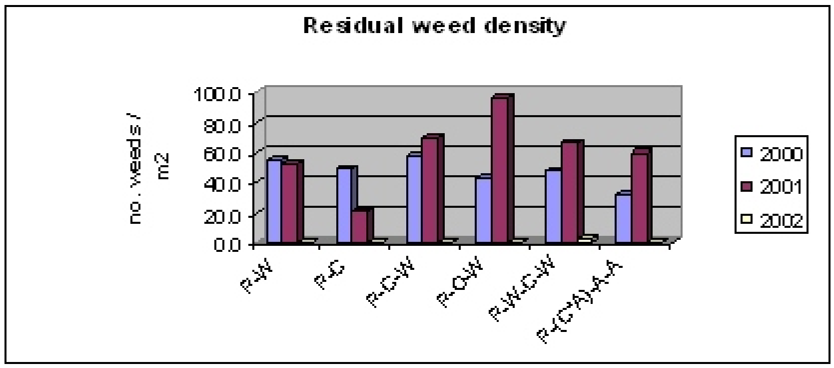


Figure 16. Rotation effect on in-season weed density in the potato year from 2000-2002.

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 (Fig. 17). 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 Fig. 18). Soil moisture, at the time

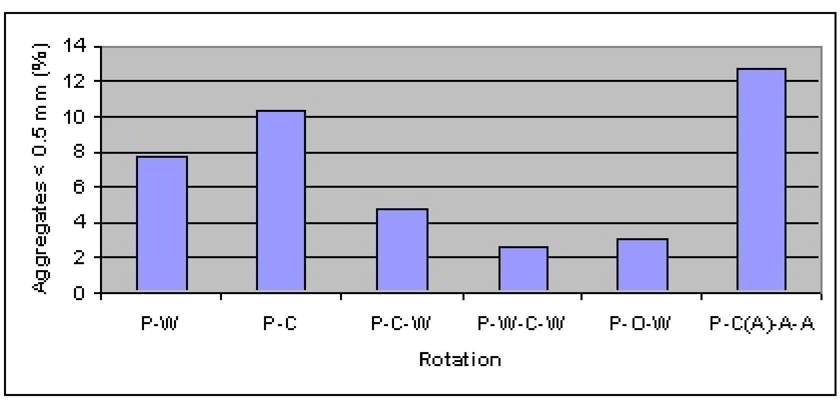


Figure 17. Aggregates less than 0.5 mm diameter (%)in potato phase of rotations.

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.

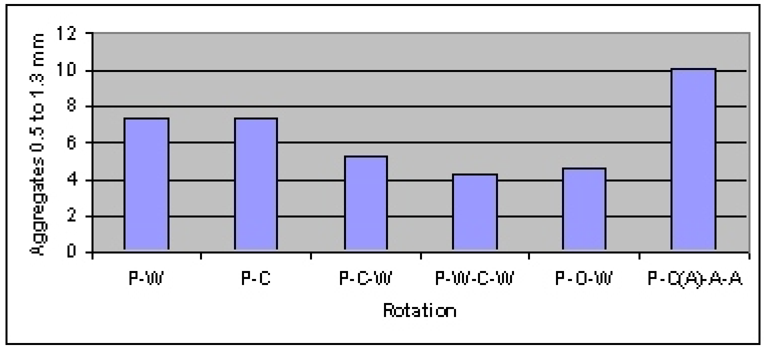


Figure 18. Aggregates 0.5 to 1.3 mm diameter (%)in potato phase of rotations.

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 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.

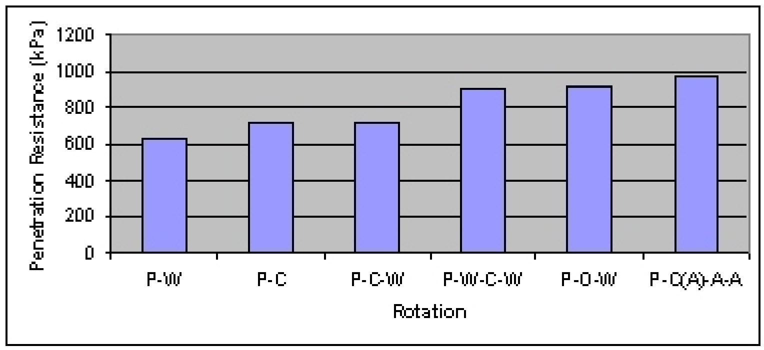


Figure 19. Penetration resistance (kPa) in potato phase of rotations.

Soil moisture

No significant differences were observed in fall soil moisture (gravimetric) between rotations for the 0-15 cm incremen,t 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.

Bulk density

No significant differences were observed in bulk density 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 (Fig. 20). No significant differences were observed between rotations for inorganic carbon.

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

Nitrate was significantly higher in fall soil samples on potato residue (Phase 1) following canola for the 0-15 cm depth increment (Fig. 21). In addition the same effect was observed for total nitrate for the 0-120 cm depth increment. High levels of nitrate in phase 1 may be residues from 2000 for phase 2.

Phosphate

Phosphate-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 (Fig. 22).

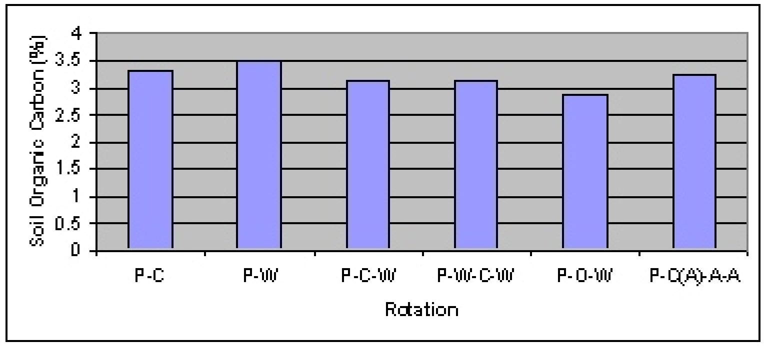


Figure 20. Soil organic carbon in potato phase of rotations.

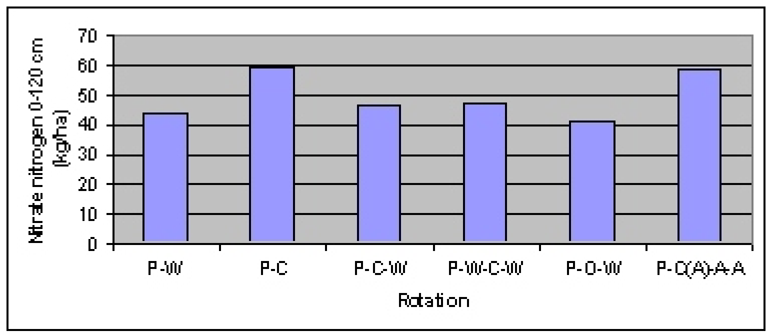


Figure 21. Nitrate-nitrogen in potato phase of rotations.

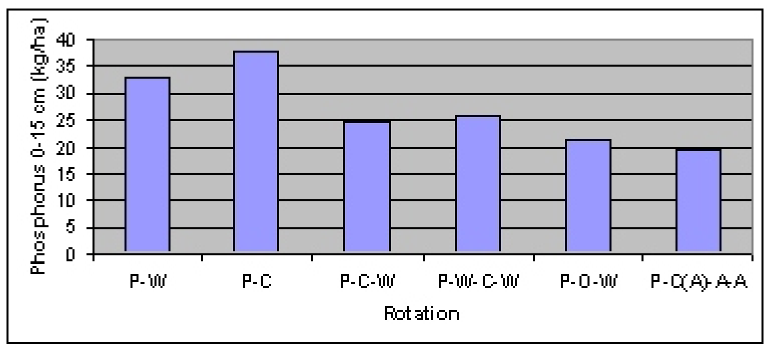


Figure 22. Phosphate-phosphorus in potato phase of rotations.

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

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).

On average, based on data from 1999-2001, the 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. The highest net income of potato-canola (P-C) rotation was due to the highest marketable yield recorded for the potato crop but not the canola yield. Canola consistently produced the lowest net income from all six rotations. A three-year average marketable 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.

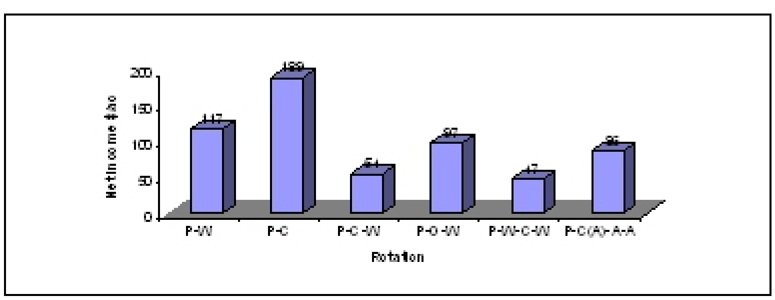


Figure 23. Effect of rotation on aggregate net income.

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.

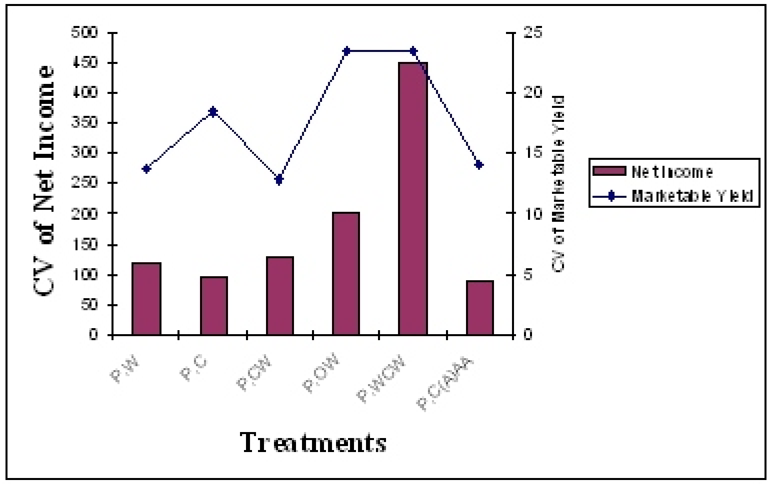


Figure 24. Effect of rotation on income variability 1999 - 2001.

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.

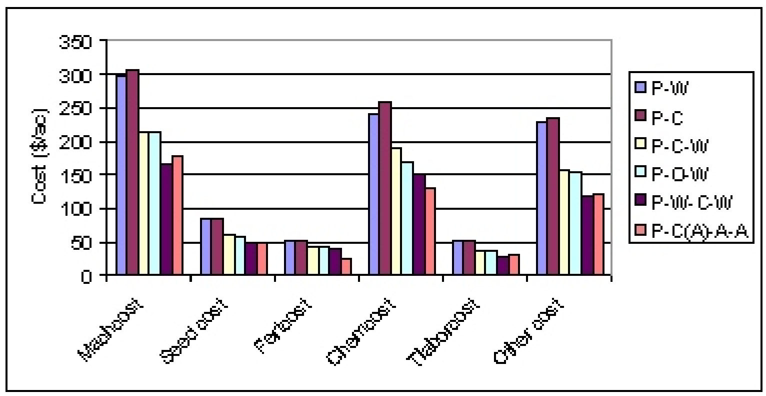


Figure 25. Effect of rotation on input costs.

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.

Soil Nematodes as Bioindicators of Sustainable Agricultural Management

Principal Investigator: Mario Tenuta, Department of Soil Science, University of Manitoba

Objective: To examine the sensitivity of nematode faunal analysis to agricultural management practices in Manitoba.

Methods

Three existing study sites providing contrasting soil types and a range of management practices were sampled in mid-summer 2003 and their nematode communities assessed. The sites were selected because each was located on the same soil type thus differences in abundances of nematode taxa within a site are a result of management. One site (site A) was located north of Spruce Woods Provincial Park. It was a sandy soil with sampling undertaken on three fields in close proximity, two native prairie fields and a potato field. The second site (site B) is the Glenlea Long-term Crop Rotation Study (Plant Sciences, U Manitoba). The site has triplicate mainplots of 3 crop rotations (wheat-pea-wheat-flax, wheat-sweetclover green manure- wheat-flax, wheat- alfalfa [two years harvested for hay]-flax) and has been ongoing for 13 years. The mainplots are divided into 4 management intensities (herbicide and fertilizer, herbicide, fertilizer, and organic). A plot adjacent to each mainplot had been restored to native prairie. The third site (site C) is located at MCDC near Carberry. A potato rotation study was initiated there in 1997 on a Wellwood silt loam. The experimental site had a randomized complete block design consisting of four replicates with eighteen plots/replicate of six crop rotation treatments: potato-wheat (p-w), potato-canola (p-c), potato-canola-wheat (p-c-w), potato-oat-wheat (p-o-w), potato-wheat-canola-wheat (p-w-c-w), and potato-canola (underseeded to alfalfa)-alfalfa-alfalfa (p-c-a(a)-a). The experiment is fully-phased with each crop present in each year. Soil in the potato phase of the p-w, p-c, p-c-w, p-w-c-w, and p-c(a)-a-a treatments were sampled June 18, 2003 by taking composite samples of 15 within hill and 15 between-hill samples to 15 cm using a soil tube sampler.

<u>Nematode extraction, identification</u>

Nematodes were extracted from soil by wet-seiving followed by sugar-centrifugation (Ingham, 1994) from a sub sample of soil from each plot (100 g). The number of nematodes in each sample was estimated by counting half the sample under low magnification (30x) using a dissecting microscope. Temporary wet-mount slides were prepared and 100 hundred nematodes from each plot identified to genera level using the taxonomic keys provided by Bongers (1994). The proportion of each taxa of the 100 identified and the total of all nematodes in a sample were used to estimate the abundance of each taxon.

<u>Community analysis</u>

Each taxon of nematode was classified to functional groups to calculate two indices describing the state of the soil food web: Enrichment (EI; indicates level of labile carbon and nutrients) and Structure (SI; physical stability of soil and low toxic conditions) (Ferris et al., 2001).

To calculate the various nematode indices, all genera were assigned weights for EI, BI and SI according to their classification in functional groups (Ferris et al., 2001). For example, bacteria-feeding nematodes with a c-p value of 1 received a weight of 3.2 for EI only. Bacteria-feeding nematodes with a c-p value of 2 received a weight of 0.8 for BI only, while fungi-feeding nematodes with a c-p value of 2 received a weight of 0.8 for EI and BI. Plant-parasitic nematodes are eliminated from the indices to remove host-status effects of the crop sequences. The sum-products (called E, B, and S) are calculated of the assigned weights and numbers of individuals in all genera. The indices are calculated as follows:

$EI = 100 \times E / (B+E)$

$SI = 100 \times S / (B+S)$

$CI = 100 \times E_f / (E_b+E_f)$,

where E_f is E of fungi-feeding nematodes and E_b of bacteria-feeding nematodes (Ferris et al., 2001a).

Total nematode counts (#/100 g soil), taxonomic richness (S), Simpon's Diversity Index (D), Shannon-Weaver Diversity Index (H), and species evenness (E) were also determined for nematode data obtained for each plot. The abundances of genera of plant-parasitic and plant-feeding nematodes were also determined according to taxonomic keys provided by Mai and Mullin (1996) and analyzed if relation to treatment and temporal effects.

Results and Discussion

The primary objective of the study was to determine the sensitivity of nematode faunal analysis to agricultural management. The rotation study at MCDC served this purpose well. Total nematode counts in soil were highest for the p-c(a)-a-a treatment (Table 1). The p-c treatment had a trend for lower species richness, diversity, and evenness (Table 1). Functional trophic levels of nematodes were less affected by rotation except for the p-c-w and p-w-c-w which had greater levels of plant feeding nematodes (Figure 1). Plant parasitic nematodes for all rotations were low. The ectoparasitic nematode *Helicotylenchus* (spiral nematode) was a dominant taxon in the rotations having wheat as a proceeding crop (data not shown). This is a nematode known to feed on grasses such as cereals. Interestingly, the ectoparasite *Xiphinema* (dagger nematode) was a dominant taxon in only the p-w-c-w rotation (data not shown). We will track populations of this nematode because in other crops it has been shown in some cases to be a vector of plant viruses. The dominant taxon in all rotations was a bacterial feeding nematode belonging to the family Rhabditidae and indicative of rapidly decomposing plant residue in soil. Future studies will aim to compare nematode communities at different times of the year as affected by rotation and levels of the dagger nematode.

Table 1. Nematode community structure results for potato rotations sampled at MCDC in summer 2003. Results are averages of 4 replicate plots. Different letters in a column indicate significant differences between rotations for a community indicator.

Crop Rotation	Counts per 100g soil	Richness (S)	Simpon's Diversity (D)	Shannon-Weaver Diversity (H)	Evenness (E)	Enrichment (EI)	Structure (SI)
P-W	971 b	14	0.88	2.28 a	0.87 a	0.77	0.14
P-C	755 b	13	0.85	2.08 b	0.81 b	0.75	0.12
P-C-W	1104 b	14	0.87	2.27 ab	0.87 a	0.74	0.17
P-W-C-W	1094 b	14	0.89	2.39 a	0.90 a	0.74	0.20
P-C(A)-A-A	1658 a	14	0.87	2.22 ab	0.85 ab	0.79	0.12

The sensitivity of nematode faunal analysis was compared for the MCDC site and other agricultural fields and Prairie sites providing a range of crop/plant management systems. Generally, Enrichment nematodes were more prevalent in all agricultural fields whereas being less abundant at the natural

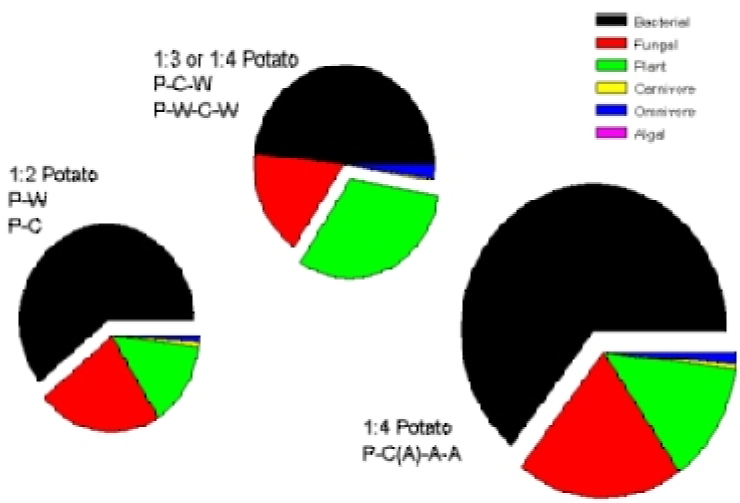


Figure 1. Nematode functional feeding groups from the potato rotations sampled at MCDC in summer 2003. The size of the overall pie for the rotations indicates relative total counts of nematodes.

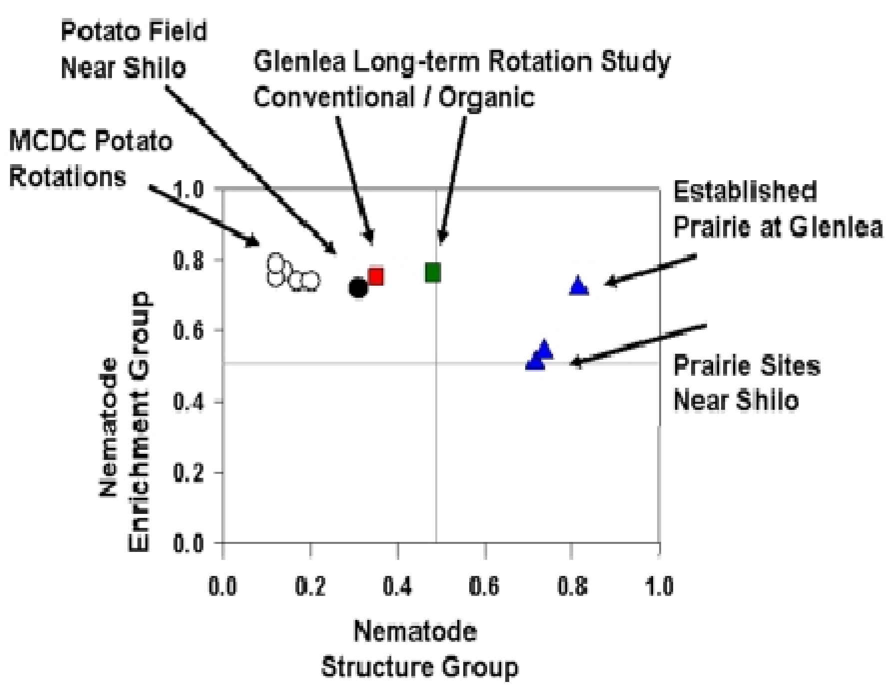


Figure 2. Summary of nematode communities using Nematode Faunal Analysis for the potato rotations at MCDC, potato near Shilo, MB, and plots of flax at Glenlea and prairie vegetation at Glenlea and Shilo, MB. Indicated as well is the crop management (conventional vs. organic) for the flax rotations at Glenlea.

Prairie sites. The established Prairie site at Glenlea (in Prairie vegetation for 13 years) had similar Enrichment level to that of the agricultural fields. The Structure nematode index seemed to be more discriminatory of crop/plant management systems. The potato fields sampled had the lowest Structure nematodes of the sites sampled. Conventional (pesticide and fertilizer addition) was lower in Structure nematodes than organic management. The Prairie sites had the highest Structure nematodes. Overall the data indicates the higher the intensity of crop management the lower the Structure nematode levels observed. These nematodes have potential based on these results to be indicators of disturbance of soil food webs as affected by management. The implications of Structure nematodes to soil health and crop production will be the focus of future studies.

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Nitrogen Management for Irrigated Potato Production in Manitoba

Principal Investigators: Ramona Mohr, AAFC-Brandon Research Centre
Dale Tomasiewicz, MCDC

Funding: J.R. Simplot Co.
Agriculture and Agri-Food Canada, Brandon
MCDC

Progress: First year of study

Objective: To assess the impact of nitrogen management in irrigated potato production systems in Manitoba in order to identify sustainable nitrogen management practices that optimize potato yield and quality while minimizing the potential for nitrogen losses from the system.

Introduction

Manitoba's processing potato industry has undergone rapid expansion in recent years, contributing to significant increases in potato production in this province. In Manitoba in 2001-02, an estimated 12.8 million cwt of processing potatoes valued at $97.3 million were marketed. As of 2001, potatoes were being produced on an estimated 78,500 acres with further expansion currently underway in order to meet the demand of a newly-constructed processing plant near Portage la Prairie.

Despite the growing importance of the processing potato industry in Manitoba, research directed at the development of agronomically and environmentally sustainable fertility management systems for irrigated potato production has been somewhat limited. As a result, much of the information currently available to Manitoba producers is based on research conducted in other potato-producing areas. This information may not be directly applicable under local environmental conditions.

The specific objectives of this study are to determine:

1) impact of rate and timing of nitrogen (N) application on potato yield and processing quality
2) relationship between petiole extractable nitrate level and yield responsiveness in order to contribute to the development of critical nutrient concentration curves for Manitoba conditions
3) impact of rate and timing of N application on soil nitrate-N levels following potato production

Methods

In 2003, one field experiment was conducted on a Stockton fine sandy loam in the Carberry area. The experiment was located on a producer's potato field that contained relatively low soil test nitrate levels (Table 1). A randomized complete block design consisting of four replicates of the following treatments was established:

1) control (no N fertilizer applied, except 14 kg N ha^{-1} as the P fertilizer source)
2) 75 kg N ha^{-1}, pre-plant
3) 150 kg N ha^{-1}, pre-plant
4) 225 kg N ha^{-1}, pre-plant

5) 75 kg N ha^{-1}, split ½ as pre-plant (37.5 kg N ha^{-1}) and ½ topdressed just prior to final hilling (37.5 kg N ha^{-1})
6) 150 kg N ha^{-1}, split ½ as pre-plant (75 kg N ha^{-1}) and ½ topdressed just prior to final hilling (75 kg N ha^{-1})
7) 225 kg N ha^{-1}, split ½ as pre-plant (112.5 kg N ha^{-1}) and ½ topdressed just prior to final hilling (112.5 kg N ha^{-1})
8) 75 kg N ha^{-1}, split 1/3 as pre-plant (25 kg N ha^{-1}), 1/3 topdressed just prior to final hilling (25 kg N ha^{-1}), 1/6 hand broadcast midway between final hilling and final application (12.5 kg N ha^{-1}), 1/6 hand-broadcast at beginning of August (12.5 kg N ha^{-1})
9) 150 kg N ha^{-1}, split 1/3 as pre-plant (50 kg N ha^{-1}), 1/3 topdressed just prior to final hilling (50 kg N ha^{-1}), 1/6 hand broadcast midway between final hilling and final application (25 kg N ha^{-1}), 1/6 hand broadcast at beginning of August (25 kg N ha^{-1})
10) 225 kg N ha^{-1}, split 1/3 as pre-plant (75 kg N ha^{-1}), 1/3 topdressed just prior to final hilling (75 kg N ha^{-1}), 1/6 hand broadcast midway between final hilling and final application (37.5 kg N ha^{-1}), 1/6 hand broadcast at beginning of August (37.5 kg N ha^{-1})

Potato (cv. Russet Burbank) was planted on May 1 using a 6-row commercial potato planter set at a row spacing of 38". Plots measured 6 rows wide x 16 m long.

Nitrogen fertilizer in the form of ammonium nitrate was applied at the rate and time indicated by treatment. Dates of N application were: April 30 (pre-plant), June 19 (pre-hilling), July 15 (midway between hilling and final application) and August 7 (final application). In order to ensure adequate levels of P, K and S across the entire experimental site, a pre-plant blanket application of 67 kg P_2O_5 ha^{-1}, 112 kg K_2O ha^{-1} and 22 kg S ha^{-1} as monoammonium phosphate, potash and K-Mg-sulphate was made. Monoammonium phosphate provided 14 kg N ha^{-1} to each treatment. As such, the control treatment received 14 kg N ha^{-1} rather than 0; in all other treatments, N rates were adjusted to account for this additional N. All pre-plant fertilizer was applied just below the soil surface using a Great Plains seeder to meter the fertilizer. Immediately following fertilizer application, the area was tilled with a Roterra. In-crop N was applied with a plot broadcaster or by hand to each row.

Pesticide applications to the plot area were conducted by the producer according to the management practices used in the surrounding potato field. The crop was irrigated as required using the field irrigation system.

Soil samples in increments of 0-15 cm, 15-30 cm, 30-60 cm, 60-90 cm and 90-120 cm were collected at approximately 16 locations within the plot area on April 29. Soil cores within each quadrant of the plot area were composited.

Plant stand in rows 3 and 4 of each plot was measured after emergence. Petiole samples were collected at approximately 10 day intervals throughout the growing season (June 19, June 30, July 9, July 18, July 29, August 7, August 18, August 27, September 10) from rows 2 and 5 within each plot. Petiole samples were oven-dried and ground. Nitrate in ground petiole samples was extracted with water, and NO_3 concentration in the extract determined colorimetrically using an autoanalyzer.
Potato plots were harvested on

Table 1. Soil nitrate-N in the four quadrants of the plot area in the spring immediately prior to planting

Soil NO_3-N	Northeast	Northwest	Southeast	Southwest	Mean
0-15 cm (mg kg^{-1})	2.5	3.0	3.3	1.8	2.7
15-30 cm (mg kg^{-1})	3.0	3.4	6.4	4.5	4.3
30-60 cm (mg kg^{-1})	4.9	1.8	7.5	4.1	4.6
60-90 cm (mg kg^{-1})	5.0	3.6	4.0	1.3	3.5
90-120 cm (mg kg^{-1})	5.5	6.3	1.9	0.8	3.6
kg ha^{-1} to 60 cm	34	22	55	32	36
kg ha^{-1} to 120 cm	81	67	82	42	68

September 23 by harvesting approximately 10-11 m of row from each of rows 3 and 4. The harvested area was measured and tuber yields were determined.

Soil samples in increments of 0-15 cm, 15-30 cm, 30-60 cm, 60-90 cm, and 90-120 cm were collected from two locations within each plot on September 23, immediately following harvest. All soil samples were air-dried and ground. Soil NO_3 was extracted with 2 M KCl, and the NO_3 concentration in the extract determined colorimetrically using an autoanalyzer. Soil samples collected in the spring have been submitted to a commercial lab for further analysis, but results were not available at the time this report was prepared.

Following harvest, a subsample of potato tubers from each plot was graded. The graded sample for each plot was equivalent to approximately 25% of the harvested yield. The number and weight of tubers was determined based on five tuber weight classes (<3 oz, 3-6 oz, 6-10 oz, 10-12 oz, >12 oz). In addition, the number and weight of small tubers was determined based on five tuber size classes (<1¾"; 1¾ " to 1 7/8", <3"; 1¾" to 1 7/8", >3"; 1 7/8" to 2", <3"; 1 7/8 to 2", >3"). The number and weight of green tubers, and tubers affected by rot and hollow heart/brown centre were determined. As well, specific gravity was determined. Due to a problem during storage, sugar content could not be determined.

Preliminary analysis of the data has been completed. Data were first analyzed as a randomized complete block design to determine the effect of treatment. Data, excluding the control, were then analyzed as a factorial of fertilizer N rate and timing of N application. Contrasts were used for specific comparisons among treatments.

Results and Discussion

Petiole NO_3 concentration was strongly influenced both by N fertilizer rate and time of application (Figure 1). Overall, higher N fertilizer rates resulted in higher petiole NO_3 levels throughout the growing season. For a given N fertilizer rate, splitting the N fertilizer application generally appeared to maintain petiole NO_3-N at a higher concentration later in the growing season.

Depending on the critical nutrient concentration curve for petiole NO_3 being used, the subset of treatments considered to have a sufficient N supply varied somewhat (Figure 1). Based on the target range for petiole NO_3 reported in the Guide to Commercial Potato Production on the Canadian Prairies (Western Potato Council, 2003), both the control and the 75 kg N ha^{-1} rate split into four applications contained less than sufficient concentrations of petiole NO_3 for most of the growing season. As the season progressed, the petiole NO_3 concentration for all 75 kg N ha-1 rates regardless of timing, and for the 150 kg N ha^{-1} rate applied pre-plant, fell below the range considered sufficient as well. Only the 225 kg N ha^{-1} rate split into four applications appeared to exceed the sufficient petiole NO_3 range later in the growing season. In contrast, based on preliminary critical nutrient concentration curves for petiole NO_3 that were developed using Manitoba data (Tomasiewicz, 1996), petiole NO_3 concentrations in the current study would be considered sufficient in all treatments except the control during the first part of the growing season. As the season progressed, the petiole NO_3 concentration in the control treatment also exceeded the critical nutrient concentration developed for potato in Manitoba. Regardless of the critical nutrient concentration curve used, petiole NO_3 concentration did not always separate treatments in terms of their yield response to fertilizer N application. While critical nutrient concentration curves suggested that petiole NO_3 concentration was sufficient in at least some treatments, a significant yield response to fertilizer N was evident.

Total tuber yield increased linearly with increasing N rate across the range of N rates applied (Figure 2; Table 2). In part, low soil NO_3 levels may have contributed to this positive yield response to N

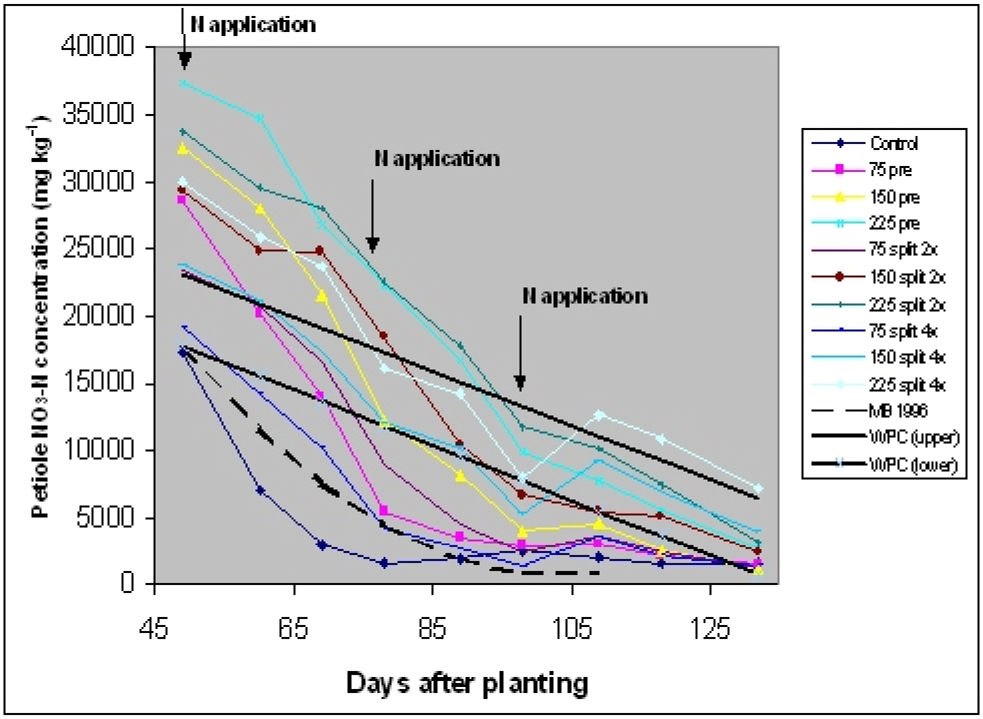


Figure 1. Effect of N fertilizer application rate and timing on petiole NO_3-N concentration of potato (cv. Russet Burbank) throughout the 2003 growing season. Two critical nutrient concentration curves for petiole NO_3-N are shown: “MB 1996” was reported by Tomasiewicz (1996) based on Manitoba field trials; “WPC” shows the upper and lower limits of the target range for potato petiole nitrate based on the Guide to Commercial Potato Production on the Canadian Prairies (Western Potato Council, 2003).

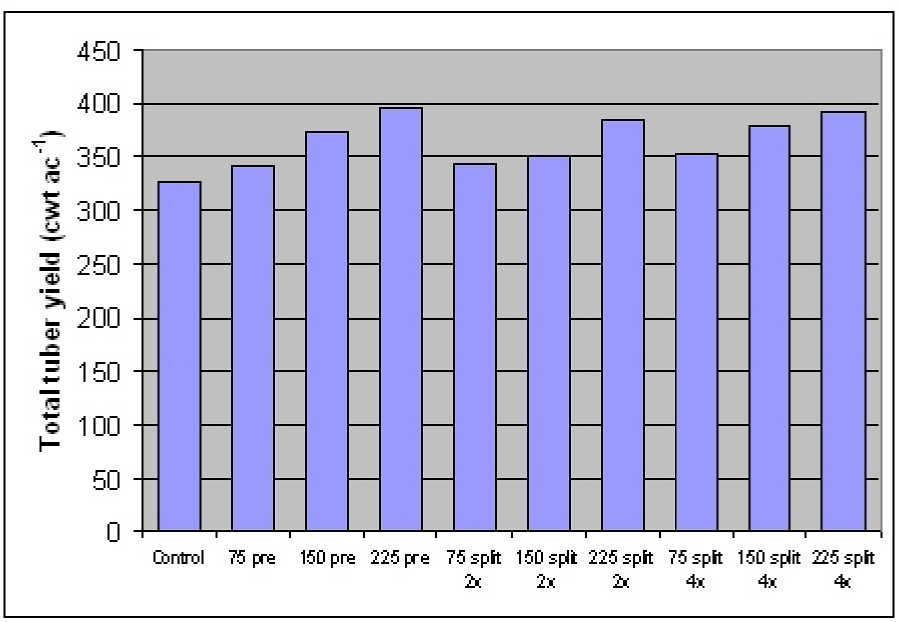


Figure 2. Effect of N fertilizer application rate and timing on total yield of potato (cv. Russet Burbank) in 2003.

Table 2. Effect of N fertilizer rate and timing of application on tuber yield for various size fractions, total tuber yield, and specific gravity

Treatment		<3 oz	3-6 oz	6-10 oz	10-12 oz	>12 oz	Total	S.G.
		------------	------------	------------	cwt acre^{-1}	------------	------------	
Means								
Control	14 kg N ha^{-1}	22.4	63.2	103.5	45.3	93.5	328	1.0860
Rate	75 kg N ha^{-1}	17.5	69.6	117.8	44.1	97.2	346	1.0878
	150 kg N ha^{-1}	16.5	75.1	124.4	44.6	107.5	368	1.0854
	225 kg N ha^{-1}	23.6	81.8	126.4	52.8	106.1	391	1.0845
Split	1	17.5	85.2	125.2	50.2	92.2	370	1.0867
	2	22.6	80.2	119.0	40.6	97.6	360	1.0858
	4	17.5	61.2	124.3	50.7	121.0	375	1.0851
P-values*								
Rate		0.15	0.57	0.73	0.62	0.81	0.05	0.07
Split		0.33	0.11	0.84	0.53	0.22	0.68	0.53
R*S		0.93	0.06	0.47	0.72	0.27	0.96	0.65
Contrasts								
Linear rate		0.13	0.30	0.45	0.39	0.61	0.02	0.03
Quadratic rate		0.23	0.95	0.82	0.66	0.69	0.98	0.51
CV (%)		48.9	37.2	22.6	51.6	40.3	11.3	0.31
P-values**								
Contrasts								
Control vs all fertilized		0.51	0.39	0.18	0.88	0.64	0.07	0.95

application (Table 1). The timing of N fertilizer application had no effect on total tuber yield however.

Interestingly, although soil NO_3 levels were relatively low in the spring prior to crop establishment (averaging 36 kg NO_3-N ha^{-1} to 60 cm), and only 14 kg N ha^{-1} as fertilizer N was applied to the control treatment, total tuber yield was nearly 84% that obtained in the highest N rate treatment. In part, mineralization of soil N may have contributed to the N supply available to the crop. Previous studies in Manitoba have similarly pointed to the potential for significant contributions of N through mineralization of soil organic matter during the growing season (Tomasiewicz, 1996).

While total tuber yield was influenced by N rate, neither rate nor timing of N fertilizer application had a statistically significant effect on the yield of the different tuber size fractions measured (Table 2; Figure 3). When the yield of tuber size fractions <3 oz, 3 to 10 oz, and >10 oz were considered, no effect of N rate or timing was evident. However, N tended (P=0.11) to increase the yield of tubers >3 oz. Contrast analysis indicated a significant (P=0.04) linear increase in the yield of tubers >3 oz with increasing N rate (Table 3).

Very few green or rotted tubers were evident in the samples graded (data not presented). However, hollow heart was observed in a number of samples. Contrast analysis comparing the control to fertilized treatments indicated that the percentage of tubers affected by hollow heart was significantly higher in the control treatment (18%) than in fertilized treatments (5%) (data not presented). Specific gravity was found to decrease linearly with increasing N rate across the range of N rates applied, but was not affected by timing of N fertilizer application (Table 2).

Where N had been applied, post-harvest soil NO_3 content to 120 cm increased linearly with increasing N fertilizer rate (Figure 4). Splitting the fertilizer applications did not have a statistically significant effect on post-harvest soil NO_3 content, which ranged among treatments from approximately 24 to 60 kg NO_3-N ha^{-1} to 120 cm.

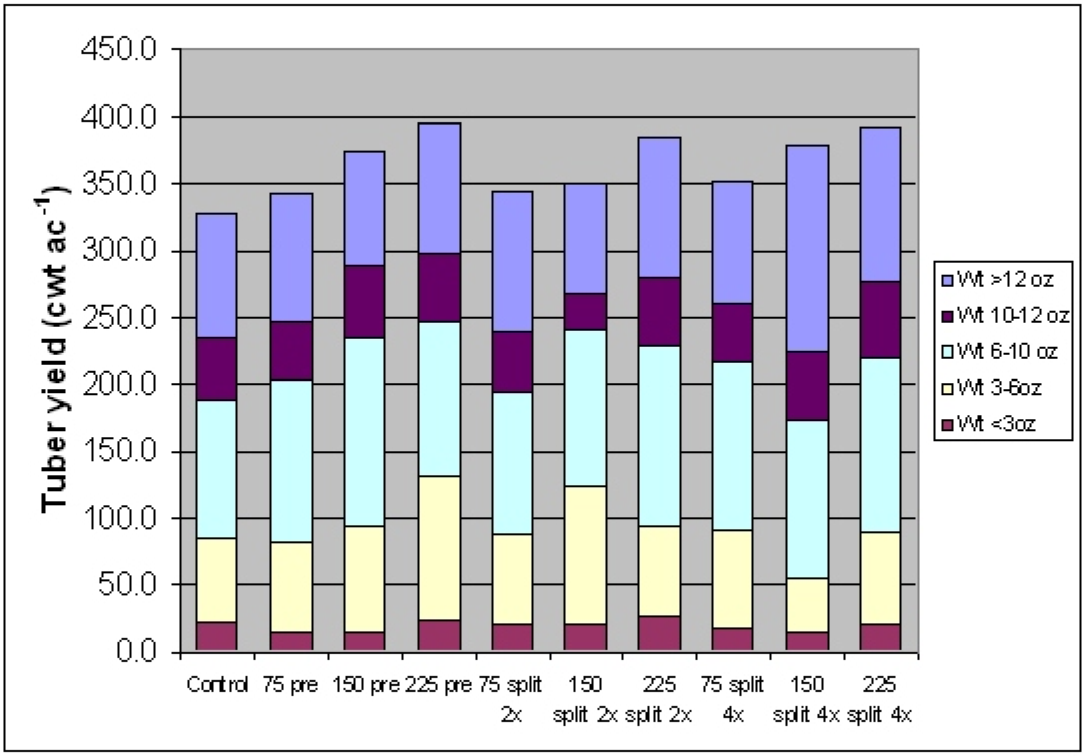


Figure 3. Effect of N fertilizer application rate and timing on yield of various tuber size fractions in 2003.

Table 3. Effect of N fertilizer rate and timing of application on yield of tubers < 3 oz, 3 to 10 oz, and > 10 oz.

Treatment		**<3 oz**	**3 to 10 oz**	**>10 oz**	**>3 oz**
		---------------------------cwt acre^{-1}---------------------------			
Means					
Control	14 kg N ha^{-1}	22.4	166.7	138.8	305.5
Rate	75 kg N ha^{-1}	17.5	187.4	141.3	328.7
	150 kg N ha^{-1}	16.5	199.5	152.1	351.6
	225 kg N ha^{-1}	23.6	208.2	158.9	367.1
Split	1	17.5	210.4	142.4	352.9
	2	22.6	199.2	138.2	337.4
	4	17.5	185.5	171.7	357.1
P-values*					
Rate		0.15	0.51	0.70	0.11
Split		0.33	0.39	0.24	0.50
R*S		0.93	0.36	0.29	0.96
Contrasts					
Linear rate		0.13	0.26	0.41	0.04
Quadratic rate		0.23	0.91	0.91	0.81
CV (%)		48.9	22.1	34.0	12.3
P-values**					
Treatment		0.54	0.34	0.39	0.30
Contrasts					
Control vs all fertilized		0.51	0.16	0.65	0.06

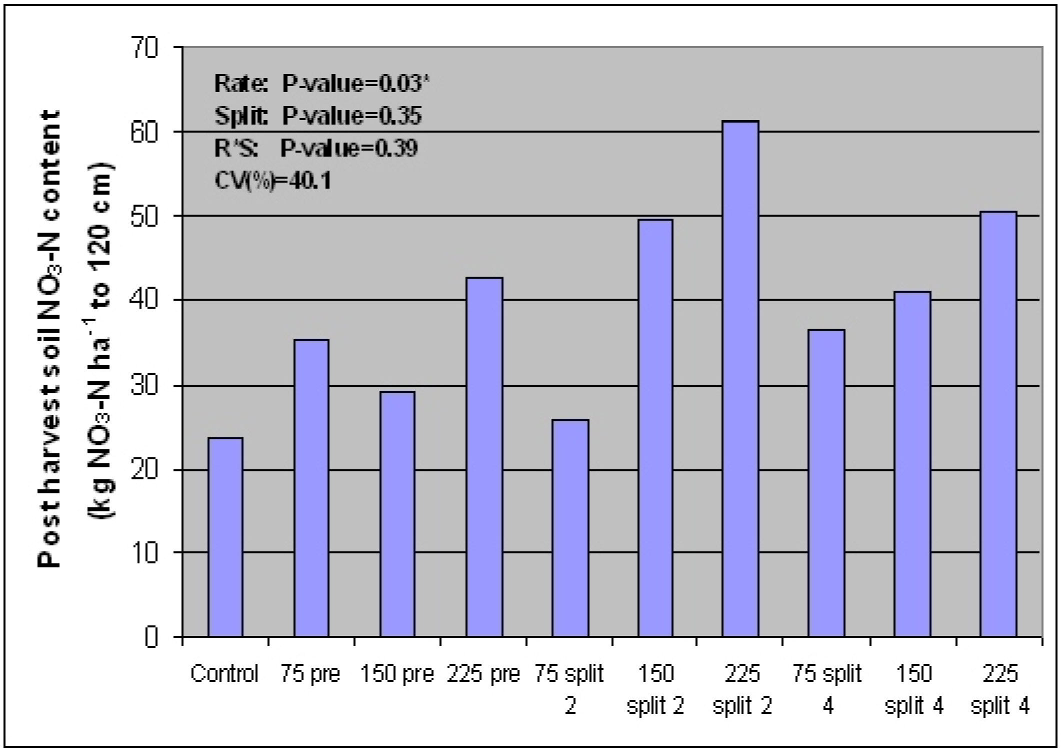


Figure 4. Effect of N fertilizer application rate and timing on post-harvest soil NO_3-N content in 2003. (Data, excluding the control, were analyzed as a factorial. Effects of N rate on post-harvest soil NO_3-N content was found to be linear (P-value=0.01)).

For all soil depths sampled, soil NO_3 concentration increased linearly with increasing N rate, except for the 60-90 cm depth where no effect of N fertilizer rate was evident (data not presented). Soil NO_3 concentration did not appear to be influenced by the timing of N application for any soil depth. A general observation was that soil NO_3 concentration was usually greater at lower than at upper soil depths for most treatments (Figure 5).

Based on a preliminary economic analysis of the yield data, the value of increased potato production associated with N application exceeded the cost of the N applied for all treatments (Table 4).

Summary

Nitrogen rate had a greater and more consistent influence on potato yield and quality, and on post-harvest soil N status, than the timing of N application.

Total tuber yield increased with increasing N rate across the range of N rates applied, but was not influenced by the timing of N application. Nitrogen also tended to increase the yield of tubers >3 oz. Neither N rate nor the timing of N application influenced the size distribution of tubers. However, increasing N rate resulted in a linear decrease in specific gravity. While tuber defects were generally low, the proportion of tubers affected by hollow heart appeared to be greater in the control than in fertilized treatments.

Petiole NO_3 concentration was strongly and consistently influenced both by N fertilizer rate and by timing of N application. Despite the yield response to N observed in this study, petiole NO_3

concentrations in some or most treatments would have been considered sufficient based on existing critical nutrient concentration curves. In those treatments categorized as sufficient, the N supply for the crop should had been sufficient to maximize yield.

At potato harvest, the influence of fertilizer N application on soil NO_3 content remained evident, with higher soil NO_3 levels present where higher rates of N had been applied.

The information presented is preliminary and based on only one field study. Field experiments will continue next year in order to collect additional information.

References

Tomasiewicz, D.J. 1996. Petiole testing and the nitrogen needs of potatoes. p. 23-27 in MCDC 1996 Annual Report. MCDC, Carberry.

Western Potato Council, 2003. Guide to Commercial Potato Production on the Canadian Prairies.

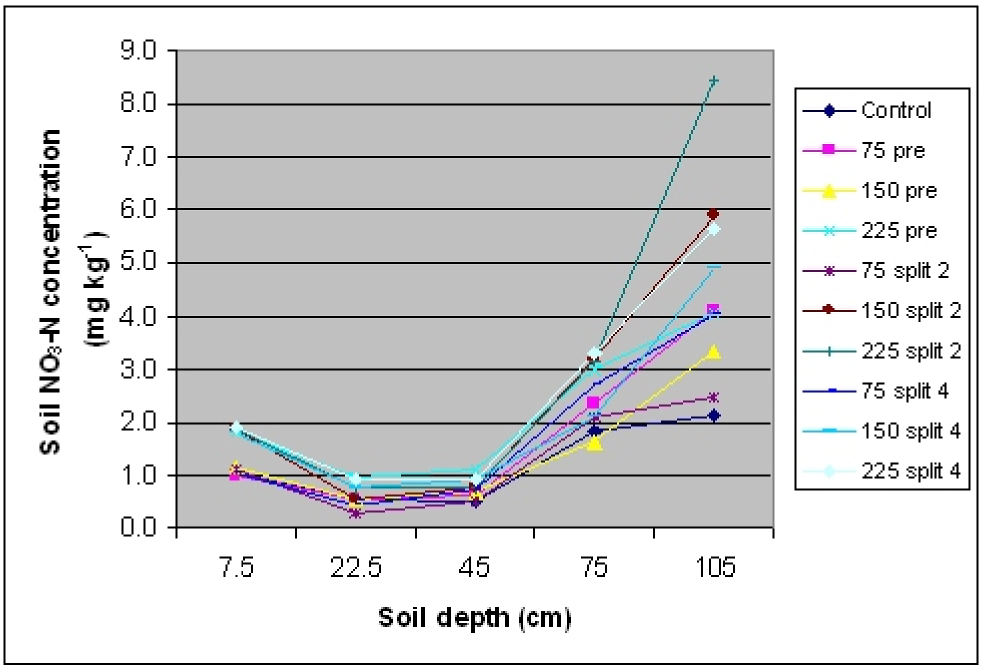


Figure 5. Effect of rate and timing of fertilizer N application on soil NO3-N concentration in the soil profile immediately following potato harvest in 2003.

Table 4. Effect of N fertilizer management on N fertilizer cost and gross return for potato.

N rate (kg N ha^{-1})	Timing of N application	N fertilizer cost/ac (assuming cost of $0.90/kg N)	$/acre gross return for potatoes produced (total value of crop)*
14	--	$5.10	$1,906
75	pre-plant	$27.33	$2,046
150	pre-plant	$54.66	$2,240
225	pre-plant	$81.98	$2,299
75	pre-plant, hilling	$27.33	$2,011
150	pre-plant, hilling	$54.66	$2,025
225	pre-plant, hilling	$81.98	$2,235
75	pre-plant, hilling, mid-July, early-August	$27.33	$2,058
150	pre-plant, hilling, mid-July, early-August	$54.66	$2,280
225	pre-plant, hilling, mid-July, early-August	$81.98	$2,325

*returns are based on: 1) $6.00/cwt for all potatoes greater than 3 oz; 2) $.60/cwt for < 3 oz tubers; 3) size bonus for tubers > 10 oz based on % bonus tubers up to a maximum of 35%

Maintaining Soil Quality in an Irrigated Potato-Bean Crop Sequence

Principal Investigators: K.M. Volkmar, K. Buckley, B. Irvine, and A. Moulin; AAFC-Brandon

Co-Investigators: D.J. Tomasiewicz and L. Mitchell, MCDC

Funding: MCDC, AAFC (Matching Investment Initiative)

Progress: Year three of four-year study

Objective: To determine the effect of alternative residue management strategies on soil erodability and quality, and on crop yield in an irrigated potato-bean sequence

Introduction

This study was undertaken to determine strategies to reduce the potential of soil erosion caused by soil disturbance, in combination with low plant residue input in a two-year potato-bean rotation. Erosion management treatments include:

1. Control (no soil amendment)
2. Fall rye after bean and potato
3. Cereal straw after bean and potato (rate based on long term cereal grain dry matter production rates on these soils)
4. Animal compost based on equivalent straw carbon, after bean and potato
5. Animal compost based on recommended P, after bean and potato
6. Polymer in the spring after bean and potato (this polymer will restrict soil erosion).

Treatments 1-5 are applied to both potato and bean fields in the fall.

The study was initiated in 2000 with the planting of potato and bean in the two main plot areas. Treatments were imposed in the fall (fall sown rye, compost, and straw treatments), and spring (polymer treatment). The year 2001 therefore marked the first year of treatment response. We report the third year of this study in this report on the 2003 field season. Treatments are replicated four times in randomized complete block design.

Results and Discussion

Gross and marketable tuber yields have increased over the course of this study (Fig. 1). This has been, in large part, due to an increase in main tuber yield, and decrease in small tubers (Fig. 2).

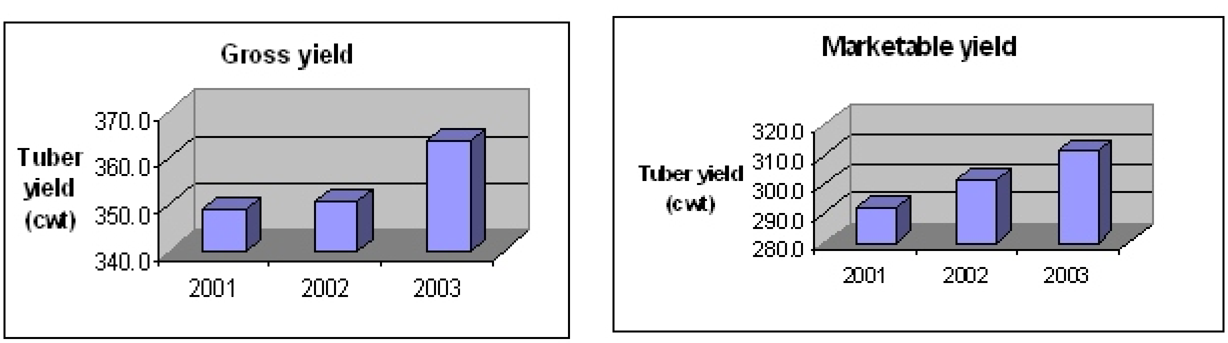


Figure 1. Change in gross and marketable tuber yield over time in a potato-bean rotation study.

In 2003, marketable tuber yield largely reflected gross tuber yield (Fig. 3). Treatment differences were not large among treatments except in the case of the plants receiving cattle compost, where both gross and marketable yields were significantly smaller than controls. This reflects a pattern observed in the last two years (Fig 4).

The lower yield of plants receiving cattle compost was related to reduced main and bonus tuber yield (Fig. 5). Potato plants receiving straw amendment had higher small tuber yields but this was compensated for by higher main tuber yields. By comparison, Fall rye-cut and Fall rye-incorporated treatments tended to have lower main tuber yields, but this was compensated for by higher bonus tuber yield.

Tuber specific gravity ranged from 1.081 to 1.095 g/cm3 (Fig. 6). Plots receiving compost produced tubers with significantly lower specific gravities.

Tuber defects were negligible. There were no treatment effects on hollow heart or brown center. There were no significant levels potato disease during the growing season or on harvested tubers two months after harvest (Table 1).

<u>Bean yield</u>

Mean bean yields across all treatments increased in 2003 (Fig. 7). All erosion control treatments had higher bean yields than that of the untreated control (Fig. 8). Plots that received the polyacrylamide gel treatment had the highest yield.

<u>Conclusions</u>

There is evidence of both a year and erosion control treatment effect on tuber yield, with some consistency in trends. The back-to-back potato-bean sequence has not resulted in a yield decline to date; to the contrary, yields are increasing.

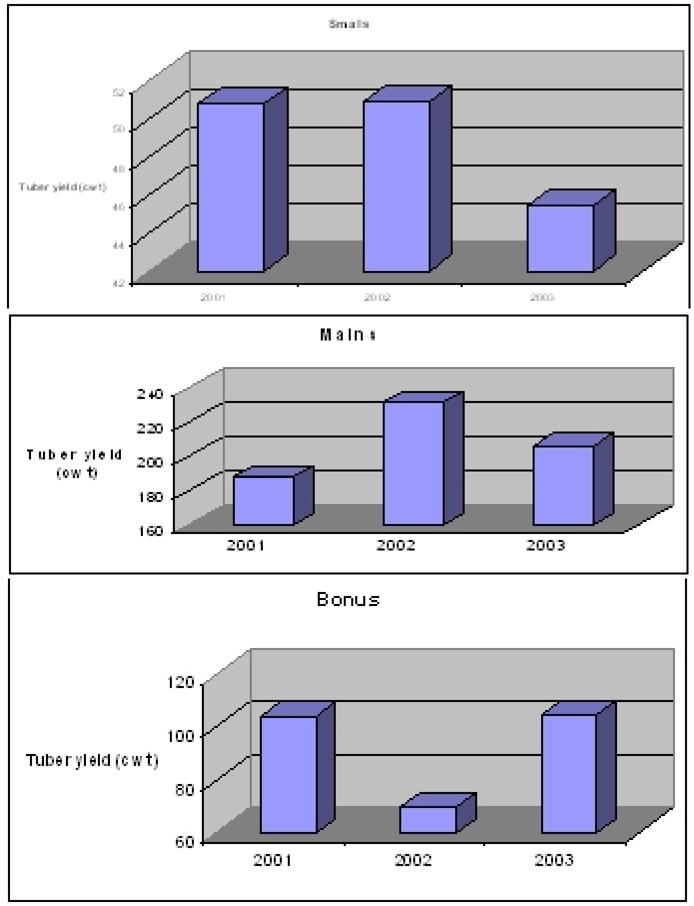


Figure 2. Treatment effects on small, main and bonus tuber yield over time.

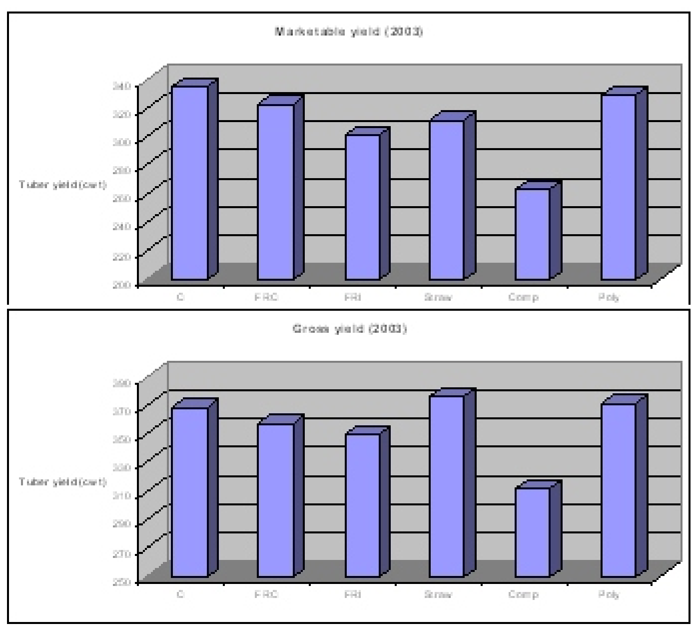


Figure 3. Erosion control treatment effect on marketable and gross tuber yield in 2003.

However, the current year marks only the first repeat of the crop sequence. Quantitative evaluation of treatment effects on soil erodability will be undertaken in year four of the rotation to compare effectiveness of erosion control treatments.

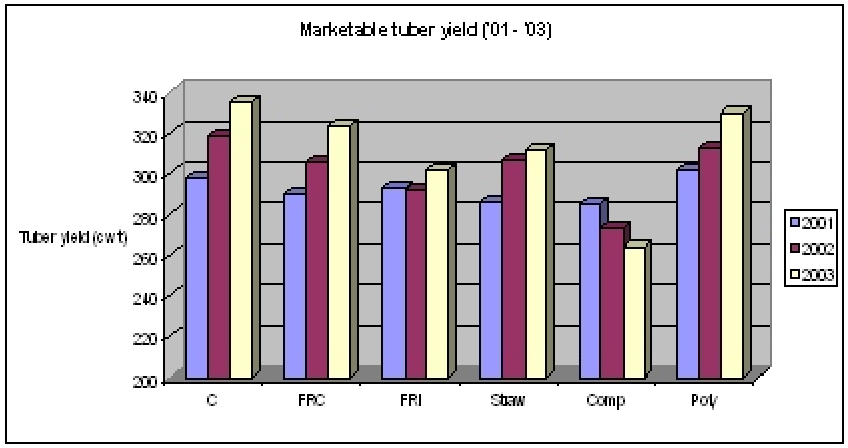


Figure 4. Erosion control treatment effects on marketable tuber yield 2001-2003.

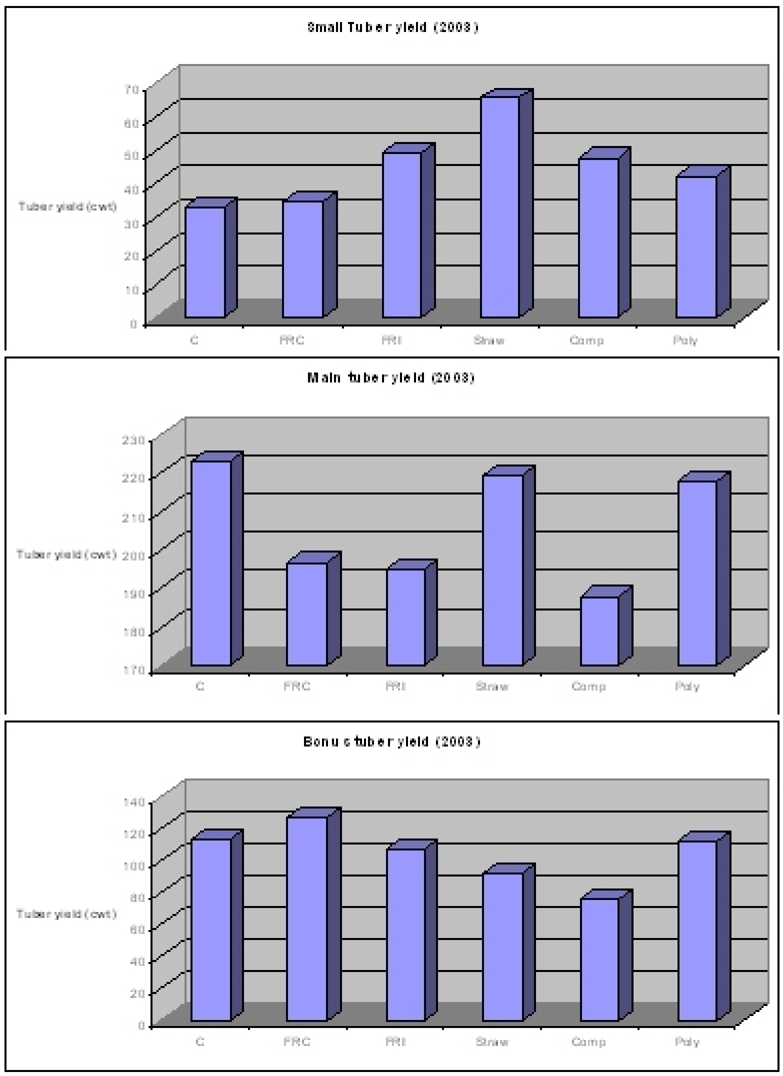


Figure 5. Effect of erosion control treatment on small, main and bonus tuber yield, 2003.

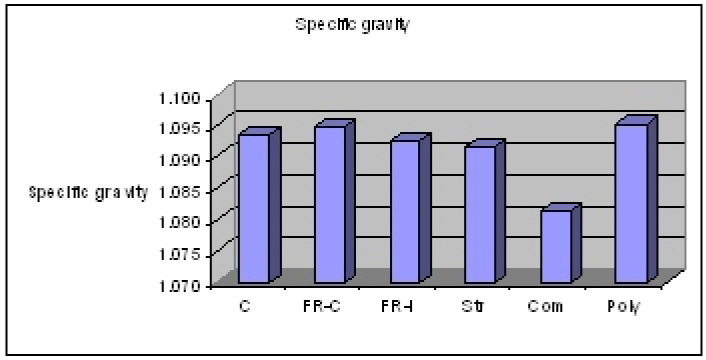


Figure 6. Effect of erosion control treatments on tuber specific gravity in 2003.

Table 1. Tuber disease and defects as affected by erosion control treatments.

	Clean	Late Blight	Blackleg	Soft Rot	FDR (<5%)	FDR (>5%)	Rhizoc.	Scab	Hollow Heart	Wire Worm
Control	42.5	0.00	0.00	0.00	2.75	2.00	0.00	0.00	1	0.5
Fall rye cut	44.0	0.00	0.00	0.00	2.00	1.00	0.00	0.00	1.75	0.25
Cereal straw	46.8	0.00	0.00	0.00	1.25	0.00	0.00	0.00	0.75	0.25
Fall compost	46.5	0.00	0.00	0.00	0.25	0.50	0.00	0.00	0.5	0
Fall rye inc.	42.0	0.00	0.00	0.00	1.75	0.50	0.00	0.00	3.25	0
Spring polymer	45.0	0.00	0.25	0.00	0.75	1.00	0.00	0.00	1	0.25

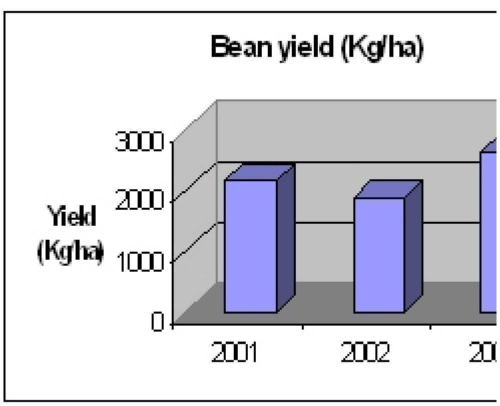


Figure 7. Change in bean yield over ti bean-potato rotation study.

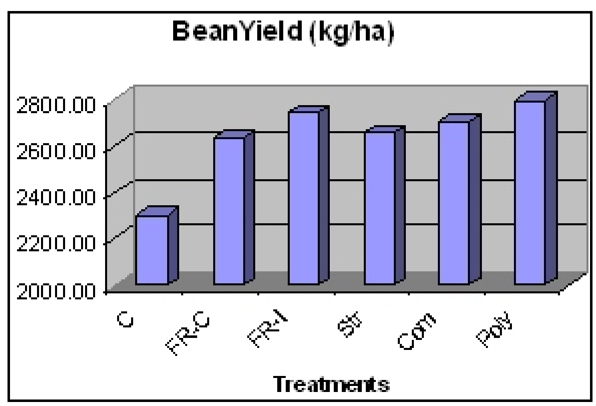


Figure 8. Effect of erosion control treatments on bean yield in 2003.

Use of Potato Processing Effluent for Irrigation of Potatoes

Principal Investigators: Karl Volkmar, AAFC-Brandon Research Centre
Dale Tomasiewicz, MCDC

Co-Investigator: Debbie McLaren, AAFC-Brandon Research Centre

Funding: Canada-Manitoba Agri-Food Research and Development Initiative
Midwest Food Products Inc.

Progress: Four-year study - completed

Objective: To determine the suitability of effluent from potato processing as a source of irrigation water for potato production in Manitoba

Introduction

The Midwest Food Products Inc. processing plant at Carberry pumps about 1.8 million US gallons per day of water from the Assiniboine Delta Aquifer (ADA). Most of it is used to wash raw potatoes and move them through the process, and to partially cook the product. The waste water is currently stored in a lagoon, after removal of particulates including about half of the starch. Historically, a small portion of the effluent (<10%) was used for irrigation of forage; the rest left the lagoon by seepage back into the ADA and by evaporation.

Irrigation development is limited by lack of allocatable water for irrigation over several sub-basins of the ADA, including the area of the Midwest plant. Almost all irrigation in the area is established for potato production. The major concern with irrigation of potatoes with processing effluent is transmission of plant diseases to the potato crop. Therefore, the suitability of the practice was assessed on the basis of potato yield, potato quality (especially characteristics affecting suitability for processing, at harvest and after storage), and disease ratings of the growing plants and tubers. Effect of the effluent on the following crops was also assessed: yield and quality of other crops in the rotations, plant pathogens in the soil, other plant pest populations and their effects, soil salinity, and other soil characteristics.

This project was conducted to determine if potato processing plant effluent, drawn from a lagoon, is a desirable water for irrigation of potatoes under conditions of the area. If there are no detrimental effects of the effluent, Midwest is interested in development of infrastructure which would facilitate use of the effluent for irrigation of potatoes. If even half of the effluent could be usable for irrigation, then more than 1000 acres of additional land in the area could be irrigated from this source (assuming a seasonal irrigation requirement of up to eight inches of water). As this water withdrawal from the ADA has already been licenced to Midwest, no further allocation of water from the aquifer is necessary to achieve the increased irrigated acreage. Soils in the immediate area are suitable for both irrigation and potato production. In the future, the information obtained may also be applicable to other potato processing plants.

Study Description

This study was established at MCDC-Carberry in 1999 and was completed in 2002. Soil sample analysis had not been completed for inclusion of results in the 2002 Annual Report; refer to 1999-2002 Reports, or full project report to ARDI, for more details on the crop yields/quality, diseases, water composition, etc.

The field plan was a split-split block design, with main plots as the starting year in the rotation (potatoes or wheat/annual forage), sub-plots as rotation (potato-wheat or potato-annual rye grass), and the sub-sub plots as irrigation treatment (fresh ADA groundwater or lagoon effluent), and with four replicates. Plots were 8x12 m. Each year of each rotation is represented in every year of the study. Treatments simulated two intensive effluent use scenarios and their respective controls:

1) Potatoes in a two-year rotation with an annual forage - both irrigated with effluent.
2) Potatoes in a two-year rotation with an annual forage - both irrigated with fresh water.
3) Potatoes in a two-year rotation with an annual cereal - potatoes irrigated with effluent; cereal not irrigated.
4) Potatoes in a two-year rotation with an annual cereal - potatoes irrigated with fresh water; cereal not irrigated.

Effluent was supplied by tanker from the Midwest Food Products Inc. waste water lagoon for each scheduled irrigation event. Irrigation water (fresh or effluent) was pumped through wobbler type sprinkler heads mounted in the center of each plot for reasonably uniform coverage. Water/effluent was applied in one-inch applications as required (minimum four times each growing season).

Effluent and groundwater was analysed for macro- and micro-nutrients, heavy metals, pH/EC and ionic composition of salts, faecal coliforms, and selected plant pathogens. Treatments were monitored for their affect on potato yield, potato quality, disease, trace- and macro-elements, and residual enteric coliforms. Results were analysed using a split-plot program to derive treatment means and analysis of variance, SAS software (SAS Institute Inc. 1990).

Results and Discussion

Water composition

The Midwest Food Products, Inc. effluent storage lagoon was sampled repeatedly throughout the course of this study for 34 dissolved elements to determine whether there are potentially toxic contaminants in the lagoon, and if they are in such concentrations to present a human health risk when applied to the soil as irrigation water. Of the thirty-four elements (including chloride and nitrogen) analysed in the water samples from the lagoon, none exceeded the amount tolerated in the Irrigation Water Quality Standards for Manitoba during the four years of the study. Nine of the thirty-four elements, including aluminum, boron, chloride, magnesium, nitrogen, phosphorus, potassium, sodium, and sulfur, had concentrations higher than that found in MCDC well water routinely used for irrigation. Four elements, including aluminum, boron, magnesium and sulfur were at levels approximately twice that of well water, while the other five were one or more orders of magnitude higher in effluent water than in well water. Chloride, sodium and magnesium were detected at concentrations between 40 and 60 mg/L, therefore falling within the acceptable level (68 mg/L) for application in irrigation water on salt-sensitive crops. Nitrogen, phosphorus, and potassium (which can serve as sources of those nutrient elements for plant growth) were present in the effluent water at levels of approximately 50, 35 and 350 ppm, respectively.

Effluent water was also sampled for presence and concentration of coliform bacteria during the growing season. Subgroups of these organisms are a risk to human health if present in high enough numbers. In all four years of the study, coliforms were present in high numbers in effluent water throughout the growing season. These levels (> 30,000 cfu per 100 ml) were well above Manitoba's thresholds prescribed for irrigated crops of 1000 cfu per 100 ml. There were very high total and faecal coliform concentrations present in the effluent at the time of the first irrigation application. A significant proportion of the total coliform population included *E. coli*. However, an assessment of the coliform population on freshly harvested tubers was negative, indicating that the introduced coliform bacteria did not survive in the soil to the harvest date.

Potato quality and yield

Potato tubers are graded based on size and quality, with a preference for a large, oblong, uniform, shape. Effluent treated plants had significantly higher total tuber yields than those that received fresh well water in one of four years, though this was a trend in all years. The effluent effect occurred in the Potato-Annual rye rotation. However, effluent treatment had a negligible effect on marketable tuber yield. This appeared to be related to an increase in small-grade tubers in the Potato Annual Rye rotation. There was a tendency to increased mean tuber size within the size classes in response to effluent treatment, an effect that was only significant in 1999, when both small and main-grade tubers were significantly larger than tubers from plants that received fresh water.

Hollow heart, a physiological defect of tubers that can result from an uneven water and/or nutrient supply, was observed at higher frequency in plants receiving clean water compared to plants receiving effluent. A possible explanation for this was that in-season application of effluent provided a regular supplementary nutrient source that better met the nutrient requirements of the developing tuber. Effluent treatment tended to reduce tuber specific gravity in all years, and significantly so in 1999, 2000, and 2001. Processors prefer a high specific gravity in tubers, though the levels observed in this study were not so low as to present a concern. Effluent treatment had no affect on reducing sugars or fry colour, though there was a tendency for higher reducing sugars and darker fry colour in effluent-treated tubers.

There was concern that fungal and/or bacterial organisms pathogenic to potato may be transmitted from the potato wastewater to the soil and to potato plants during irrigation. Tubers were rated for diseases following approximately two months storage at 10˚C each year of the study. In general, disease incidence was very low in all treatments. In fact, in 2000, rotations that included effluent irrigation were, by and large, less diseased than those that received fresh water.

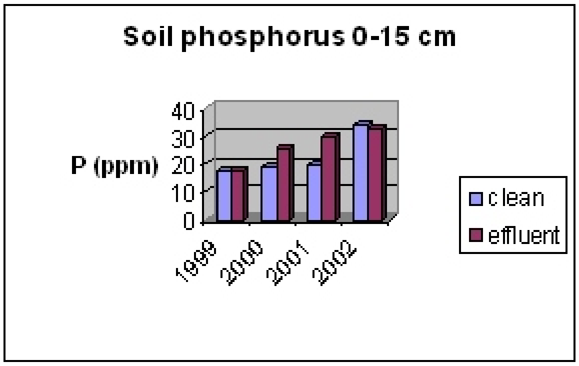
Annual ryegrass and wheat yield

An important consideration is that other irrigable crops in rotation with potato are not damaged by wastewater effluent irrigation. Yield of annual ryegrass was generally enhanced by effluent irrigation on all cutting dates, though this was only significant ($P<0.05$) in the third cut in 2000, the first cut in 2001, and the second cut in 2002. Visually, effluent treated plots appeared to have more vigorous and growth and were greener. Wheat yields were generally unaffected by effluent irrigation.

Soil nutrients

Because the effluent is rich in macronutrients, there is a risk that over-application could result in leaching of these nutrients below the root zone, to potentially enter the groundwater. There was a tendency for increasing nutrient levels in the surface 30 cm of soil over time in response to effluent. For example, in 2001 plots receiving effluent had higher phosphorus levels in both rotations, though soil P was not affected by treatments in 2002 (Figure 1). Nitrate levels were not consistently affected by effluent treatment or rotation. The amount of potassium in the 0-30 cm soil layer was significantly ($P<0.05$) higher in the effluent-treated plots in both rotations (Figure 2). As for soil P, K in the upper profile increased with time, but this increase was in response to effluent.

The results suggest that potato waste water can be used effectively as an irrigation source without affecting potato yield or quality. The effluent was found to be rich in plant nutrient, including N, P and K. There was evidence in this study that these elements contributed positively to the productivity of potato tubers as well as the biomass of annual ryegrass and wheat. There was no evidence to indicate that repeated effluent application resulted in increasing levels of P or N in the soil.



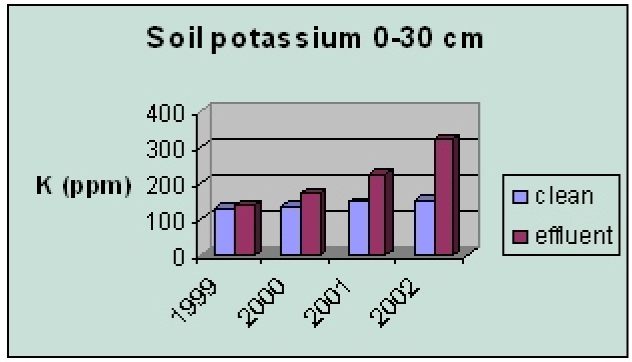


Figure 1. Effect water source on soil extractable phosphorus.

Figure 2. Effect water source on soil extractable potassium.

An important question asked in this study was whether repeated application of effluent waste water would result in accumulation of harmful metals or organisms originating in the effluent. While the effluent was shown to contain a number of potentially hazardous soluble metal contaminants, their levels were below the application guidelines for Manitoba. Repeated application of these elements through the effluent was not found to result in their accumulation, though it is likely that this would be a logical outcome after a long application history. While coliform bacteria were present at very high levels in the raw effluent, they apparently do not survive in the soil long enough to present a health risk at tuber harvest.

Conclusions

Potato wastewater effluent can be applied to process potato crops to supplement or replace water supplied as well water without loss to yield or quality. It can also be applied to crops within a potato rotation, including annual ryegrass and wheat, without risk to crop productivity.

Because of the high levels of coliform bacteria in the Midwest effluent lagoon water, caution should be observed in handling and distributing the effluent as irrigation water. Coliform bacteria were not detected on tubers grown on effluent irrigated fields.

Potato wastewater effluent is rich in plant nutrients. These nutrients supplement the crops' nutrient supply from other sources.

Potato effluent was found to contain levels of sodium and chloride that could pose a risk to crop growth and to soil quality with repeated and unmonitored use.

Potato Variety Development for Manitoba - 2003

Principle Investigator: Dermot Lynch, Agriculture and Agri-Food Canada, Research Centre, Lethbridge, Alberta

Co-Investigators: Les Mitchell, Manitoba Crop Diversification Centre
Henry Wolfe, Manitoba Crop Diversification Centre

Support: Manitoba Horticulture Productivity Enhancement Centre Inc.
Keystone Vegetable Producers Association Inc.
Manitoba Chipping Potato Growers Association
Midwest Food Products Inc.
Peak of the Market
Simplot Canada Inc.
Agriculture and Agri-Food Canada Matching Investment Initiative

Progress: Year 2 of a 3 year project.(renewal of existing project)

Objective: To develop potato varieties with superior yield, quality and disease resistance for the Manitoba potato industry.

Introduction

The major focus of the western Canadian potato breeding program based at the Agriculture and Agri-Food Canada (AAFC) Research Centre at Lethbridge is the development of high yielding processing and fresh market varieties with superior quality and high levels of durable resistance to diseases prevalent in western Canada. The project at the Manitoba Crop Diversification Centre evaluates advanced material developed by the AAFC program as well as material from US breeding programs based in the North Central and Pacific Northwest States.

Methods

Advanced clones from the western Canadian potato breeding program located at the Lethbridge Research Centre as well as promising clones and new varieties from US breeding programs located in the North Central and Pacific Northwest states are included in adaptation trials (randomised complete blocks design/4 replications) and early (harvested at 80 and 90 days after planting) and maincrop advanced trials (harvested 110 days after planting) (randomised complete blocks design/4 replications). Data collected includes yield, tuber characteristics, internal and external defects and processing and culinary quality. The North Central (US) Breeders' Trial (9 US locations and 3 Canadian locations) was conducted at the Winkler MCDC site.

Results and Discussion

<u>Maincrop Advanced Yield Trial</u> (Table 1)

French fry clones in the trial which outyielded Russet Burbank include CV92009-3 (oblong, buff skin), CV95002-1 (oblong, russet skin), FV12228-5 (oblong, white skin) and FV12235-3 (oblong, white skin). These clones also had acceptable specific gravity and fry color, similar to Russet Burbank. FV12228-5 and FV12235-3 were the highest yielding clones but specific gravity was considerable lower than that of Russet Burbank and internal necrosis occurred at high levels (27.5%). While hollow heart occurred at levels similar to Russet Burbank and Russet Norkotah for

CV95002-1 the clone has excellent processing characteristics and processes directly from 5 C storage with excellent fry colour. The yield and process quality of CV92009-3 was superior to Russet Burbank and with very low defect levels.

The two outstanding chip clones with yields similar to or better than Snowden were FV12292-10 (oval, white skin) and V0379-2 (oval, white skin). The chip color of both clones was superior to Snowden with a specific gravity in excess of 1.085. V0379-2 chips directly with acceptable colour from 6 C storage after 8 months.

The yields of the oval, red skinned clones V0498-9 and CV89023-2 were similar to Norland and with very low defect levels.

Early Advanced Yield Trial (Tables 2 and 3)

The highest yielding clone at both harvest dates was FV12486-2 (oval, red skin) and exceeded that of all check cultivars. The clone has low defect levels with a fry color similar to Atlantic at E1 and superior to Atlantic at E2. Specific gravity at both harvest dates was less than Atlantic. The overall appearance of FV12486-2 was rated superior to Norland at the E2 harvest date.

North Central Trial (US) (Tables 4 and 5)

The clones CV89023-2 and MN19525R were the highest yielding red skinned test clones in the trial. CV89023-2 had very low internal and external defects while MN19525R had moderately high internal and external defects. CV89023-3 was the only test entry with a US#1 yield similar to that of Norland.

The highest yielding russet entries in the trial were W1836-3 Rus and Mn15620 LR which out-yielded both Russet Burbank and Russet Norkotah. The specific gravity of both entries was similar to Russet Burbank. MN15620 LR had an excellent fry colour score, far superior to that of Russet Burbank.

Test entries with chip scores similar to Snowden and NorValley were V0379-2 and W1201. The specific gravity of W1201 was similar to Snowden but that of V0379-2 lower than Snowden. Both clones had low levels of hollow heart. V0379-2 chips directly with acceptable colour from 6˚C storage after 8 months.

Table 1. Tuber yield, quality and defects - Main Crop Advanced Yield Trial at Carberry - 2003.

Cultivar	Overall appear.[1]	Total yield (t/ha)	Marketable yield (t/ha) (>48mm)	Percent large[2]	Deformed tubers (t/ha) (>48mm)	Hollow heart %	Internal necrosis %	Fry quality[3]	Specific gravity
ATLANTIC	3.0	48.8	43.4	6.7	0.2	10.0	0.0	51.4	1.106
CV89023-2	3.0	50.7	41.1	1.3	0.6	0.0	0.0	29.7	1.083
CV92009-3	3.3	44.5	38.7	2.1	0.3	0.0	0.0	34.4	1.092
CV93017-1	3.0	42.7	31.9	4.2	3.7	0.0	0.0	36.1	1.099
CV94101-1	3.0	36.6	29.9	1.0	0.5	2.5	0.0	48.0	1.088
CV95002-1	3.0	47.1	39.9	2.2	0.6	20.0	2.5	46.0	1.099
CV95070-3	3.0	38.2	30.7	1.4	1.2	2.5	0.0	61.7	1.086
CV95115-4	3.0	37.1	29.8	0.0	0.5	0.0	0.0	32.4	1.081
CV95122-1	3.0	41.4	33.1	0.0	1.2	0.0	2.5	52.3	1.092
FV12228-5	3.0	45.5	40.0	0.7	0.0	5.0	2.5	46.0	1.088
FV12235-3	3.0	47.2	43.8	16.4	0.6	2.5	27.5	38.0	1.086
FV12272-3	3.0	28.9	22.8	1.2	0.8	2.5	27.5	58.8	1.100
FV12291-10	3.0	42.7	33.6	1.6	0.2	0.0	2.5	55.2	1.088
FV12292-10	3.0	50.1	43.9	6.1	0.6	0.0	0.0	32.9	1.081
JACQUELINE	3.0	43.5	31.8	1.0	0.4	0.0	0.0	38.7	1.088
NORLAND	3.0	51.6	44.4	4.7	1.8	0.0	0.0	38.3	1.074
RANGER RUS.	3.3	49.5	40.4	16.2	4.3	0.0	0.0	29.9	1.104
RUS. BURBANK	3.0	52.6	37.4	5.7	3.8	22.5	0.0	32.6	1.097
RUS. NORKOTAH	3.5	47.3	41.0	6.3	3.1	20.0	2.5	24.5	1.087
SANGRE	3.0	49.3	41.6	10.7	1.6	37.5	0.0	28.0	1.085
SERAFINA	3.0	47.1	35.0	0.0	0.0	0.0	0.0	41.5	1.081
SHEPODY	3.0	51.4	44.2	17.0	3.5	10.0	0.0	36.4	1.089
SNOWDEN	3.0	47.1	41.0	3.7	0.0	0.0	0.0	51.9	1.106
V0379-2	3.0	47.0	38.3	3.5	0.9	12.5	2.5	57.7	1.089
V0498-9	3.0	45.8	40.8	1.5	0.4	0.0	0.0	30.8	1.080
V0865-1	3.0	44.4	32.2	6.9	2.8	0.0	0.0	41.7	1.098
V1062-1	3.0	40.4	31.3	0.0	1.6	0.0	0.0	53.3	1.083
V1076-1	3.0	41.6	33.4	0.7	0.0	0.0	0.0	28.5	1.073
V1089-2	3.0	39.5	35.1	0.0	0.0	5.0	0.0	48.4	1.103
V1097-1	3.0	39.6	32.0	3.0	1.8	17.5	0.0	36.2	1.091
CV%	-	8.7	10.2	78.3	-	-	-	-	0.304
Prob	-	0.0001	0.0001	0.0001	-	-	-	-	0.0001
LSD (.05)	-	5.4	5.3	5.6	-	-	-	-	0.005

[1] Appearance - 1 (very poor) - 5 (outstanding)
[2] Cultivars with 0 means were omitted from the analysis
[3] Fry colour measured using Agtron E15FP

Table 2. Tuber yield and appearance for Early Advanced Yield Trial at Winkler - 2003.

Cultivar	Overall appearance[1]		Total yield (t/ha)		Marketable yield (t/ha) (>48mm)		% Marketable (>48 mm)		Percent large	
	E1[2]	E2	E1	E2	E1	E2	E1	E2	E1	E2
AC PTARMIGAN	3.0	3.3	15.1	45.2	12.0	36.3	79.6	80.3	0.0	13.8
ATLANTIC	3.0	3.0	16.8	47.7	13.7	43.6	81.9	91.5	0.0	0.0
CV94048-1	3.0	3.0	15.7	33.9	9.2	27.8	57.3	82.4	0.0	0.0
CV94048-6	3.0	3.0	14.3	35.4	9.4	28.7	66.2	81.0	0.0	0.0
FV11734-5	3.0	3.0	17.9	42.6	13.7	38.0	76.9	89.2	0.0	0.5
FV11983-1	3.0	3.0	13.1	35.2	10.2	32.0	76.8	90.8	0.0	12.0
FV12232-9	3.3	3.0	13.6	34.7	10.6	30.2	77.5	86.8	0.0	12.3
FV12246-6	3.0	3.0	13.4	34.3	10.7	31.3	79.2	90.6	0.0	1.5
FV12486-2	3.3	4.0	21.0	49.7	18.3	46.3	86.8	93.3	0.0	4.0
NORLAND	3.0	3.0	22.8	46.2	19.7	43.2	86.1	93.6	0.0	2.8
NORVALLEY	3.0	3.0	18.5	46.9	12.8	40.0	68.9	85.3	0.0	0.6
RUSSET NORK	3.5	4.0	15.8	43.0	10.3	38.4	65.1	89.1	0.0	1.9
V0391-4	3.0	3.5	15.0	44.6	11.4	35.1	75.7	78.7	0.0	16.8
V0950-3	3.0	3.0	19.5	40.4	12.5	32.8	64.2	80.9	0.0	0.7
V1002-2	2.8	3.0	14.7	47.9	8.2	39.5	56.1	82.2	0.0	1.0
CV%	-	-	14.7	9.6	18.4	11.4	7.4	3.8	-	-
Prob	-	-	0.0001	0.000	0.0001	0.0001	0.0001	0.0001	-	-
LSD (.05)	-	-	3.5	5.7	3.2	5.9	7.7	4.7	-	-

[1] Appearance - 1 (very poor) - 5 (outstanding)
[2] E1, E2 - Harvested 80 and 90 days after planting, respectively

Table 3. Tuber defects, specific gravity, and fry quality score for Early Advanced Yield Trial at Winkler - 2003.

Cultivar	Deformed tubers (t/ha) (>48mm)		Hollow Heart %		Internal necrosis %		Fry quality[1]		Specific gravity	
	E1[2]	E2	E1	E2	E1	E2	E1	E2	E1	E2
AC	0.5	3.9	0.0	0.0	0.0	0.0	49.8	50.7	1.063	1.064
ATLANTIC	0.0	0.0	0.0	2.5	0.0	0.0	49.3	43.3	1.083	1.089
CV94048-1	0.0	0.0	0.0	0.0	0.0	0.0	43.8	53.2	1.076	1.078
CV94048-6	0.0	0.0	0.0	0.0	0.0	0.0	51.3	53.5	1.074	1.077
FV11734-5	0.1	0.1	7.5	2.5	0.0	2.5	36.6	49.5	1.065	1.073
FV11983-1	0.0	0.5	2.5	0.0	0.0	0.0	37.7	48.2	1.058	1.065
FV12232-9	1.2	0.9	0.0	2.5	0.0	0.0	37.2	37.1	1.065	1.071
FV12246-6	0.0	0.1	0.0	12.5	0.0	7.5	49.0	51.2	1.074	1.081
FV12486-2	0.0	0.3	0.0	0.0	0.0	0.0	37.9	42.8	1.063	1.067
NORLAND	0.0	0.0	0.0	0.0	0.0	0.0	37.5	47.4	1.064	1.069
NORVALLEY	0.0	0.0	0.0	0.0	0.0	0.0	45.5	53.9	1.066	1.073
RUSSET	0.0	0.0	0.0	12.5	0.0	0.0	36.9	39.4	1.073	1.078
V0391-4	0.6	5.1	5.0	0.0	0.0	0.0	30.1	28.5	1.057	1.059
V0950-3	0.1	0.0	0.0	0.0	0.0	0.0	35.8	47.4	1.062	1.068
V1002-2	0.0	0.0	0.0	0.0	0.0	0.0	39.9	56.1	1.066	1.072
CV%	-	-	-	-	-	-	-	-	0.201	0.189
Prob	-	-	-	-	-	-	-	-	0.0001	0.0001
LSD (.05)	-	-	-	-	-	-	-	-	0.003	0.003

[1] Fry colour measured with Agtron E15FP
[2] E1, E2 - Harvested 80 and 90 days after planting, respectively

Table 4. Tuber yield and quality - North Central Potato Variety Trial at Winkler - 2003.

Clone	Maturity[1]	Total yield (cwt/A)	US #1 yield (cwt/A)	% US #1	Specific gravity	General merit rating[2]	Fry rating[3]	Comments
CV 89023-2 R	3.5	385	309	79	1.078	2	26.3	
MN 19525 R	4.5	460	289	63	1.067	5	26.1	
ND 3196-1 R	1.5	327	264	81	1.081	4	27.8	
W 2275-3 R	3.0	328	193	59	1.071		37.3	
R. Norland	1.0	360	316	88	1.071	3	28.6	
R. Pontiac	4.0	549	467	85	1.070	1	21.7	
MN 15620 LR	4.0	372	311	84	1.083	1	57.2	
MN 18710 Rus	4.0	344	279	81	1.081		36.5	
MN 18747 Rus	2.0	299	257	86	1.073	3	56.0	
MSE 202-3 Rus	4.5	240	181	75	1.089		36.7	
Pacific Russet	1.5	271	236	87	1.075		25.8	
W 1836-3 Rus	5.0	417	350	84	1.084	2	31.4	
A 9014-2 Rus	-	-	-	-	-		-	
A 90586-11 Rus	5.0	315	237	75	1.093		35.4	
AC Stampede Rus	2.0	229	173	76	1.068		36.4	
R. Burbank	5.0	378	306	81	1.084	4	28.0	
R. Norkotah	2.0	322	247	76	1.081	5	23.7	
MSE 221-1	3.0	366	293	81	1.082		29.3	
MSG 227-2	4.5	296	180	59	1.095		45.7	
MSH 031-5	3.0	308	160	50	1.090		37.1	
ND 2470-27	5.0	391	313	81	1.086		47.5	
ND 5822C-7	5.0	424	282	67	1.092		45.3	
V 0379-2	2.0	315	239	74	1.085	3	58.5	
V 0056-1	2.0	309	234	76	1.087		49.7	
W 1201	5.0	366	319	87	1.103	1	57.3	
W 1773-7	4.5	411	359	87	1.099	4	51.4	
B 0766-3								
Atlantic	5.0	400	312	78	1.105	5	37.2	
NorValley	3.5	391	299	77	1.083	2	59.4	
Snowden	4.5	385	279	72	1.103		55.1	
MEAN		356	274	77	1.084			

[1] Maturity 1= Very Early - Norland; 2=Early - Norchip / Irish Cobbler; 3=Medium - Red Pontiac; 4= Late - Katahdin; 5=Very Late - Kennebec / Russet Burbank

[2] General merit rating - Rate top FIVE for each market use classification

[3] Fry colour rating using Agtron E15FP

Table 5. Tuber defects for North Central Potato Variety Trial at Winkler - 2003.

Clone	Scab Severity[1]	Scab area[2]	Percent external defects[3]: Growth cracks	2nd growth	Green	Rotten	Percent Internal Defects[4]: Hollow heart	Internal necrosis	Vasc. discolor.	Brown center	No def.
CV 89023-2 R	1	T	0	0	2	0	0	0	0	0	100
MN 19525 R	1	1	17	3	4	0	8	0	0	0	92
ND 3196-1 R	1	T	0	0	0	0	5	0	0	0	95
W 2275-3 R	2	1	0	1	1	0	0	0	0	0	100
R. Norland	1	1	1	0	5	0	0	0	0	0	100
R. Pontiac	2	1	4	1	1	0	6	0	0	0	94
MN 15620 LR	1	T	1	1	5	0	0	0	1	0	99
MN 18710 Rus	0	0	0	0	0	0	0	0	0	0	100
MN 18747 Rus	1	T	0	0	0	3	0	0	0	0	100
MSE 202-3 Rus	0	0	0	0	0	0	4	0	0	0	96
Pacific Russet	0	0	0	0	0	0	0	0	0	0	100
W 1836-3 Rus	0	0	1	7	1	0	14	0	0	0	86
A 9014-2 Rus	-	-	-	-	-	-	-	-	-	-	-
A 90586-11 Rus	1	T	1	0	0	1	0	0	0	0	100
AC Stampede Rus	0	0	0	0	2	0	0	0	0	0	100
R. Burbank	0	0	0	8	0	0	26	0	0	0	74
R. Norkotah	0	0	0	0	0	0	11	0	0	0	89
MSE 221-1	0	0	0	1	0	7	3	0	1	0	96
MSG 227-2	0	0	0	0	0	0	0	0	0	0	100
MSH 031-5	1	T	0	0	0	0	1	0	0	0	99
ND 2470-27	1	T	1	0	8	0	0	0	0	0	100
ND 5822C-7	1	T	0	0	0	0	2	0	0	1	97
V 0379-2	1	T	2	1	1	0	5	0	0	0	95
V 0056-1	1	T	0	0	0	0	7	0	0	0	93
W 1201	1	T	0	1	0	1	6	1	0	0	93
W 1773-7	1	T	0	0	0	0	20	0	0	0	80
B 0766-3	-	-	-	-	-	-	-	-	-	-	-
Atlantic	1	T	0	1	0	1	8	0	0	0	92
NorValley	1	T	0	0	0	1	0	0	0	0	100
Snowden	0	0	0	0	0	0	1	0	0	0	99

[1] Scab Severity 1=small superficial; 2=larger superficial; 3=larger rough pustules; 4=larger pustules, shallow holes; 5=Very large pustules, deep holes.

[2] Scab Area T<=1%; 1=1-20%; 2=21-40%; 3=41-60%; 4=61-80%; 5=81-100% tuber coverage (25 tuber sample per rep)

[3] Expressed as a percentage of A yield (> 1.7/8)

[4] Expressed as a percentage of 100 tubers (25 tuber sample per rep)

Nutrient Accumulation and Partitioning by Potatoes in Manitoba

Principal Investigator: John Heard, Manitoba Agriculture, Food and Rural Initiatives

Funding and Support: Greenhouse Gas Mitigation Program
Manitoba Agriculture, Food and Rural Initiatives
AgVise Labs
MCDC

Objective: To develop information on nutrient uptake and partitioning within the potato crop under Manitoba's environment.

It is recognized that high yields of potatoes require a substantial supply of nutrients. Not all nutrients are removed with potato harvest, and it is of interest to know the amount and rate of nutrient accumulation in different plant parts and nutrient movement to the growing tuber.

Methods

A commercial field of Ranger Russet potatoes was planted at MCDC-Carberry on 13 May 2003. The soil is a well-drained Ramada clay loam soil. Cut seed was planted at a 95-cm row spacing and 40-cm in-row seed piece spacing. Fertilizer was banded at seeding to supply 66 kg N/ ha, 77 kg P_2O_5/ha and 33 kg K_2O/ha. Additional N at 77 kg N/ha was broadcast just prior to hilling on June 24. The field was commercially harvested on October 7 with a marketable yield of 288 cwt/ac.
Soil sampling was done at intervals during the growing season to depths of 90 cm in order to track moisture (Table 1) and nitrate depletion in the soil (Table 2). Petiole analysis of plants was done mid-season to assess nutritional status of the plant (Table 3).

In order to measure nutrient uptake and accumulation, whole plant samples were taken at selected growth stages during the season (Table 4). Sampling was according to a randomized complete block design with 3 replicates. Growth stages were determined according to accepted guidelines (Rowe, R.C. Potato Health Management. APS Press. 1993). At sampling the plants were cut at ground level and dug, separated into plant portions (leaf, stem, and tubers), dried, ground and submitted for full nutrient analysis to AgVise Laboratories. At the last sampling tubers were separated into marketable and undersize (<2" diameter) classes.

In reporting of the results, P and K levels and uptake are converted to the oxide forms (P_2O_5 and K_2O) to equate to "fertilizer nutrient" values. The daily rate of dry matter and nutrient accumulation was determined based on the interval between samplings and recorded in Table 6.

Results and Discussion

Gravimetric soil moisture was maintained at levels of 20% or greater in the rooting zone through the growing season (Table 1). In general for Ramada clay loam, field capacity occurs at 30-35% and wilting point at 10-11% gravimetric water content, indicating this 2003 crop had adequate soil moisture and yields would not be limited.

Soil nitrate levels actually increased between the June and late July sampling date, presumably a result of the pre-hill broadcast application of 77 kg N/ha (Table 2). The depletion between the late July and harvest measurement would largely be due to plant uptake.

Measurement of plant nutrition through mid-season petiole sampling and analysis indicated that nutrients were in adequate supply (Table 4). Dry matter accumulation and nutrient concentration (Table 5, Figure 1), and rate of dry matter and nutrient accumulation (Table 6) are also shown.

Total measured dry matter accumulation at harvest was 14,656 kg/ha (Table 5). The tuber portion was 80% of total dry matter production, with 72% as maingrade size and 8% undersize. Yield of maingrade potatoes was 376 cwt/ac. The remaining biomass at maturity consisted of 11% leaves and 9% stem. Dry matter declined slightly in the leaves, but not in the stem, during the final tuber bulking (Figure 1). Dry matter disappeared from leaves at a rate of 21 kg/ha/day during the final month of growth, while dry matter accumulated in tubers at 138 kg/ha/day (Table 6).

Total N accumulation in the potato was 199 kg/ha, with 67% or 134 kg/ha in the tubers. Peak accumulation in potato tops was 119 kg N/ha at early tuber bulking on July 23 (Figure 1). Between tuber initiation and early bulking (July 23), the plant accumulated N at 5.2 kg N/ha/day. After this stage, N content declined in leaf and stem tissue at 0.5 to 1.4 kg N/ha/day, while N accumulated in the tuber at 1.7 to 2.1 kg N/ha/day.

Total P accumulation was 77 kg P_2O_5/ha, with 86% or 67 kg P_2O_5/ha in the tubers. Peak accumulation in potato tops was 17 kg P_2O_5/ha through the tuber bulking on July 23 to August 18 (Figure 1). Between tuber initiation and early bulking (July 23), the plant accumulated P at 1.3 kg P_2O_5/ha/day. After August 18, P content declined slightly in leaf tissue at 0.2 kg P_2O_5/ha/day, while P accumulated in the tuber at 0.9 to 1.0 kg P_2O_5/ha/day. P uptake occurs at a fairy constant rate over the growing season, indicating that a good supply of P is important throughout the season.

Total K accumulation was 369 kg K_2O/ha, with 69% or 254 kg K_2O/ha in the tubers. Peak accumulation in potato tops was 134 kg K_2O/ha at tuber bulking on August 18 (Figure 1). Between tuber initiation and early bulking (July 23), the plant accumulated K at a rate of 5.2 kg K_2O/ha/day. After August 18, K content declined in leaf tissue at 0.8 kg K_2O/ha/day, while K accumulated in the tuber at 3.6 kg K_2O/ha/day. As for P, K accumulated throughout the growing season.

Sulphur uptake by the plant was only 26 kg S/ha, with 16 kg S/ha or 62% in tubers. Peak accumulation in potato tops was 13 kg S/ha on August 18 (Figure 1). After August 18, S content declined slightly in leaf tissue at 0.1 kg S/ha/day, while S accumulated in the tuber at 0.2 kg S/ha/day. The greatest S accumulation rate of the plant was 0.5 kg S/ha/day between tuber initiation and early bulking (July 23).

Calcium uptake was greatest on the August 18 date at 59 kg Ca/ha. The Ca was almost exclusively in the above ground portion, with 62% in the leaves and 32% in stems (Figure 1). The greatest Ca accumulation rate of the plant was 1.9 kg Ca/ha/day between tuber initiation and early bulking (July 23). Loss in plant Ca was observed during the last month, exclusively from leaf tissue. The magnesium uptake pattern was similar to that of Ca, with greatest uptake occurring at August 18, followed by a decline, with most present in leaf (62%) and stem (24%) portions (Figure 1).

Total accumulation of micronutrients was small: 340 g Zn/ha, 2489 g Fe/ha, 920 g Mn/ha, 66 g Cu/ha and 133 g B/ha. The high Fe content at the July 23 date may be due to contamination of tissue with soil. At other sampling times the leaf, stem, and tubers were rinsed with water to remove soil, the likely contributor to inflated Fe measurements. Zinc and copper tended to accumulate in the plant until maturity, whereas B content had plateaued and Mn and Fe content actually declined as maturity approached. Manganese was almost exclusively found in the leaf tissue (84%), whereas copper accumulated in tubers (75% of total Cu).

The comparison on nutrient uptake (total accumulated nutrients) and removal (those harvested tubers) from this study is compared to published values from various sources (Table 7). Most uptake and removal values were similar to standard values when scaled by yield. Nitrogen total uptake levels were slightly less and P removal was slightly greater than standard values. It appears that use of the standard values is appropriate for Manitoba growers.

Summary

Potatoes took up and removed considerable amounts of macro and secondary nutrients. The increase in plant uptake of N coincided with nitrate depletion of the rooting zone. The nutrients behaved differently in terms of uptake pattern, partitioning in the plant, and translocation within the plant. Nitrogen, Mn, and B were taken up at highest rates earlier and rates declined as maturity approached. Phosphorus, K, S, Zn, and Cu were still being taken up at moderate rates to maturity, indicating that a good supply throughout the growing season is important. Calcium, Mg, and Fe actually declined in the plant as maturity approached.

More than half the N, P, K, S, and Cu was found in the tuber at harvest. Calcium, Mg, Fe, and Mn were found predominantly in the leaves. Boron and Zn had similar levels in leaf and tubers. Nitrogen, P, K, S, Cu, and B showed some partitioning from leaves to tubers as maturity approached, but Mn did not appear to translocate to the tuber from above ground material.

The values of crop uptake and removal were similar to published book values, particularly when compared on a per unit of yield basis.

Table 1. Soil gravimetric moisture.

Sampling Depth	Moisture content		
	June 1	July 28	Sept 26
cm		(% dwb)	
0-15	28	22	30
15-30	20	20	25
30-60	19	22	23
60-90	15	19	20

Table 2. Soil nitrate levels through the growing season.

	Soil depth (cm)									
	0-15		15-30		30-60		60-90		Total 0-90	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
	Nitrate-N (kg/ha)									
June 1	34	6.9	19	5.6	18	8.1	6	2.6	76	16.7
July 28	30	1.6	34	7.2	27	6.4	19	11.1	110	13.5
Sept 26	6	1.1	1	0.7	2	0.0	2	0.0	11	1.3

Table 3. Nutrient sufficiency levels of petioles (4th petiole).

Date	Tuber Stage	Nitrate-N	P	K	S	Ca	Mg	Na	Zn	Fe	Mn	Cu	B
		ppm	%						ppm				
23-Jul	3/4-2"	13846	0.46	9.3	0.26	0.96	0.92	0.02	35	89	127	5	24
	Rating*	S	S	S	S	H	H	S	H	H	VH	H	S
31-Jul	>2	9722	0.35	7.2	0.23	0.9	0.81	0.02	24	112	99	4	22
	Rating	S	S	S	S	H	H	S	S	H	H	S	S
6-Aug	>2	6407	0.37	7.1	0.22	0.84	0.74	0	25	85	126	4	22
	Rating	S	S	S	S	H	H	-	S	H	VH	S	S

* petiole nutrient ratings per AgVise criteria: S = sufficient, H = high, VH = very high

Table 4. Heat units (P-days) between planting and each plant sampling date.

Sampling Date	Cumulative P-days from seeding	Growth stage and description
June 23	259	Growth stage 2 = vegetative
July 7	362	Growth stage 3 = tuber initiation
July 23	473	Growth stage 4 = tuber bulking (<2" diameter)
August 18	667	Growth stage 4 = tuber bulking (>2" diameter)
September 18	862	Growth stage 5 = maturity

Table 5. Aerial dry matter accumulation and nutrient concentrations in potatoes.

Stage and date	Leaves		Stem		Plant Fraction Tubers		Undersize tubers		Maingrade tubers	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
					Dry matter, kg/ha					
GS 2 = June 23	255	16								
GS 3 = July 7	860	26	265	9						
GS 4 = July 23	1589	76	988	249	2004	190				
GS 4 = Aug 18	2192	335	1319	39	7425	1558				
GS 5 = Sept 18	1546	132	1416	192			1140	75	10554	625
					Nitrogen %					
GS 2 = June 23	5.40	0.26								
GS 3 = July 7	6.07	0.21	3.53	0.23						
GS 4 = July 23	5.63	0.12	2.97	0.25	1.27	0.06				
GS 4 = Aug 18	3.75	0.35	1.90	0.71	1.10	0.14				
GS 5 = Sept 18	2.77	0.15	1.53	0.23			1.27	0.06	1.13	0.12
					Phosphorus %					
GS 2 = June 23	0.39	0.01								
GS 3 = July 7	0.33	0.05	0.33	0.01						
GS 4 = July 23	0.33	0.03	0.22	0.02	0.25	0.02				
GS 4 = Aug 18	0.23	0.00	0.17	0.01	0.22	0.00				
GS 5 = Sept 18	0.19	0.01	0.12	0.02			0.25	0.02	0.24	0.03
					Potassium %					
GS 2 = June 23	4.27	0.29								
GS 3 = July 7	3.33	0.57	5.97	0.32						
GS 4 = July 23	3.60	0.00	4.70	0.44	1.83	0.06				
GS 4 = Aug 18	3.10	0.57	3.30	0.28	1.60	0.00				
GS 5 = Sept 18	3.07	0.29	3.37	0.42			1.83	0.06	1.63	0.06
					Sulphur %					
GS 2 = June 23	0.36	0.01								
GS 3 = July 7	0.38	0.03	0.27	0.02						
GS 4 = July 23	0.45	0.00	0.23	0.03	0.14	0.01				
GS 4 = Aug 18	0.42	0.04	0.33	0.03	0.12	0.00				
GS 5 = Sept 18	0.41	0.04	0.30	0.01			0.14	0.01	0.13	0.01
					Calcium %					
GS 2 = June 23	1.50	0.19								
GS 3 = July 7	1.83	0.09	1.63	0.07						
GS 4 = July 23	2.37	0.17	1.24	0.17	0.04	0.00				
GS 4 = Aug 18	1.98	0.01	0.98	0.00	0.03	0.00				
GS 5 = Sept 18	2.12	0.08	1.19	0.14			0.04	0.00	0.02	0.01

(continued next page)

Table 5. Continued

Stage	Leaves Mean	Leaves SD	Stem Mean	Stem SD	Tubers Mean	Tubers SD	Undersize tubers Mean	Undersize tubers SD	Maingrade tubers Mean	Maingrade tubers SD
					Magnesium %					
GS 2 = June 23	0.57	0.07								
GS 3 = July 7	0.78	0.06	0.67	0.07						
GS 4 = July 23	1.14	0.05	0.59	0.10	0.12	0.01				
GS 4 = Aug 18	1.41	0.23	0.93	0.21	0.10	0.01				
GS 5 = Sept 18	0.94	0.05	0.86	0.10			0.12	0.01	0.10	0.01
					Zinc ppm					
GS 2 = June 23	48	3								
GS 3 = July 7	40	1	87	7						
GS 4 = July 23	60	3	72	12	16	1				
GS 4 = Aug 18	44	4	56	4	12	1				
GS 5 = Sept 18	62	4	60	2			16	1	13	2
					Iron ppm					
GS 2 = June 23	1175	202								
GS 3 = July 7	1194	181	805	101						
GS 4 = July 23	1227	314	388	136	78	30				
GS 4 = Aug 18	574	81	92	0	73	11				
GS 5 = Sept 18	484	48	92	38			78	30	50	13
					Manganese ppm					
GS 2 = June 23	149	1								
GS 3 = July 7	276	24	131	8						
GS 4 = July 23	509	66	88	7	5	2				
GS 4 = Aug 18	373	18	50	4	5	0				
GS 5 = Sept 18	470	21	69	14			5	2	3	1
					Copper ppm					
GS 2 = June 23	5	1								
GS 3 = July 7	6	1	5	1						
GS 4 = July 23	9	1	4	0	5	1				
GS 4 = Aug 18	6	0	4	1	4	0				
GS 5 = Sept 18	5	0	3	1			5	1	5	1
					Boron ppm					
GS 2 = June 23	5	1								
GS 3 = July 7	27	1	30	0						
GS 4 = July 23	31	1	23	2	6	1				
GS 4 = Aug 18	29	2	18	1	5	0				
GS 5 = Sept 18	29	1	20	1			6	1	5	0

Table 6. Daily rate of accumulation of dry matter and nutrients.

Stage	Date Interval	Interval In days	Plant Fraction Leaves	Stem	Tubers	Total
				Dry matter kg/ha/day		
Seeding-2	My13-Jn23	40	6			6
2-3	Jn23-Jl7	14	43	19		62
3-4	Jl7-Jl23	16	46	45	125	216
4	Jl23-Ag18	27	22	12	201	235
4-5	Ag18-Sp18	31	-21	3	138	120
				Nitrogen kg/ha/day		
Seeding-2	My13-Jn23	40	0.3			0.3
2-3	Jn23-Jl7	14	2.7	0.7		3.4
3-4	Jl7-Jl23	16	2.3	1.2	1.6	5.2
4	Jl23-Ag18	27	-0.3	-0.2	2.1	1.7
4-5	Ag18-Sp18	31	-1.3	-0.1	1.7	0.3
				P_2O_5 kg/ha/day		
Seeding-2	My13-Jn23	40	0.1			0.1
2-3	Jn23-Jl7	14	0.3	0.1		0.4
3-4	Jl7-Jl23	16	0.4	0.2	0.7	1.3
4	Jl23-Ag18	27	0.0	0.0	1.0	0.9
4-5	Ag18-Sp18	31	-0.2	0.0	0.9	0.7
				K_2O kg/ha/day		
Seeding-2	My13-Jn23	40	0.3			0.3
2-3	Jn23-Jl7	14	1.5	1.4		2.9
3-4	Jl7-Jl23	16	2.1	2.3	2.8	7.2
4	Jl23-Ag18	27	0.5	-0.1	3.6	4.0
4-5	Ag18-Sp18	31	-0.8	0.2	3.6	3.0
				Sulphur kg/ha/day		
Seeding-2	My13-Jn23	40	0.02			0.02
2-3	Jn23-Jl7	14	0.2	0.1		0.2
3-4	Jl7-Jl23	16	0.2	0.1	0.2	0.5
4	Jl23-Ag18	27	0.1	0.1	0.2	0.4
4-5	Ag18-Sp18	31	-0.1	0.0	0.2	0.1
				Calcium kg/ha/day		
Seeding-2	My13-Jn23	40	0.1			0.1
2-3	Jn23-Jl7	14	0.9	0.3		1.2
3-4	Jl7-Jl23	16	1.4	0.5	0.1	1.9
4	Jl23-Ag18	27	0.2	0.0	0.1	0.3
4-5	Ag18-Sp18	31	-0.3	0.1	0.0	-0.2
				Magnesium kg/ha/day		
Seeding-2	My13-Jn23	40	0.04			0.04
2-3	Jn23-Jl7	14	0.4	0.1		0.5
3-4	Jl7-Jl23	16	0.7	0.3	0.2	1.1
4	Jl23-Ag18	27	0.5	0.2	0.2	0.9
4-5	Ag18-Sp18	31	-0.5	0.0	0.2	-0.4

(continued)

Table 6. Continued

Stage	Date Interval	Interval in days	Plant Fraction Leaves	Stem	Tubers	Total
				Zinc g/ha/day		
Seeding-2	My13-Jn23	40	0.3			0.3
2-3	Jn23-Jl7	14	1.6	1.6		3.2
3-4	Jl7-Jl23	16	3.8	3.0	2.0	8.9
4	Jl23-Ag18	27	0.0	0.1	1.9	2.0
4-5	Ag18-Sp18	31	0.0	0.4	2.4	2.8
				Iron g/ha/day		
Seeding-2	My13-Jn23	40	7.49			7.5
2-3	Jn23-Jl7	14	51.9	15.2		67.1
3-4	Jl7-Jl23	16	57.7	10.7	9.7	78.1
4	Jl23-Ag18	27	-25.6	-9.7	14.3	-21.0
4-5	Ag18-Sp18	31	-16.4	0.3	2.4	-13.8
				Manganese g/ha/day		
Seeding-2	My13-Jn23	40	1.0			1.0
2-3	Jn23-Jl7	14	14.2	2.5		16.7
3-4	Jl7-Jl23	16	35.7	3.3	0.7	39.6
4	Jl23-Ag18	27	0.3	-0.8	1.0	0.5
4-5	Ag18-Sp18	31	-2.9	1.0	0.1	-1.8
				Copper g/ha/day		
Seeding-2	My13-Jn23	40	0.03			0.03
2-3	Jn23-Jl7	14	0.3	0.1		0.4
3-4	Jl7-Jl23	16	0.5	0.2	0.6	1.3
4	Jl23-Ag18	27	0.0	0.0	0.8	0.8
4-5	Ag18-Sp18	31	-0.2	0.0	0.8	0.6
				Boron g/ha/day		
Seeding-2	My13-Jn23	40	0.03			0.03
2-3	Jn23-Jl7	14	1.5	0.6		2.1
3-4	Jl7-Jl23	16	1.6	0.9	0.7	3.3
4	Jl23-Ag18	27	0.5	0.0	1.0	1.5
4-5	Ag18-Sp18	31	-0.6	0.2	0.7	0.3

Table 7. Potato nutrient uptake and removal values from current study compared to published values.

	Source:	MCDC	SFG	CFI - West		CFI- East		MCDC	SFG	CFI - West		CFI- East	
	Yield (cwt/ac):	**376**	300	400	400	400	400						
				min	max	min	max			min	max	min	max
Nutrient			lb nutrient/acre						lb nutrient per cwt				
N	tubers	**119**	96	115	141	125	135	**0.32**	0.32	0.29	0.35	0.31	0.34
	total	**177**	171	205	251	210	230	**0.47**	0.57	0.51	0.63	0.53	0.58
P_2O_5	tubers	**60**	28	33	40	35	50	**0.16**	0.09	0.08	0.10	0.09	0.13
	total	**68**	50	60	73	65	75	**0.18**	0.17	0.15	0.18	0.16	0.19
K_2O	tubers	**227**	162	194	238	210	250	**0.60**	0.54	0.49	0.60	0.53	0.63
	total	**328**	224	268	327	300	440	**0.87**	0.75	0.67	0.82	0.75	1.10
S	tubers	**14**	9	11	13	10	12	**0.04**	0.03	0.03	0.03	0.03	0.03
	total	**23**	14	16	20	18	18	**0.06**	0.05	0.04	0.05	0.05	0.05
Ca	tubers	**3**	4			5		**0.01**	0.01			0.01	
	total	**47**				20		**0.13**	0.00			0.05	
Mg	tubers	**11**	8			10		**0.03**	0.03			0.03	
	total	**35**	30			40		**0.09**	0.10			0.10	
Zn	tubers	**0.14**	0.10					**0.0004**	0.0003				
	total	**0.30**						**0.0008**					
Fe	tubers	**0.54**	0.70					**0.0014**	0.0023				
	total	**1.32**						**0.0035**					
Mn	tubers	**0.04**	0.15					**0.0001**	0.0005				
	total	**0.76**						**0.0020**					
Cu	tubers	**0.05**	0.10					**0.0001**	0.0003				
	total	**0.06**						**0.0002**					
B	tubers	**0.05**	0.05					**0.0001**	0.0002				
	total	**0.12**						**0.0003**					

MCDC: current study at MCDC; yield = 376 cwt/ac maingrade; 416 cwt/ac of total.

SFG: Fertility Guide (Manitoba Agriculture and Food), Table 1, page 2.

CFI-West = Canadian Fertilizer Institute. Minimum and maximum expected values are given.

CFI-East = Canadian Fertilizer Institute. Minimum and maximum expected values are given.

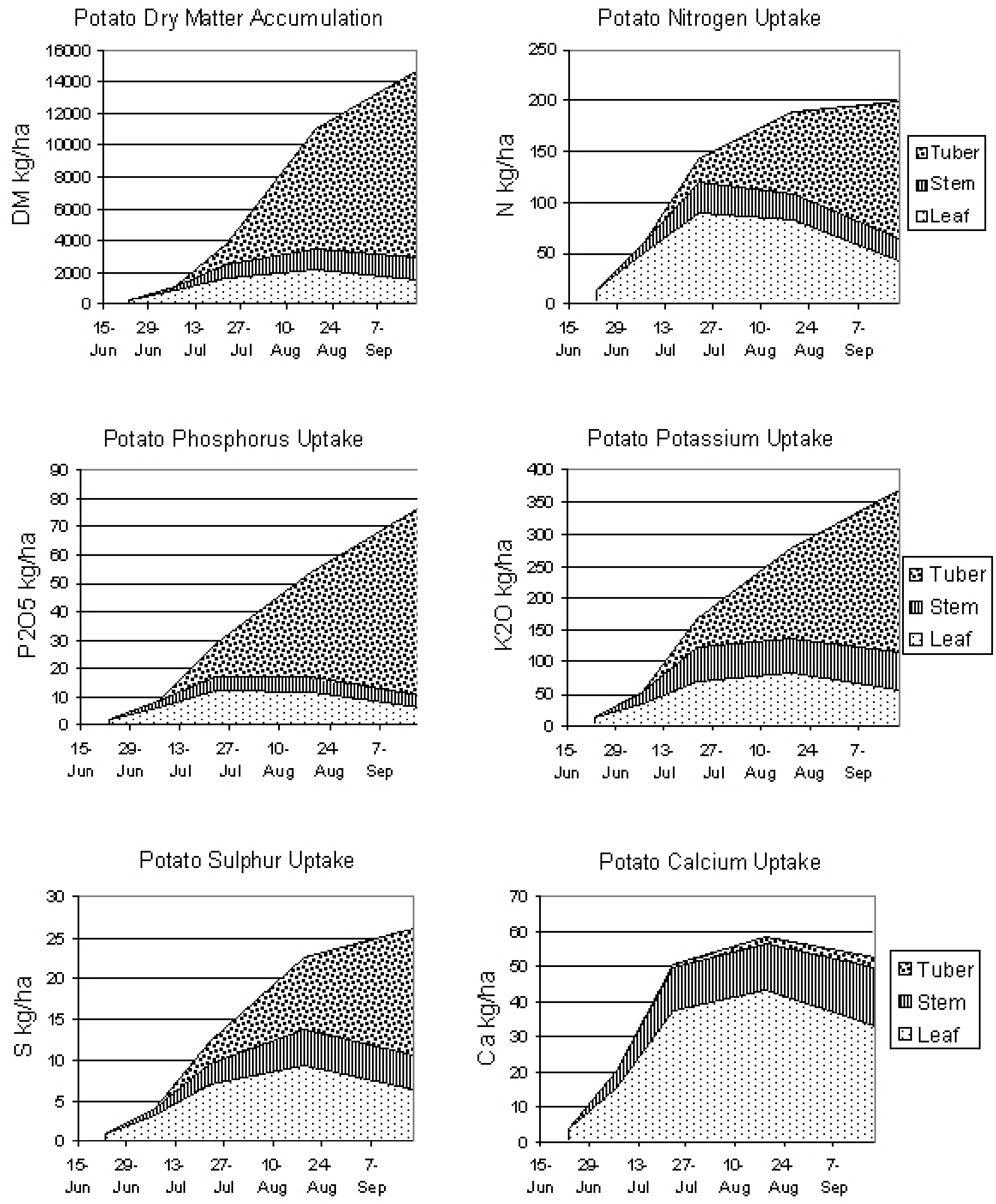


Figure 1. Dry matter and nutrient uptake and partitioning in the potato (continued next page.)

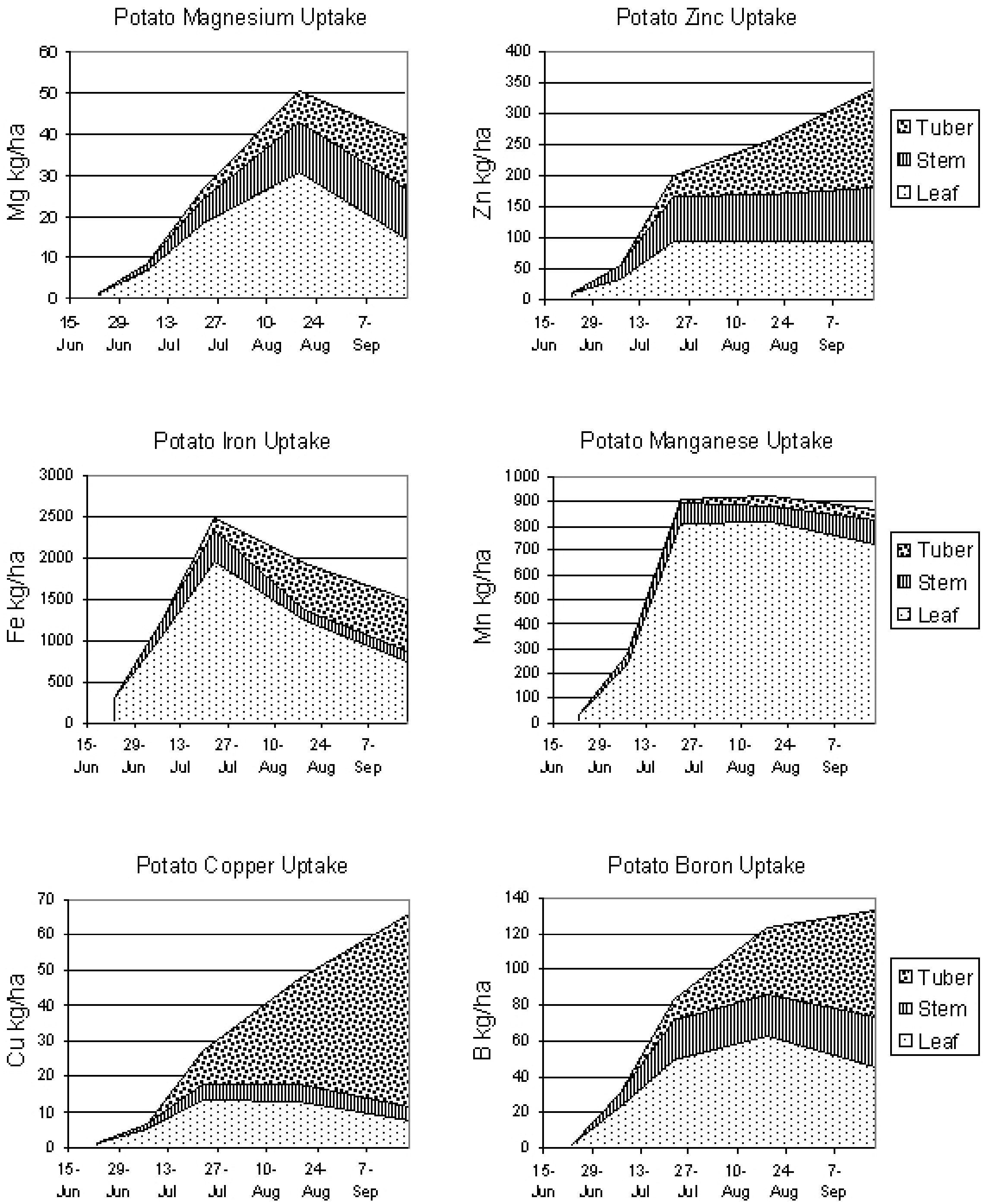


Figure 1. (continued)

Potato Plant Spacing Study

Principal Investigator: L.G. Mitchell, MCDC

Funding: MCDC

Progress: Fourth year of study

Objective: To determine the effects of plant spacing within the potato row on yield, quality, and size distribution of Russet Burbank potatoes.

Introduction

Seed piece spacing has become an important issue in potato production due to its effects on tuber size distribution and marketable yield. There are incentives to produce tubers of a size distribution that meets the needs of the processors. Since these size requirements often change over time and vary by processor, it is important to fully understand the relationships between seed piece spacing, tuber size distribution and quality, and marketable yield, so that producers can maximize their net returns by changing seed piece spacing.

It has been widely reported that increasing seed piece density increases the number of plant stems, leading to an increase in tuber number but a decrease in tuber size. Previous studies at MCDC in 1998 and 1999 had shown little change in marketable yield with changes in seed piece spacing.

The first three years of the current study produced variable results. Marketable yield (>2" diameter) increased with seed spacing for early seeded potatoes at the Carberry site in 2000, but decreased for late seeded potatoes at the Winkler site. The late seeded potatoes at the Carberry site and the early seeded potatoes at the Winkler sight showed slightly lower marketable yields at increased seed spacings in 2000. Late planting decreased yields at both sites. The incidence of hollow heart increased with increased seed spacing in the late planted potatoes at Winkler in 2000. In 2001, slightly higher marketable yields were observed at the 18" seed spacing, except the late seeded potatoes at the Winkler site. Here, marketable yield decreased with wider seed spacing. Late planting decreased yields, except in the closely spaced Winkler plots. Yields were higher at Carberry for the early seeded plots, but higher at Winkler for the late seeded plots. No effects of seed piece spacing on tuber quality were observed. In 2002, seed piece spacing had no effect on tuber quality. The Winkler site potatoes had a significantly higher incidence of hollow heart, especially the early seeded ones. The 18" spacing tended to produce the highest marketable yields (though not statistically significant) at the Carberry site and the early seeded Portage site. At the late seeded Portage site, both 15" and 21" spacing produced higher marketable yield than 18" spacing (again not statistically significant). A 15" seed spacing produced a significantly higher marketable yield than the other spacings at the early seeded Winkler site. At the late seeded Winkler site, the 21" spacing yielded highest, but the difference was not significant. Late seeding decreased yields at all sites. The Carberry site had the highest marketable yield, followed by the Portage site, then the Winkler site. The close spacings produced a higher proportion of smaller tubers and the wider spacings produced a higher proportion of large tubers at the Carberry and Winkler sites. The Portage site did not show these relationships.

Study Description

The study was set up as two randomized complete block designs (one for each planting date) at each of three locations. The treatments were assigned randomly to each of six blocks. Seed piece spacings were 12, 15, 18, 21, and 24" (30.5, 38.1, 45.7, 53.3, and 61.0 cm). Russet Burbank potatoes were seeded during both the first and third weeks of May at the MCDC-Carberry site (Wellwood clay loam), the MCDC-Portage site (Neuhorst clay loam), and the MCDC-Winkler site (Reinland fine sandy loam). The seed was cut and treated in one lot. Seed for the second planting was kept under potato storage conditions. Fertilizers were applied to meet crop requirements based on soil samples taken the previous fall. Plots were 12 m long and 4 rows wide with a row spacing of 37.4" (95 cm). Irrigation water and pesticides were applied to prevent drought stress and control pests. After fall desiccation, the plots were harvested for yield and tuber size and quality assessment.

Data was analysed as a separate randomized complete block design for each planting date at each site. Statistix® software was used for the statistical analysis.

Results and Discussion

Seed piece spacing had little effect on tuber quality (data not shown).

The 12" spacing produced the highest total yields (though not always statistically significant) at nearly all sites and planting dates in 2003 (Table 1). The Portage site had the highest yield, followed by the Carberry site, then the Winkler site. Yields at the Winkler site were least affected by seed spacing in 2003.

Table 1. Total yield at MCDC sites in 2003.

In-row seed piece spacing	Tuber yield					
	Carberry early	**Carberry late**	**Portage early**	**Portage late**	**Winkler early**	**Winkler late**
inches	cwt. $acre^{-1}$					
12	414	360	460	408	336	312
15	399	348	430	371	340	307
18	358	300	397	376	306	289
21	405	324	399	349	310	287
24	337	296	369	334	304	263
LSD (0.05)	44	36	46	35	18	16

The effect of seed spacing on tuber size profile is shown in Tables 2, 3, and 4. Generally, the close plant spacings tended to produce a higher proportion of smaller tubers and the wider plant spacings produced a higher proportion of large tubers at all sites. The most profitable spacing would depend on the desired tuber size profile.

Late seeding resulted in reduced yield and a higher proportion of smaller tubers at all three sites.

Additional site years of study may be useful in assessing the effect of seed piece spacing on tuber yield, size distribution, and quality.

Table 2. Tuber size distribution at Carberry in 2003.

In-row seed piece spacing	Tuber yield											
	<3 oz.		3 - 6 oz.		6 - 10 oz		10 - 12 oz		>12 oz.		2" to 6 oz.*	
	early	late	early	late	early	late	early	late	early	late	early	late
inches	cwt. $acre^{-1}$											
12	25	32	83	126	131	140	58	43	134	40	65	87
15	21	23	80	86	141	118	58	39	112	99	60	60
18	18	18	71	67	91	85	58	49	134	94	49	48
21	20	15	69	62	123	97	69	42	137	119	52	46
24	14	13	52	54	97	78	62	49	122	109	38	39
LSD (0.05)	7	9	18	21	41	28	22	16	43	40	19	17

* some contracts use this category at the small end of the size profile

Table 3. Tuber size distribution at Portage in 2003.

In-row seed piece spacing	Tuber yield											
	<3 oz.		3 - 6 oz.		6 - 10 oz		10 - 12 oz		>12 oz.		2" to 6 oz.*	
	early	late	early	late	early	late	early	late	early	late	early	late
inches	cwt. $acre^{-1}$											
12	15	45	91	136	150	167	66	29	139	31	64	107
15	14	34	65	118	155	160	56	37	139	23	49	75
18	11	23	57	82	114	153	60	46	154	73	43	60
21	10	22	44	81	97	127	52	42	197	79	34	53
24	8	17	33	61	72	106	39	55	217	96	25	44
LSD (0.05)	4	9	23	30	30	39	21	22	54	40	15	20

* some contracts use this category at the small end of the size profile

Table 4. Tuber size distribution at Winkler in 2003.

In-row seed piece spacing	Tuber yield <3 oz.		3 - 6 oz.		6 - 10 oz		10 - 12 oz		>12 oz.		2" to 6 oz.*	
	early	late	early	late	early	late	early	late	early	late	early	late
inches	cwt. $acre^{-1}$											
12	31	31	79	108	115	124	45	27	66	25	74	88
15	21	25	99	107	120	127	36	25	64	23	80	89
18	16	23	71	79	99	109	44	30	76	48	58	62
21	15	20	67	89	111	109	48	30	76	40	53	73
24	12	16	63	76	105	111	50	30	68	30	57	59
LSD (0.05)	11	12	26	23	27	21	23	13	35	16	21	21

* some contracts use this category at the small end of the size profile

Manitoba Potato Research Coordination Meeting

Funding: MCDC

Progress: Biennial meeting, held in 2003

Objectives:
1) Identify resources potentially available to meet Manitoba potato industry needs.
2) Create an environment of collaboration.
3) Identify research and extension priorities of the Manitoba potato industry.
4) Define specific research & extension goals and time frames.

Organization and Participation

The Manitoba Potato Research Coordination Meeting 2003 was an initiative of the Manitoba Crop Diversification Centre. The Organizing Committee, responsible for most of the of the planning, organization, conduct, and reporting of the meeting, consisted of: Dale Tomasiewicz, Les Mitchell, Sherree Olmstead, and Gerald Loeppky from MCDC; Bill Moons, Nandita Selvanathan, and Marina Chabbert from the Soils and Crops Branch of Manitoba Agriculture, Food and Rural Initiatives; and Erwin Allerdings from the Prairie Farm Rehabilitation Administration Branch of Agriculture and Agrifood Canada in Regina). Erwin also facilitated the event. Additional help with facilitating the breakout groups was provided by MAFRI staff. Time and travel costs of all participants (including individuals from Idaho, Prince Edward Island, New Brunswick, and Saskatchewan) were borne by themselves and the agencies they represented.

The third Manitoba Potato Research Coordination Meeting was coordinated by the Manitoba Crop Diversification Centre, and held in Portage la Prairie on November 5, 2003. The previous Meetings were held in November of 2000 and 2001. Approximately fifty people participated in the one-day event, including potato growers and representatives of potato processing companies, research, extension, funding, and regulatory agencies, and suppliers. Several research, funding, and other agencies had displays set up to provide information about their programs and projects to participants at the breaks and during the lunch hour.

Review of Priorities Issues from the 2001 Meeting, Actions, and Agency Programs

Research and extension Priorities identified at the 2001 Meeting were reviewed, with comments on actions taken since then to follow up on the issues. Brief presentations were then made on the potato research capacities and programs in Agriculture and Agri-Food Canada (by Karl Volkmar), and at the University of Manitoba (by Merv Prirtchard).

Current Potato Industry Perspectives - Panel

A panel of three potato growers and three processor representatives made brief presentations on industry issues and research and extension needs, in the following three broad areas:

1) Variety Development, Crop Quality, and Storage (Marv Dyck- producer, Dale Ziprick - processor)
2) Pest Management (Randy Painter - producer, Dieter Schwarz - processor)
3) Production Practices and Issues of Food Safety and Environment (Dan Sawatsky - producer, Mick Peck - processor)

The panel then responded to questions.

Identification and Prioritization of Issues; Action Plans

For the remainder of the day, the Facilitator lead the group through a process to discuss and prioritize the issues raised, and develop some preliminary action plans to address some of the most important ones. This was done using both small breakout groups and in plenary.

Research and extension challenges and needs were identified and categorized under eight themes. Activities to address the needs were described and prioritized by the group, and action plans for the following six highest priority research and extension issues were developed:

1) Early Dying Complex - a complex production probem reducing yields and sustainability
2) Potato Fertility Taskforce - need to review fertility management information for Manitoba
3) Water and Nutrient Management - need to better understand and develop water management practices for production and control of leaching
4) Centralized Funding - for coordination
5) Expertise and resource database - to improve ease of access to information and timeliness
6) Early maturing variety - a suitable variety that matures in 100 days is desirable

The meeting should assist all agencies involved in research and extension for the Manitoba Potato Industry to focus their efforts on the priorities identified, and work together to most efficiently address the issues.

The Effect of Gibberellic Acid Application Timing and Concentration on Shepody Tuber Number and Size

Principal Investigator: Blair Geisel, Gaia Consulting Ltd.

Funding and support: Keystone Vegetable Producers Association.
Midwest Food Products Inc.
McCain Foods Ltd.
MCDC

Objective: To determine the effect of Gibberellic acid (GA) application timing and concentration on Shepody tuber number and size.

Abstract

Gibberellic acid (GA) is a naturally occurring plant hormone, which is used to modify plant growth in the fruit and vegetable industry. Previous research in Manitoba demonstrated that applying a 10-15 ppm GA solution at 150 ml/100 kg of seed will increase tuber number and decrease the tuber size profile by 20-30% in Shepody potatoes. This effect would be a real advantage for seed growers, as it is generally accepted that tubers used for seed should be 8 oz in weight or less. Oversize seed tubers result in many cut-seed pieces that are too large or too small. Small seed pieces produce weak, unproductive plants. An application of GA will increase the premium seed yield. Seed growers can choose between two seed cutting methods: 1) standard seed cutting, where seed is cut, treated, and planted the same or next day, or 2) pre-cutting, where the seed is cut, treated, and stored for up to 3 weeks before planting. Initial testing indicates that applying a 10-15 ppm GA solution at a rate of 150 ml/100 kg of seed can produce a more desirable tuber size profile whether using the standard seed cutting (fresh cut) method or the pre-cut method. Gibberellic acid treatments decreased tuber size and increased premium seed yield as compared with the check.

Methods

Shepody potatoes were planted May 13 at MCDC-Portage la Prairie (Neuhorst clay loam), using a 1-m row spacing and 30-cm in-row seed piece spacing. Plots were 4 rows by 40 ft long, laid out in a two-factor randomized complete block design with four replicates. They were top-killed September 12 and harvested September 16.

The GA was applied to the seed pieces immediately after cutting (Table 1). The seed pieces were placed in a seed treater and 166 mL/ 100 kg of seed of the desired GA solution was sprayed onto the seed pieces. The spray was applied while the tubers were tumbling to allow for even application of the GA. Fungicide seed piece treatment was applied following the GA application. Precut seed was placed into storage at a temperature of 7-10˚C and 90% R.H. until planting.

The assessments, conducted on the two centre rows of each plot, included:

1. Stand counts in 40 feet of row at 27, 32, and 37 days after planting, and a stem count at 37days after planting.
2. Yield (total, marketable, undersize), tuber profile (0-2 oz, 2-6, 6-10, and >10 oz), grade (hollow heart, specific gravity), and total tuber count.
3. Seed retention - 50 lb of tubers were collected from each plot and retained in storage as seed. It will be planted in 2004 to determine whether there are any residual affects from the GA.

Table 1. Treatments.

Trt #	Application Method	GA Concentration (ppm)	Rate of active
1	Pre-cut [1]	5	750 [1]
2	Pre-cut [1]	10	1500 [1]
3	Pre-cut [1]	15	2250 [1]
4	Pre-cut [1]	20	3000 [1]
5	Pre-cut [1]	30	4500 [1]
6	Pre-cut [1]	Untreated check	0
7	Pre-cut [1]	Sham - water only	0
8	Fresh cut [2]	5	750 [1]
9	Fresh cut [2]	10	1500 [1]
10	Fresh cut [2]	15	2250 [1]
11	Fresh cut [2]	20	3000 [1]
12	Fresh cut [2]	30	4500 [1]
13	Fresh cut [2]	Untreated check	0
14	Fresh cut [2]	Sham - water only	0

[1] Pre-cut: interval = 2 weeks prior to planting
Fresh cut: interval = 1 day prior to planting

[2] µg ai/100 kg

Results and Discussion

Stand, stem number, and phytotoxicity (Table 2)

Pre-cutting seed resulted in earlier emergence but total emergence (37 DAP) was the same. There were fewer stems with the pre-cut seed.

Slight phytotoxic effects as a result of the 20 and 30 ppm GA treatments were detected. Pre-cut seed was more affected, especially at 30 ppm. Water (sham) had a negative impact on stand and stem numbers, whether due to a physiological change, increased potential for disease or other factors brought about by the presence of water.

Yield (Table 3 and Figure 1)

Pre-cutting resulted in a higher yield of undersize tubers. There were higher yields of undersize tubers with pre-cut at higher concentrations of GA (15, 20, 30). Premium seed yield was greater with fresh-cut, and with 10-30 ppm GA application. The sham treatment reduced total and premium seed yield. Total yield was also depressed at high concentrations of GA (20, 30).

Tuber size (Table 4 and Figure 2)

Tuber size decreased with increasing GA concentration. That decrease in tuber size compensated for lower total yield at high GA concentrations, resulting in a constant premium seed yield over the 10, 15, 20, and 30 ppm GA concentrations. All GA treatments reduced tuber size as compared to the check and the sham.

Quality (Table 4)

There were no differences between the treatments for specific gravity or for hollow heart.

Table 2. Effect of Gibberellic Acid treatment timing and concentration on stand and phytotoxicity rating.

	Concentration							
Timing	5 ppm	10 ppm	15 ppm	20 ppm	30 ppm	check	sham	Mean
Stand 27 DAP - pre-cut	9.0	11.8	16.3	10.3	9.8	12.0	4.5	10.5
Stand 27 DAP - fresh cut	3.0	7.3	4.5	6.5	8.8	4.5	3.5	5.4
Stand 27 DAP - mean	6.0	9.5	10.4	8.4	9.3	8.3	4.0	
Stand 27 DAP (timing) P[1] =	0.0000							
Stand 27 DAP lsd (concentration)	NSD							
Stand 27 DAP CV	51.9%							
Stand 32 DAP - pre-cut	26.3	27.3	33.5	29.0	23.8	26.5	24.3	27.2
Stand 32 DAP - fresh cut	24.5	28.0	25.8	27.3	26.3	23.8	20.3	25.1
Stand 32 DAP - mean	25.4	27.6	29.6	28.1	25.0	25.1	22.3	
Stand 32 DAP (timing) P =	0.0506							
Stand 32 DAP lsd (concentration)	4.0							
Stand 32 DAP CV	14.9%							
Stand 37 DAP - pre-cut	36.5	36.3	38.5	36.5	33.5	36.8	33.5	35.9
Stand 37 DAP - fresh cut	34.8	37.8	37.8	36.3	36.8	36.0	36.0	36.5
Stand 37 DAP - mean	35.6	37.0	38.1	36.4	35.1	36.4	34.8	
Stand 37 DAP (timing) P =	>0.9999							
Stand 37 DAP lsd (concentration)	NSD							
Stand 37 DAP CV	7.2							
Stems 37 DAP - pre-cut	58.8	72.0	78.5	70.5	63.3	57.8	50.3	64.4
Stems 37 DAP - fresh cut	70.3	75.3	74.0	70.3	79.5	64.5	61.5	70.8
Stems 37 DAP - mean	64.5	73.6	76.3	70.4	71.4	61.1	55.9	
Stems 37 DAP (timing) P =	0.0001							
Stems 37 DAP lsd (concentration)	5.4							
Stems 37 DAP CV	7.9%							
Stems/plant 37 DAP - pre-cut	1.6	2.0	2.0	1.9	1.9	1.6	1.5	1.8
Stems/plant 37 DAP - fresh cut	2.0	2.0	2.0	1.9	2.2	1.8	1.7	1.9
Stems/plant 37 DAP - mean	1.8	2.0	2.0	1.9	2.0	1.7	1.6	
Stems/plant 37 DAP (timing) P =	0.0001							
Stems/plant 37 DAP lsd (conc.)	0.1							
Stems/plant 37 DAP CV	7.1%							
Phytotoxicity - pre-cut	8.8	8.5	8.8	8.3	7.5	9.0	9.0	8.5
Phytotoxiicity - fresh cut	9.0	9.0	8.5	8.8	8.8	9.0	9.0	8.9
Phytotoxiicity - mean	8.9	8.8	8.6	8.5	8.1	9.0	9.0	
Phytotoxicity (timing) P =	0.0056							
Phytotoxicity lsd (concentration)	0.4							
Phytotoxicity CV	4.7%							

[1]P = Probability. Considered statistically significant at 0.05 level.

Table 3. Effect of Gibberellic Acid treatment timing and concentration on yield, and grade.

Timing	Concentration							
	5 ppm	10 ppm	15 ppm	20 ppm	30 ppm	check	sham	Mean
2-6 oz yield[1] - pre-cut	51.3	70.8	91.8	85.2	90.9	36.7	30.3	65.3
2-6 oz yield - fresh cut	63.2	81.5	96.0	92.2	78.6	52.0	50.6	73.5
2-6 oz yield - mean	57.3	76.2	93.9	88.7	84.8	44.3	40.5	
2-6 oz yield (timing) P =	0.0685							
2-6 oz lsd (concentration)	16.5							
2-6 oz CV	23.5%							
6-10 oz yield - pre-cut	90.5	129.9	108.3	110.3	97.7	96.7	72.0	100.8
6-10 oz yield - fresh cut	123.3	132.7	121.4	128.0	125.4	97.3	87.1	116.5
6-10 oz yield - mean	106.9	131.3	114.8	119.1	111.5	97.0	79.6	
6-10 oz (timing) P =	0.0024							
6-10 oz lsd (concentration)	18.3							
6-10 oz CV	16.6%							
>10 oz yield - pre-cut	225.9	161.6	157.0	110.8	142.6	255.7	246.3	185.7
>10 oz yield - fresh cut	192.5	162.4	137.4	119.9	120.2	219.6	230.9	169.0
>10 oz yield - mean	209.2	162.0	147.2	115.3	131.4	237.6	238.6	
>10 oz (timing) P =	0.0674							
>10 oz lsd (concentration)	33.6							
>10 oz CV	18.8							
Total yield - pre-cut	370.3	367.4	362.6	312.9	339.7	389.9	350.1	356.1
Total yield - fresh cut	381.2	378.1	362.2	343.7	327.0	369.8	370.9	361.8
Total yield - mean	375.7	372.7	362.4	328.3	333.4	379.9	360.5	
Total yield (timing) P =	>0.9999							
Total yield lsd (concentration)	33.5							
Total yield CV	9.2%							
Premium[2] seed yield - pre-cut	141.8	200.7	200.1	195.5	188.5	133.4	102.3	166.0
Premium seed yield - fresh cut	186.5	214.2	217.3	220.2	204.0	149.0	137.8	189.9
Premium seed yield - mean	164.2	207.4	208.7	207.8	196.3	141.4	120.1	
Premium seed (timing) P =	0.0018							
Premium seed lsd (conc.)	26.9							
Premium seed CV	15.0%							

[1] Yield expressed as hundred weights per acre (cwt/ac).
[2] Premium seed yield = 2 - 10 oz.

Figure 1. Effect of Gibberellic Acid on Shepody yield and grade. (Letters designate separation between premium seed yield means.)

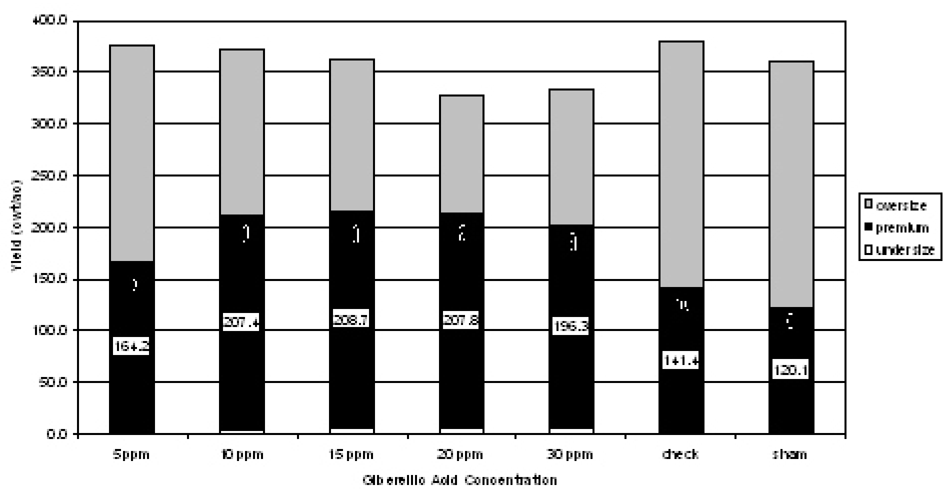


Table 4. Effect of Gibberellic Acid treatment timing and concentration on tuber characteristics.

Timing	Concentration: 5 ppm	10 ppm	15 ppm	20 ppm	30 ppm	check	sham	Mean
Specific Gravity - pre-cut	1.091	1.093	1.094	1.095	1.094	1.094	1.093	1.092
Specific Gravity - fresh cut	1.092	1.093	1.093	1.091	1.093	1.095	1.093	1.093
Specific Gravity - mean	1.091	1.093	1.093	1.093	1.094	1.094	1.093	
Specific Gravity lsd (timing)	NSD							
Specific Gravity (concentration) P =	0.3949							
Specific Gravity CV	0.2%							
Bonus % - pre-cut	61.0	44.0	43.4	35.3	41.7	65.6	70.2	51.6
Bonus % - fresh cut	50.4	43.1	37.7	34.5	35.4	59.0	61.9	46.0
Bonus % - mean	55.7	43.6	40.6	34.9	38.5	62.3	66.1	
Bonus % lsd (timing)	1.3							
Bonus % (concentration) P =	0.0000							
Bonus % CV	14.5%							
Avg Tuber Size[1] (oz) - pre-cut	9.2	7.5	7.3	6.4	6.5	10.6	10.6	8.3
Avg Tuber Size (oz) - fresh cut	8.6	8.3	7.4	7.0	7.2	9.6	9.7	8.3
Avg Tuber Size (oz) - mean	8.9	7.9	7.4	6.7	6.9	10.1	10.2	
Avg Tuber Size (oz) lsd (timing)	>0.9999							
Avg Tuber Size (oz) (concentration) P =	0.8							
Avg Tuber Size (oz) CV	9.8%							
Tuber No. per Plot - pre-cut	387.3	469.4	485.9	482.3	502.0	358.2	317.9	429.0
Tuber No. per Plot - fresh cut	425.1	444.5	470.4	474.4	436.1	373.7	368.2	427.5
Tuber No. per Plot - mean	406.2	456.9	478.1	478.4	469.0	366.0	343.1	
Tuber No. per Plot lsd (timing)	54.9							
Tuber No. per Plot (concentration) P =	0.0000							
Tuber No. per Plot CV	12.7%							
Hollow Heart % - pre-cut	2.9	0.0	1.9	0.0	0.0	0.0	2.3	1.1
Hollow Heart % - fresh cut	0.0	0.0	0.0	0.0	0.0	7.7	0.0	1.1
Hollow Heart % - mean	1.5	0.0	1.0	0.0	0.0	3.8	1.1	
Hollow Heart % lsd (timing)	NSD							
Hollow Heart % lsd (concentration)	NSD							
Hollow Heart % CV	325.5%							

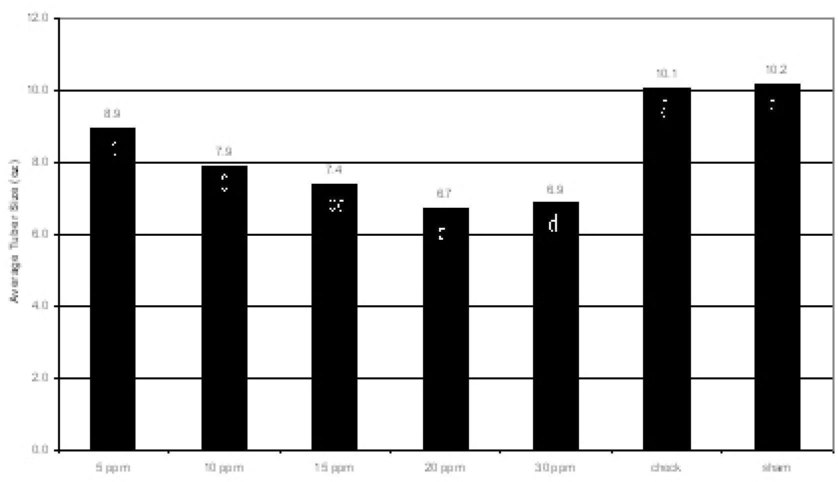


Figure 2. Effect of Gibberellic Acid on Shepody tuber size. (Letters designate separation between premium seed yield means.)

The Effect of Giberellic Acid Solution Volume on Shepody Tuber Number and Size

Principal Investigator: Blair Geisel, Gaia Consulting Ltd.

Funding and support: Keystone Vegetable Producers Association.
Midwest Food Products Inc.
McCain Foods Ltd.
MCDC

Objective: To determine the effect of Gibberellic acid solution volume and rate on Shepody tuber number and size.

Abstract

Gibberellic acid (GA) is a naturally occurring plant hormone, which is used to modify plant growth in the fruit and vegetable industry. Researchers in New Brunswick and Alberta have demonstrated that dipping seed tubers in a 5 ppm GA solution will increase tuber number and decrease the tuber size profile by 20% in some varieties. Trials sponsored by Keystone, Midwest and McCain only measure a change in tuber number and size when applying >10 ppm GA solution in 150 ml water/100 kg of seed. The difference in rate response between the Manitoba and New Brunswick and Alberta trials is attributed to the application method resulting in different application rates of solution. The dipping method results in a much higher application rate of both solution and active GA. Until this study, it was accepted that the concentration of GA in the solution, not rate of active, was critical to produce a response, unlike the application of most pesticides where rate of application per unit of seed, not concentration, is critical to produce a response. To resolve this question a 10 ppm GA solution was applied at 50, 125 and 200 ml/100 kg of seed that results in an application of 500, 1,250 and 2,000 micrograms (µg) of active GA/100 kg of seed respectively. The results show that when <125 ml of the 10 ppm GA solution/100 kg of seed or 1,250 µg of GA/100 kg of seed are applied there is no response. These results indicate that rate of active applied and not concentration is the key to GA response. Gibberellic acid should be applied at a rate of 1,500 - 2,000 µg active/ 100 kg of seed in 100 to 150 ml of water/100 kg seed.

Methods

Shepody potatoes were planted May 12 at MCDC-Portage la Prairie (Neuhorst clay loam), using a 1-m row spacing and 30-cm in-row seed piece spacing. Plots were 4 rows by 12 m long, laid out in a randomized complete block design with four replicates. They were top-killed September 12 and harvested September 17.

The treatments (Table 1) were applied to the seed pieces immediately after cutting. The seed pieces were placed in a seed treater and the desired GA solution volume was sprayed onto the seed pieces. The spray was applied while the tubers were tumbling to allow for even application of the treatment. Fungicide seed piece treatment was applied following the application.

The assessments, conducted on the two centre rows of each plot, included:

1. Stand counts in 12 m of row 27, 33 and 38 days after planting (DAP) and a stem count 38 DAP.
2. Yield (total, marketable, undersize), tuber profile (0-2 oz, 2-6, 6-10, and >10oz), grade (hollow heart, specific gravity) and total tuber count.

Table 1. Treatments.

Trt #	Treatment	GA Concentration (ppm)	Solution Volume (ml/100kg)	Rate of active (µg ai/100 kg)
1	Gibberellic acid	10	50	500
2	Gibberellic acid	10	125	1250
3	Gibberellic acid	10	200	2000
4	Sham – sprayed with water	0	125	0
5	Untreated check	0	0	0

Results and Discussion

Stand and Stem Counts (Table 2)

At 27 DAP the 125 and 200 ml rates (#2 & 3) had more emerged plants than the 50 ml rate, check, and sham (#1, 4, & 5). At 33 and 38 DAP, the three GA treatments (#1, 2, & 3) had more emerged plants than the check and sham. The number of stems in 12m increased with increased rate of GA (#1, 2, & 3). Treatments 2 and 3 (GA applied at 125 and 200 ml rates) had significantly more stems per plant than the 50 ml GA rate, check, and sham (#1, 4, & 5). There were no differences in stand and stems/plant between the check (4) and sham (5).

Table 2. Effect of GA on stand and stems per plant.

Trt #	Treatment	Rate[1]	Stand Count in 12 m 27 DAP	33 DAP	38 DAP	Stem Count[2] 38 DAP	Stems per Plant
1	GA	50	4.8 b	28.8 a	37.8 a	63.8 c	1.7 b
2	GA	125	8.3 a	28.5 a	36.8 ab	70.8 b	1.9 a
3	GA	200	9.0 a	30.5 a	38.3 a	77.5 a	2.0 a
4	Sham(water)	125	5.3 b	21.8 b	34.3 c	58.0 c	1.7 b
5	Check	0	4.0 b	21.8 b	35.0 bc	58.5 c	1.7 b
Probability			0.0100	0.0100	0.0100	0.0001	0.0069
CV%			30.7	13.7	4.3	6.5	7.5
LSD (0.05)			3.0	5.6	2.4	6.5	0.2

[1] ml of water or GA solution/100 kg seed

[2] Stems in 12 m

Yield (Table 3)

The 125 and 200 ml treatments (#2, 3) resulted in a significantly lower yield of tubers greater than 10 ounces indicating a smaller tuber size profile. The 125 ml rate (#2) produced the highest yield. An orthogonal contrast comparing the 125 rate (#2) to showed a significant difference (P=0.05) between the three GA treatments (1, 2 & 3) and the two non-GA treatments (4 & 5). Although the highest volume (Treatment 3) showed the lowest yield, there were no significant differences between the treatments.

Table 3. Effect of GA on stand and stems per plant.

Trt #	Treatment	Rate[1]	Stand Count in 12 m 27 DAP	Stand Count in 12 m 33 DAP	Stand Count in 12 m 38 DAP	Stem Count[2] 38 DAP	Stems per Plant
1	GA	50	4.8 b	28.8 a	37.8 a	63.8 c	1.7 b
2	GA	125	8.3 a	28.5 a	36.8 ab	70.8 b	1.9 a
3	GA	200	9.0 a	30.5 a	38.3 a	77.5 a	2.0 a
4	Sham (water)	125	5.3 b	21.8 b	34.3 c	58.0 c	1.7 b
5	Check	0	4.0 b	21.8 b	35.0 bc	58.5 c	1.7 b
Probability			0.0100	0.0100	0.0100	0.0001	0.0069
CV%			30.7	13.7	4.3	6.5	7.5
LSD (0.05)			3.0	5.6	2.4	6.5	0.2

[1] ml of water or GA solution/100 kg seed
[2] Stems in 12 m

Tuber density, number and size (Table 4)

Treatments 2 and 3 (125 and 200 ml solution volumes respectively) produced significantly smaller tubers, roughly 2 ounces smaller than the other treatments. These same treatments produced a significantly smaller percentage of bonus tubers. No hollow heart was detected in this trial.

Table 4. Effect of GA solution volume on tuber density, number, and size.

Trt #	Treatment	Specific Gravity	Percent Total Solids	Tuber Number per Plot	Average Tuber Size	Percent Bonus Tubers
1	GA @50 mL/100 kg of seed	1.092	23.5	359.4	10.7 a	66.0 a
2	GA @125 mL/100 kg of seed	1.091	23.4	420.9	8.9 b	54.9 b
3	GA @200 mL/100 kg of seed	1.094	24.0	394.1	8.8 b	54.2 b
4	Sham with water @125 mL/100 kg of seed	1.095	24.3	360.8	10.6 a	64.1 a
5	Untreated check	1.094	23.9	363.1	10.7 a	70.1 a
Probability		0.6310	0.6336	0.3403	0.0164	0.0153
CV%		0.4	3.9	12.8	9.0	26
LSD (0.05)		NSD	NSD	NSD	1.4	10.0

The Effect of Gibberellic Acid on the Performance of Progeny Tubers

Principal Investigator: Blair Geisel, Gaia Consulting Ltd.

Funding and support: Keystone Vegetable Producers Association.
Midwest Food Products Inc.
McCain Foods Ltd.
MCDC

Objective: To determine the effect of Gibberellic acid (GA) on the performance (yield and grade) of progeny tubers.

Abstract

Gibberellic acid (GA) is a naturally occurring plant hormone, which is used to modify plant growth in the fruit and vegetable industry. Previous research in Manitoba has demonstrated that applying a 10-15 ppm GA solution at a rate of 150 ml/100 kg of seed will increase tuber number and decrease the tuber size profile by 20-30% in Shepody potatoes. This effect would be a real advantage for seed growers as it is generally accepted that tubers used for seed should be 8 oz in weight or less. Oversize seed tubers result in many cut-seed pieces that are too large or too small. Small seed pieces produce weak, unproductive plants. An application of GA will increase the premium seed yield. It is important to know however if GA carries over into the progeny tubers and affects the performance of those tubers.

GA treated seed from 2002 was grown out in 2003. No differences were found in the progeny tubers for stand, yield, or quality. Initial testing indicates that GA can be used to produce a more desirable tuber size profile without negatively affecting the performance of the daughter tubers.

Methods

Shepody potatoes were planted May 12 at MCDC-Portage la Prairie (Neuhorst clay loam), using a 1-m row spacing and 30-cm in-row seed piece spacing. Plots were 1 row by 12 m long, laid out in a randomized complete block design with four replicates. They were top-killed October 1 and harvested the next day. Gibberellic acid had been applied to the potato seed planted in 2002, at 5, 10 and 15 ppm, and the progeny collected to plant in 2003 to determine if there is an affect on yield and grade.

Assessments included:

1. Stand counts in 12 m of row at 20, 25 and 35 days after planting, and a stem count at 35 days after planting.

2. Yield (total, marketable, undersize) tuber profile (0-2 oz, 2-6, 6-10, and >10oz), grade (hollow heart, specific gravity) and total tuber count.

Table 1. Treatments - GA seed trial.

Trt. #	Treatment	Parent GA Concentration (ppm)	Rate of active (μg ai/100 kg)
1	Untreated check	0	
2	Sham – sprayed with water	0	
3	Gibberellic acid	5	750
4	Gibberellic acid	10	1500
5	Gibberellic acid	15	2250

Results and Discussion

Stand and Stem Counts

There were no significant differences in the number of plants or stems between the GA treatments, the check and the sham (Table 2).

Table 2. Effect of gibberellic acid treatment on potato progeny stand and stem number.

		Stand Count					Stem Count			Stems per
Trt #	Treatment	27 DAP	30 DAP	35 DAP	38 DAP	42 DAP	35 DAP	38 DAP	42 DAP	Plant
1	Untreated check	13.25	26.25	35.50	37.75	37.75	68.50	72.25	72.25	1.9
2	Sham	11.00	23.50	36.25	38.25	38.25	68.75	72.25	72.25	1.9
3	GA @ 5 ppm	14.25	26.00	36.50	38.75	38.75	73.75	76.50	76.50	2.0
4	GA @ 10 ppm	8.00	18.00	35.75	36.50	36.50	66.75	73.00	73.00	2.0
5	GA @ 15 ppm	9.25	20.50	37.75	39.50	39.50	75.75	75.50	75.50	1.9
Probability		0.4936	0.1216	0.6857	0.0641	0.0641	0.1610	0.5133	0.5133	0.3248
CV %		49.62	20.72	6.36	3.43	2.01	7.72	6.54	5.75	4.21
LSD (0.05)		NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD

NSD = No Significant Difference

Yield and Grade

There were no significant differences between treatments for total yield or for yield of any of the grade categories (Table 3). Yields were very consistent between treatments, all were 400+ cwt/ac.

Table 3. Effect of gibberellic acid treatment on potato progeny yield and grade.

Trt #	Treatment	0 - 2 oz (cwt/ac)	2 - 6 oz (cwt/ac)	6- 10 oz (cwt/ac)	>10 oz (cwt/ac)	Total (cwt/ac)	Premium seed 2- 10 oz (cwt/ac)
1	Untreated check	2.3	39.6	94.3	272.7	408.9	133.9
2	Sham	2.4	41.0	112.6	270.7	426.6	153.5
3	GA @ 5 ppm	1.9	34.9	98.0	304.4	439.2	132.9
4	GA @ 10 ppm	2.0	40.4	119.1	279.2	440.7	159.5
5	GA @ 15 ppm	3.0	46.7	135.2	254.5	439.4	181.9
Probability		0.6953	0.6101	0.3345	0.8030	0.6377	0.3480
CV%		48.1	24.9	26.3	20.7	7.8	24.0
LSD (0.05)		NSD	NSD	NSD	NSD	NSD	NSD

Tuber Characteristics

There were no differences between treatments for tuber number, size, specific gravity or percentage hollow heart (Table 4).

Table 4. Effect of gibberellic acid treatment on potato progeny tuber, number, size, specific gravity and percentage hollow heart.

Trt #	Treatment	Specific Gravity	Percent Total Solids	Tuber Number per Plot	Average Tuber Size	Percent Bonus Tubers	Percent Hollowheart
1	Untreated check	1.092	23.5	204.7	9.7	65.3	0.0
2	Sham	1.092	23.5	221.2	9.3	63.5	7.2
3	GA@5 ppm	1.092	23.6	202.3	10.6	68.9	0.0
4	GA@10 ppm	1.092	23.5	207.4	10.3	63.4	4.9
5	GA@15 ppm	1.095	24.2	235.4	9.0	57.7	0.0
Probability		0.4877	0.4899	0.2792	0.3809	0.5724	0.2491
CV%		0.3	2.7	10.9	12.7	14.6	226.1
LSD (0.05)		NSD	NSD	NSD	NSD	NSD	NSD

Potato Virology Projects

Impact of Seed Source, Host Crops and an Early Warning System on PVY Disease Management in Potato

Investigators: D.L. McLaren, Agriculture and Agri-Food Canada - Brandon Research Centre
R.P. Singh, Agriculture and Agri-Food Canada Potato Research Centre (Fredericton)
R. Mohr, Agriculture and Agri-Food Canada - Brandon Research Centre
T. Shinners-Carnelley, Manitoba Agriculture, Food and Rural Initiatives (Carman)
Brent Elliott, Manitoba Agriculture, Food and Rural Initiatives (Carman)

The study was arranged in a randomized complete block design with three potato cultivars - Russet Burbank, Norland, and Shepody. Each treatment involved one row of virus-infected tubers planted in the middle of six healthy rows of the same variety. The treatments were replicated four times and there were a total of 12 plots in the study. Data collection included collection of tubers from the healthy rows over a number of sampling dates to assess time and spread of infection, assessment of aphid numbers and species within the area (traps) and assessment of potato leaves, within predetermined locations within each plot, for aphids. Other aspects of this study involving seed source and host crops were conducted at locations other than MCDC. Assessment of materials for viruses using RT-PCR is ongoing.

Symptomatology of Potato Viruses on Commonly Grown Cultivars - Demonstration

Investigators: D.L. McLaren, Agriculture and Agri-Food Canada - Brandon Research Centre
R.P. Singh, Agriculture and Agri-Food Canada Potato Research Centre (Fredericton)
T. Shinners-Carnelley, Manitoba Agriculture, Food and Rural Initiatives (Carman)
Brent Elliott, Manitoba Agriculture, Food and Rural Initiatives (Carman)

To illustrate symptoms of potato virus Y (PVY) and potato leafroll virus (PLRV) on different potato varieties, infected tubers of Russet Burbank, Shepody, and Ranger Russet potatoes were planted alongside rows of healthy tubers. The combination of healthy and virus-infected material of potato varieties was surrounded by a wheat crop border. Both a pan and suction trap were located within the study. Aphids were collected weekly from the pan trap but the suction trap was used for demonstration purposes only. Material was also collected from this trial to provide additional information on time of virus spread. Assessment of materials for viruses using RT-PCR is ongoing.

Use of Soil Moisture Probes (C-Probe) for Irrigation Scheduling and Soil Moisture Monitoring in Potato Fields at MCDC

Principal Investigator: Brian Wiebe, Agrometeorological Centre of Excellence (ACE)

Co-Investigators: Bill Moons, Manitoba Agriculture and Food
Les Mitchell, Clayton Jackson, and Gerald Loeppky; MCDC

Funding: ACE

Objective: To demonstrate use of soil moisture probes (c-probe) for irrigation scheduling and soil moisture monitoring in potato fields

During the 2003 growing season, each MCDC site designated locations for side-by-side demonstrations of potato grown under irrigated and rainfed conditions. The varieties used were Ranger Russet at Carberry, and Russet Burbank at the Portage la Prairie and Winkler sites. At each location two C-probe™ soil moisture probes (with rain gauges) were installed in a potato row, one under irrigation and the other in the rainfed portion of the demonstration area.

The C-probes each had four sensors, located at 10, 20, 30, and 50 cm below the top of the hill, and were therefore measuring soil moisture content of the 5-15 cm, 15-25 cm, 25-35 cm, and 45-55 cm depths respectively. The C-probes were connected to telemetry units which collected soil moisture readings and transmitted 15-minute average values back to the base computers at the ACE office in Carmen. MCDC computers at Carberry and Portage la Prairie were set up to access the data and Bill Moons and Brian Wiebe periodically checked the data and assisted MCDC staff in interpreting the results.

The slope of the soil moisture lines (Figures 1, 2, and 3) indicate the rate of crop water use. Changes in the slope suggest either a change in availability of soil water or a change in demand by the crop (changes due to crop stage, canopy development, and weather conditions).

Under rain-fed conditions (Figure 1), water use was slowing by June 20 as the crop had to go deeper and deeper into the profile for water. By July 4, most of the crop's water needs were being supplied from below 35 cm and by mid-July the profile contained little available water to 55 cm.

The irrigated plot (Figure 2) also shows water use from the 50 cm depth in early July indicating that the crop is beginning to undergo stress. Regular irrigations followed and were able to prevent further water stress during the season but were unable to refill the profile until assisted by rain in late August.

The summed graph (sum of each of the sensor values) for the MCDC Portage la Prairie plot shows how water use (slope) changes with reduced water supply and can be used as an indicator of water stress (Figure 3). The horizontal "refill point" line is assigned by looking at these slope changes and the irrigation trigger is then set so that the soil moisture content does not reach this line.

The C-Probes were able to give a clear picture of changes in soil moisture during the season and as a result were helpful in timing of irrigations. Observing the rate of change of soil moisture allowed us to anticipate when the soil was approaching the refill point and get the irrigation on in time.

Figure 1. Rainfed - MCDC-Carberry. Potato crop is experiencing water stress by early July as it is meeting most of its water needs from below 30 cm.

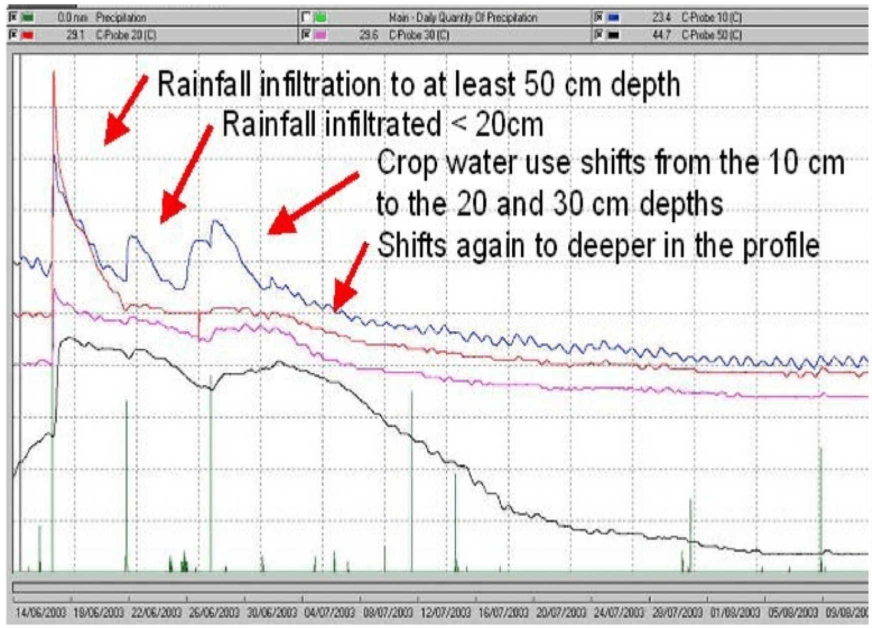


Figure 2. Irrigated potato - MCDC-Carberry.

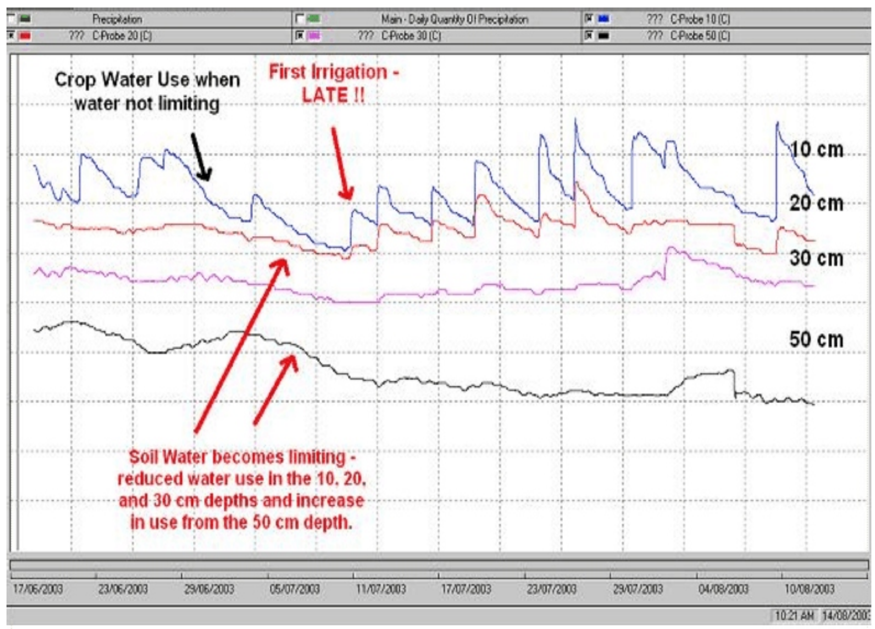
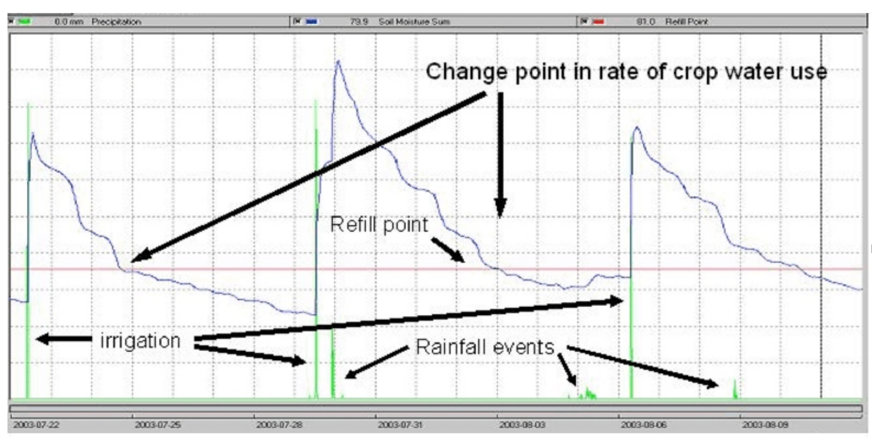


Figure 3. Irrigated potato - MCDC-Portage la Prairie. Summed graph of all C-Probe sensors shows reduction in crop water use below the assigned refill point.



Potato Diagnostic School

A Potato Diagnostic School was held at MCDC-Carberry on August 13 and 14, 2003. It was a cooperative effort between Manitoba Agriculture and Food (MAF) and MCDC. Participants were presented with information and in-field demonstrations in each of the following sections during the one-day event held on successive days (presenters and topics indicated):

Diseases (D. McLaren, Agriculture and Agri-Food Canada; N. Selvanathan and P. Northover, MAF)
- virus identification and management, sanitation to control spread of bacterial diseases, disease scouting and ID, and Early Dying Complex

Crop Management (B. Moons, MAF)
- seed size, physiological maturity of seed, water management and nitrogen management

Weeds (B. Hunt, MAF)
- herbicide carryover, application at ground crack, use of Sencor on Shepody potatoes, vine killing options, and spray drift

Insects (B. Elliott, MAF)
- Colorado Potato Beetle thresholds, % defoliation, timing of reduced risk chemistry, conventional chemistry, scouting and identification of potato insects

Soil Fertility (J. Heard, MAF)
- plant nutrition, fertilizer placement, diagnosis of deficiencies and fertilizer toxicity

Soil Management (C. Cavers, MAF)
- wind erosion control, salinity control and management

Potato Variety Development (D. Lynch, Agriculture and Agri-Food Canada)
- new processing varieties

The 2003 Potato Diagnostic school was attended by 120 people from many levels of the potato production industry. Feedback was very positive. Plans are underway to hold the event on a bi-annual basis.

Other Crops and Projects

Manitoba Oriental Vegetable Production and Marketing Evaluation Project

Principal Investigator: Anthony Mintenko, MB Agriculture, Food and Rural Development

Co-Investigators: Danny Bouchard, MCDC
Gerald Loeppky, MCDC

Project Support: Manitoba Rural Adaptation Council
Covering new Ground
Manitoba Agriculture and Food and Rural Initiatives
MCDC
T&T Seeds
Garden Market IGA

Progress: Ongoing study

Objective: To evaluate the agronomic and market potential of selected Oriental vegetable crops and varieties for irrigated commercial production under Manitoba conditions.

Methods

The study used a three-acre field site at MCDC-Portage la Prairie. It consisted of four main areas of study: variety screening and evaluation, testing of organic pest control products, testing the effects of mulch on produce quality and yield, and consumer market testing of harvested produce.

Variety trials were conducted with 26 varieties of nine crops: bok choy, cabbage, cucumber, watermelon, muskmelon, baby corn, carrots, daikon and snow peas.

Four products (BTK, End-All, Tombstone, and Success 480SC) were tested for their effectiveness in controlling pests on bok choy, gai lon, eggplant, and cabbage.

Four colours of plastic mulch (solar, black, green, and red) were tested on watermelon, muskmelon, cucumber, and peppers.

Produce harvested from the various trials was delivered to the local Garden Market IGA, where staff evaluated the produce and included it in their in store displays.

Results

Preliminary results showed improved yields using mulch with the pepper, watermelon, and muskmelon crops. Many of the variety trials showed considerable differences in yields among varieties for this field season, such as the cucumber and daikon varieties. The alternative pest control trial showed better results using the new registered insecticide Success 480SC, especially with the eggplant crop. However, flea beetle and potato beetle infestations were very high again this summer, causing significant damage to the bok choy crop.

Consumer acceptance of the cabbage was over whelming. They cited the large leaves and a sweeter taste as the characteristics they liked. Some watermelon varieties could not be displayed in the store because of their rapid deterioration in storage. Hot bell peppers were considered a favourite of the Mexican seasonal workers.

Pulse Crop Pathology Projects

These projects were conducted by Agriculture and Agri-Food Canada - Morden Research Station. The data from these studies will be used to support the registration of new disease control products and in the development of new recommendations for reducing losses in dry beans caused by white mould, common bacterial blight, and anthracnose.

<u>Projects carried out at MCDC-Portage la Prairie</u>

Impact of Seed Size on Agronomic, Disease and Quality Traits in Field Pea (*Pisum sativum*)

Investigators: R.L. Conner, D.W. McAndrew, and D.J. Bing

The effect of sorting for seed size on the performance of four field pea cultivars was examined in a randomized complete block design that contained twelve treatments that were replicated four times.

Anthracnose Seed Infection Trial

Investigators: R.L. Conner, D.W. McAndrew, and Mr. F.A. Kiehn

Seed lots containing either healthy seed or 10% anthracnose infected seed of six different cultivars was tested in wide and narrow plots. The study was arranged in a split-plot design that used row spacing as the main treatments and cultivar/seed infection rate as the subplot treatments. The treatments were replicated four times and there was a total of 96 plots in this study.

Effect of Seed Infection on the Rate of Anthracnose Transmission to Bean Seedlings

Investigators: R.L. Conner, D.W. McAndrew and Mr. F.A. Kiehn

Examined the effect of six rates of seed infection (i.e., 0-20%) in two dry bean cultivars on anthracnose development, yield and seed quality. The experiment consisted of 12 treatments that were arranged in a randomized complete block design with four replications.

Seed Treatment to Control Anthracnose in Dry Beans - Gustafson

Investigator: R.L. Conner.

Four experimental seed-treatments, an untreated check, and the registered seed-treatment product DCT were evaluated for their effectiveness in reducing seedling infection and the subsequent spread of bean anthracnose, and in controlling losses in seed yield and quality. The experiment was arranged in a randomized complete block design with four replications.

Efficacy of Quadris Against Anthracnose of Field Beans - Syngenta

Investigator: R.L. Conner.

Five foliar fungicides applied at either the early- or late-bloom stage were evaluated for their efficacy in reducing the spread of bean anthracnose and in preventing seed yield and quality losses caused by this disease. The experiment consisted of eight treatments replicated four times.

Projects carried out at MCDC-Winkler

White Mould of Bean Forecasting Study

Investigators: R.L. Conner (Morden) and D.L. McLaren (Brandon Research Centre)

The effect the timing of single or split applications based on crop stage or a computer forecasting system was evaluated. Seven treatments were replicated four times. Separate experiments with the bean cultivars Envoy and NW63 were carried out.

Biocontrol of White Mould in Field Bean Using *Coniothyrium minitans*

Investigators: R.L. Conner (Morden) and D.L. McLaren (Brandon Research Centre)

The effectiveness of single or split applications of the biocontrol agent *C. minitans* and the fungicide Ronilan in controlling white mould in dry beans was compared. The experiment consisted of six treatments replicated four times.

Calcium Products and Fungicides to Control White Mould in Dry Beans

Investigators: D.W. McAndrew and R.L. Conner

The effect of different calcium products was tested alone and in combination with different fungicide and bactericide treatments to determine their effectiveness in controlling white mould and common bacterial blight in dry beans. The experiment included ten treatments which were replicated four times.

Fungicide and Cereal Silage Demonstrations at MCDC-Portage la Prairie

Fungicides on Canola (MCDC and Manitoba Agriculture, Food and Rural Initiatives)

An eight acre block of Liberty Link 2553 canola was seeded at a rate of 5 lbs/ac on May 15. Fertilizer had been applied pre-plant at 45-40-0-1.5 lbs/ac (actual N-P_2O_5-K_2O-S). Liberty and Poast were applied for weed control. The field was divided into six equal sized areas and fungicide treatments indicated below were applied. Treatments were not replicated.

Fungicide	Time of application	Yield (lb ac^{-1})
Check		1513
Benlate	20-30% flowering	1546
Quadris	20-30% flowering	1706
Ronilan EG	20-30% flowering	1538
Ronilan EG	20-30% flowering + 7 days later	1226
Rovral Flo	20-30% flowering	1349

Fungicides on Navy Bean (MCDC and Manitoba Agriculture, Food and Rural Initiatives)

An eight acre block of Envoy navy beans was planted at a rate of 40 lbs/ac on May 21. For weed control, the area was treated with Treflan prior to planting, and with Basagran +Reflex and Poast Ultra post-emergent. The field was divided into seven areas and fungicide treatments indicated below were applied. Treatments were not replicated.

Fungicide	Time of application	Yield (lb ac^{-1})
Check		1891
Headline	beginning of flowering	2076
Parasol	12' plant height + 7 days later	2025
Ronilan EG	30% flowering	1942
Ronilan EG	30% flowering + 7 days later	2064
Ronilan EG	70% flowering	1917
Senator 70WP	early flowering	2013

Fungicides on Spring Wheat (MCDC)

An eight acre block of AC Barrie wheat was seeded at a rate of 90 lbs/ac on May 5. Fertilizer had been applied pre-plant at 45-40-0-1.5 lbs/ac (actual N-P_2O_5-K_2O-S). For weed control, the area was treated with Puma Super and Refine Extra post-emergent. The field was divided into five equal sized areas and fungicide treatments indicated below were applied. Treatments were not replicated.

Fungicide	Time of application	Yield (lb ac^{-1})
Check		3152
Dithane	tillering + flag leaf	3189
Folicur	flowering	3356
Headline	late flag leaf	3137
Tilt	flag leaf	3232

Cereal Silage (MCDC, John Douma, and Manitoba Agriculture, Food and Rural Initiatives)

An eight-acre block of land was divided into nine equal sized areas and the crops indicated below were seeded on May 14. Fertilizer had been applied pre-plant at 45-40-0-1.5 lbs/ac (actual N-P_2O_5-K_2O-S). For weed control, the barley and triticale were sprayed with Puma Super and Refine Extra, and the other crops were sprayed with Refine Extra. The plots were cut for silage at the late milk to early dough stage of the seed maturity. The total silage harvested from each variety was weighed. Three square-metre samples were cut from each variety prior to harvest, and used for determination of moisture content. Treatments were not replicated.

Crop/variety	Yield (tonnes ha^{-1})
Barley - Robust	3582
Barley - Virden	6367
Millet	8076
Oats - AC Ronald	6571
Oats - Assisiniboia	5828
Oats - Boudrias	7051
Sorghum	6758
Triticale - Sandro	5547
Triticale - Standswell	4557

Cereal Research Centre Activities at MCDC-Portage la Prairie

Principal Investigators: Doug Brown, CPS wheat
Gavin Humphreys, Extra strong wheat
Jennifer Mitchell Fetch, Oats
Jim Bole, Director, CRC

The relationship between the Agriculture and Agri-Food Canada Cereal Research Centre (Winnipeg, Manitoba) and the Portage site of MCDC that has been ongoing for many years continued in 2003. Early generation screening nurseries and advanced line yield trials of wheat of various classes (Hard Red Spring, Canada Prairie Spring, and Extra Strong wheat) plus oats were tested. Approximately eight acres were planted to yield trials.

Early generation hills and rows planted in a six acre nursery were screened for leaf rust, stem rust, bunt or smut and Fusarium Head Blight. This entire nursery was inoculated with economically important, locally occurring strains of these diseases. To provide an environment conducive to infection, the nursery was misted with frequent light irrigations. Although much of the breeding material was susceptible to one or more of the diseases, many lines were identified as having complete resistance plus good agronomic appearance; these lines were harvested for additional future testing.

Morden Research Centre Trials at MCDC-Portage la Prairie and MCDC-Winkler

Principal Investigators: F. Kiehn, dry bean agronomist
D. Bing, pulse breeder
C. Campbell, buckwheat breeder

Seven yield trials of late generation seed selections of field beans were grown at the Portage la Prairie and Winkler sites of MCDC. The trials were of randomized complete block design. The lines in the trials were monitored for their agronomic suitability, yield potential, and seed quality. The information collected was used to recommend cultivars for production in the respective regions of the province.

One soybean co-op yield trial was grown at Portage la Prairie. The lines in the trial were selections coming out of the breeding program at the Central Cereal Research Centre in Ottawa. The agronomic information collected was used to recommend cultivars for production in the Portage la Prairie area of the Province.

Two buckwheat yield trials were grown at Portage la Prairie. The lines in the trials were selections coming out of the breeding program at the Morden Research Centre. The agronomic information collected was used to recommend cultivars for production in the Portage la Prairie area of the Province.

Forage Crops Demonstration at MCDC-Portage la Prairie

This demonstration was established in cooperation with Manitoba Agriculture and Food. It included varieties of the following forage species:

Alfalfa	Italian ryegrass	Reed canarygrass
Annual ryegrass	Meadow bromegrass	Slender wheatgrass
Birdsfoot trefoil	Orchardgrass	Tall fescue
Dahurian wild ryegrass	Red clover	Timothy

Herbs, Nutraceuticals, and Fruit Crops

The garden area at MCDC-Carberry demonstrated the following plants in 2003.

Herbs, Spices, Nutraceuticals

Angelica	Grain Amaranth	Pyrethrum	Summer Savory
Chamomile	Horehound	Red Clover	Sweet Basil
Chives	Hyssop	Rosemary	Tarragon
Comfrey	Lavender	Roses	Triple Curled Parsley
Echinacea	Lovage	Rue	Valerian
Elecampane	Monarda	Spearmint	Wild Chicory
English Thyme	Oregano	St. John's Wort	Wormwood
Garden Sorrel	Parsley	Stinging Nettle	Yarrow

Fruits and Vegetables

Apple	Chokecherry	Eggplant	Raspberry	Snow Pea
Apricot	Corn	Jalapeno Pepper	Red Currant	Tomato
Asparagus	Crab Apple	Onion	Rhubarb	Watermelon
Black Currant	Cranberry	Pear	Saskatoon	Yellow Melon
Cherry	Daikon	Plum	Shen Ji Pepper	Yellow Melon

Crops Grown in the Production Areas of MCDC 2002

The following crops were grown in the field scale production areas of MCDC sites in 2003:

Portage la Prairie:	barley (Robust)	Carberry:	CWRS wheat (CDC Bounty)
	navy bean (Envoy)		potato (Ranger Russet)
			canola (InVigor 2663)
Winkler:	barley (Robust)		

Agriculture and the Sustainability of Water Quality in the Assiniboine Delta Aquifer

Principal Investigator: Lorry Broatch, MCDC

Support: Sustainable Development Initiative Fund
MCDC

Progress: Ongoing

Objective: To monitor the quality of water in the Assiniboine Delta Aquifer (ADA) with respect to potential contaminants that may be associated with intensive field crop production.

The Assiniboine Delta Aquifer (ADA) is a classic unconfined sand aquifer of glacial origin covering a land area of almost 3,900 km^2 centred around Carberry. Depth to the water table varies from 0 to more than 20 m, with an average saturated thickness of 18 m. The major land uses associated with the ADA region are cropland and improved forage land (46%), grassland (27%), and forest (21%), with other land uses accounting for less than 10%. Approximately 39% of the total land area over the aquifer is rated excellent or good for irrigation. However, much of the same land is also considered environmentally sensitive due to the predominance of well-drained coarse-textured surface deposits. The combination of an unconfined aquifer underlying coarse-textured material with agricultural land use creates the potential for aquifer contamination.

Methods

The MCDC ADA monitoring project has been conducted each year since 1994 as an important element of the Centre's commitment to environmentally sustainable agriculture. In the spring of 1994, prior to irrigation development, the soil, soil water and groundwater was sampled and analyzed for pesticide and nitrate concentrations to establish baseline conditions at the MCDC-Carberry site. Since then, sampling and analysis of these media have been done to determine the presence and concentration of these compounds. Production of irrigated potatoes in a three-year rotation has been practised on the site. An off-site network of monitoring wells has also been sampled and analyzed for nitrate and pesticide concentrations. This report updates the more comprehensive reports for this project contained in previous MCDC Annual Reports. Soil water analysis was discontinued after 1995, and soil sample analysis for pesticides after 1999. No soil sampling and analysis was included in the 2003 program.

In 1994, five monitoring wells were installed prior to MCDC commencing operations (Figure 1). The wells were sampled in the spring and fall of 1994 and analyzed for nitrate and a wide range of pesticides. In August 1995 regular monthly sampling and analysis for nitrate was initiated. Three off-site wells (MW-A, B, and C; Figure 2) were included in the program and sampled regularly for nitrate and annually in the fall for pesticides. On-site monitoring wells are numbered (e.g. MW-1) and off-site monitoring wells are lettered (e.g. MW-A). The off-site program was expanded in the spring of 1996. Monitoring wells were installed at four more locations (MW-D, E, F and G). Wells MW-A, B, C, D and F are located adjacent to irrigated fields, while wells MW-E and G are located in non-agricultural areas. In the spring of 1998, MW-H was installed in a field that was going to be irrigated for the first time. All the monitoring wells are completed into the aquifer with 1.5 m of screen set to sample the top 1.5 m of the aquifer (Figure 3), the portion of the aquifer most susceptible to contamination. Each well has a dedicated inertial pump for sampling purposes.

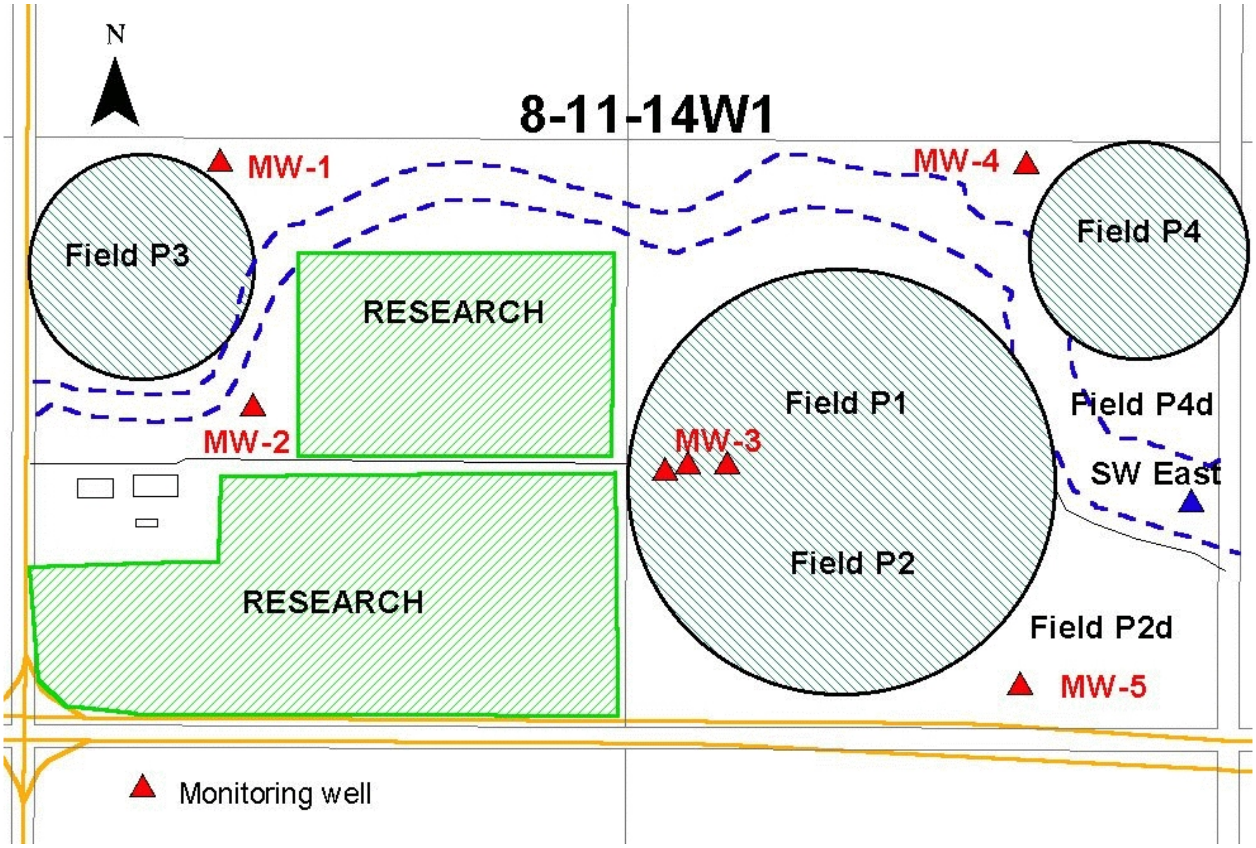


Figure 1. Field layout and groundwater monitoring well locations at MCDC-Carberry.

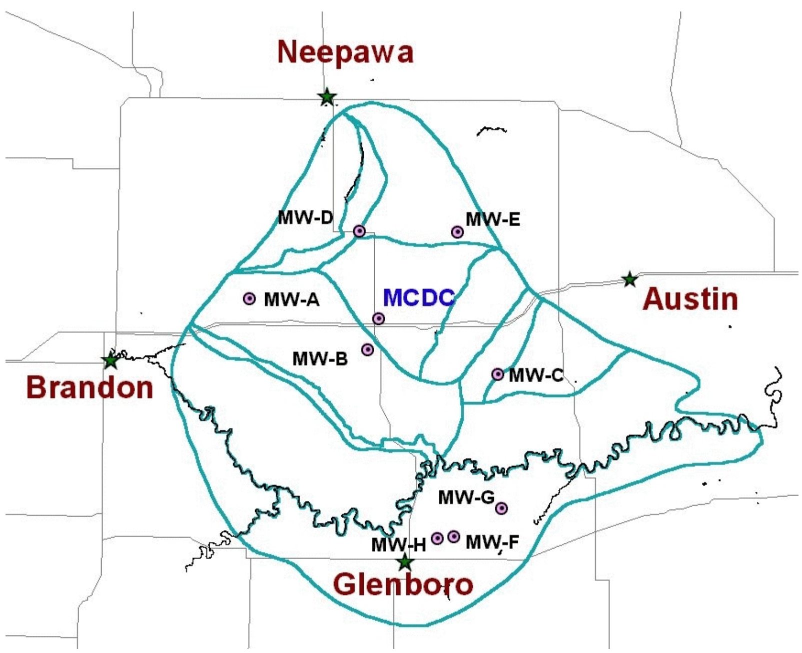


Figure 2. Off-site monitoring well locations.

Two additional monitoring wells were installed adjacent to both MW-3 on-site, and MW-F off-site, in the fall of 1997 and the spring of 1998 respectively. These additional wells were installed to determine the variation of nitrate at depth in the water bearing layer. These wells sample from a depth 1.5 to 3 m below water table and from 3 to 4.5 m below water table. The monitoring wells are all sampled and analyzed for nitrate on a regular basis.

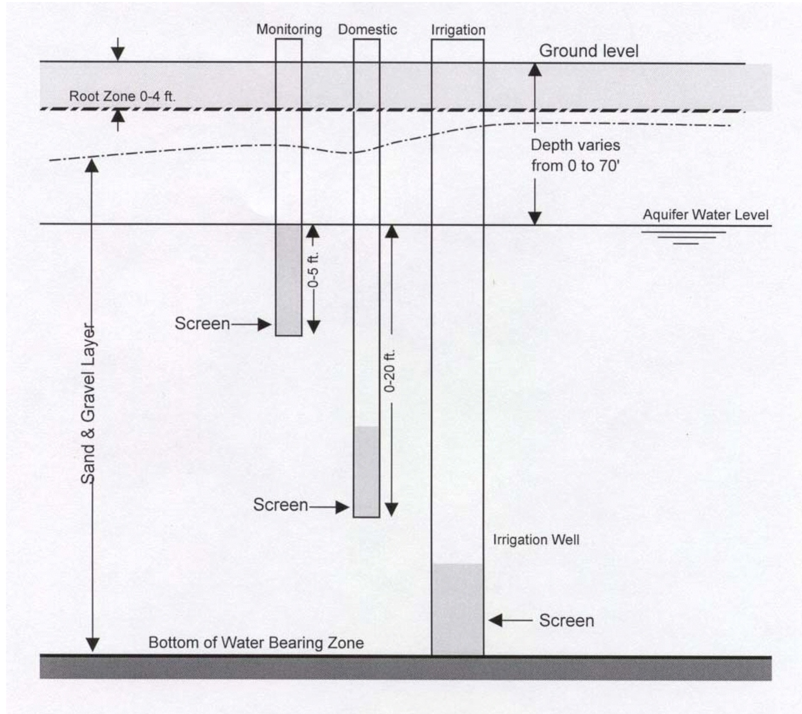


Figure 3. Typical monitoring well construction.

Results and Discussion

Groundwater flows in the MCDC area tend to be in a southwesterly direction.

Monitoring wells MW-1 and MW-4 were located near the north boundary of the MCDC site to indicate the quality of groundwater entering the site. Nitrate concentrations of slightly above the Maximum Acceptable Concentration (MAC) of 10 mg l^{-1} NO_3-N have been steady in both these wells since 1994 (Figure 4). However in June of 2001 nitrate concentrations in MW-4 began to climb, peaking at approximately 98 mg l^{-1} NO_3-N in April of 2002.

The three nested wells, MW-3A, 3B and 3C, sampling the top 1.5m, from 1.5 - 3.0m and from 3.0 - 4.5m depths initially showed a nitrate distribution thought to be typical of an unconfined sand aquifer. Due to limited vertical mixing, nitrate concentrations decreased quickly with depth. However, over the next few years the results from these wells varied widely with nitrate concentrations at the 1.5 to 3.0m depth being higher than that at a shallower depth (Figure 5). This may could partially be the result of the proximity of the wells to each other (<2m apart).

Nitrate concentrations in MW-2 have been steady at or near detections levels while those in MW-5 have shown an increase from below 5 mg l^{-1} NO_3-N at the beginning of the program to a peak of over 18 mg l^{-1} in December of 2002 (Figure 6). Nitrate concentrations in off-site monitoring wells MW-A, B and C have remained relatively stable since 1994. Results from MW-D have shown a constant increase in nitrate concentrations from less than 5 mg l^{-1} NO_3-N in 1996 to a high of over 20 mg l^{-1} NO_3-N in August 2002 (Figure 7).

In 1996 monitoring well MW-F was installed adjacent to a field about to be irrigated for the first time (Figure 8). Prior to 1996 the field had been in a traditional cereal crop rotation. Nitrate concentrations in this well remained stable at slightly above 10 mg l^{-1} NO_3-N until the spring of 1997. Concentrations then began to increase rapidly, peaking at near 40 mg l^{-1} NO_3-N in August of 1997 and decreasing back to near 10 mg l^{-1} by October of 1997. This rapid spiking could be the result of two separate factors. Anecdotal evidence has indicated that it is not unusual for the groundwater beneath a field being irrigated for the first time to show a rapid increase in nitrate concentrations followed by a return to near historic levels. Also, in early July of 1997 the potato crop in this field suffered approximately 90% top kill as a result of an intense rain and hail storm. The possible

Figure 4. Nitrate concentrations in monitoring wells MW-1 and MW-4.

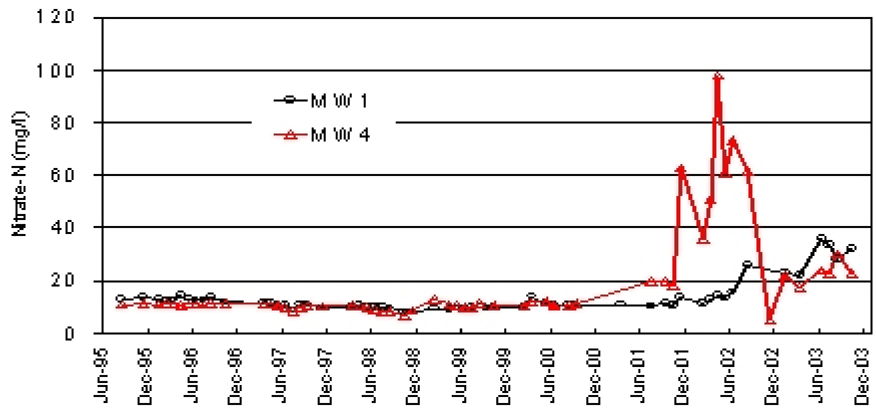


Figure 5. Nitrate concentrations in monitoring wells MW-3A, MW-3B, and MW-3C.

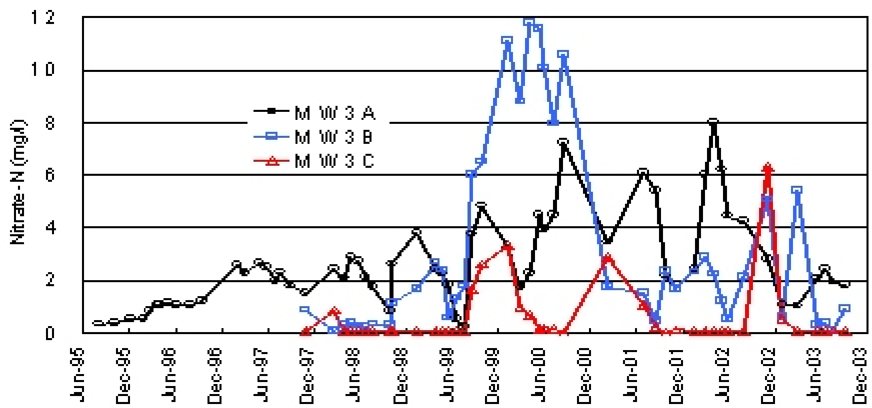


Figure 6. Nitrate concentrations in monitoring wells MW-2, and MW-5.

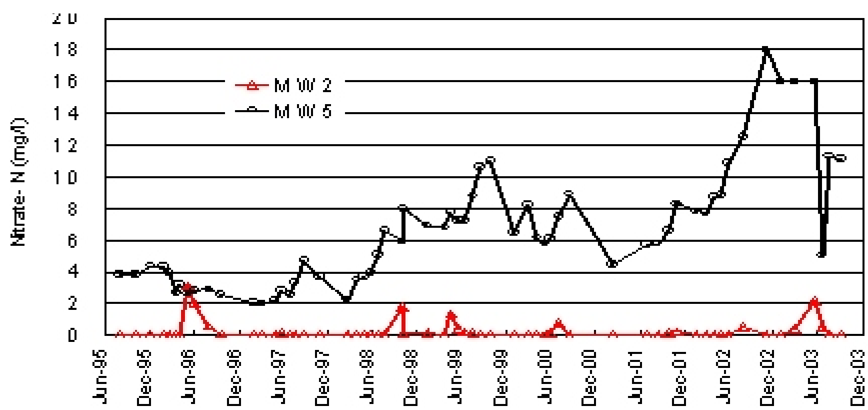
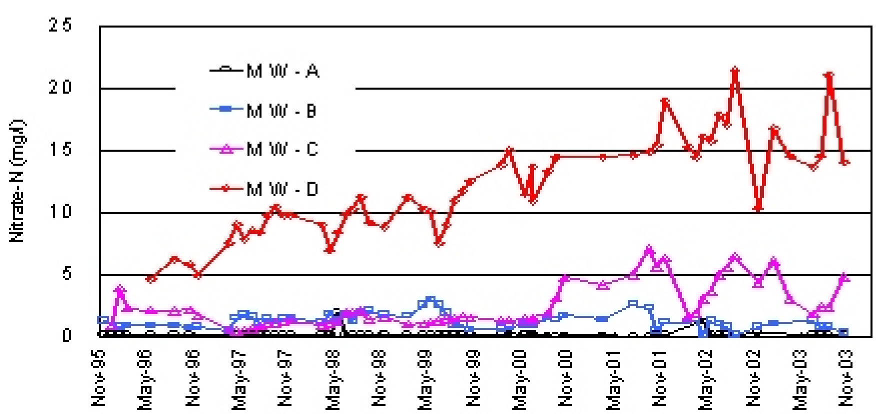


Figure 7. Nitrate concentrations in monitoring wells MW-A, MW-B, MW-C, and MW-D.



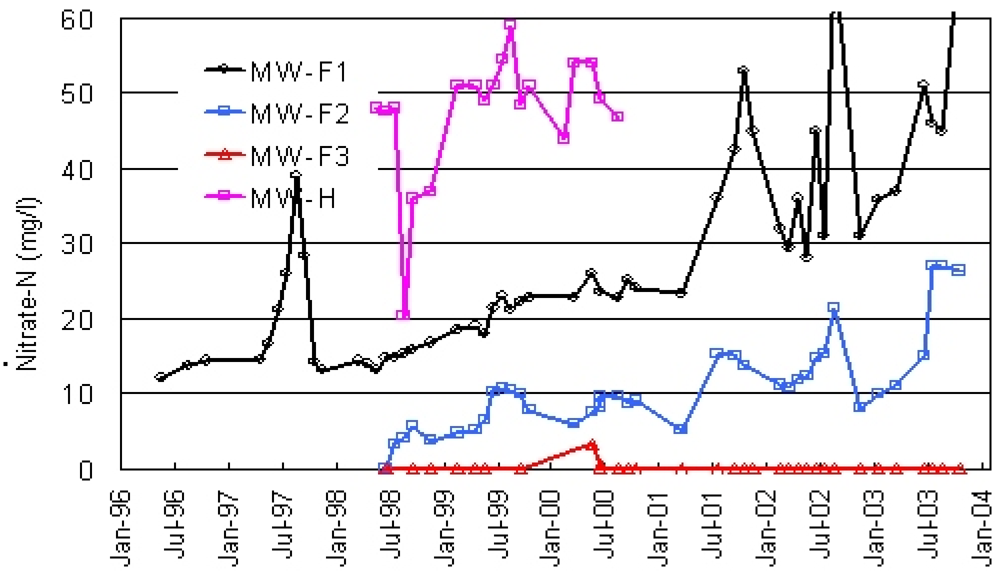


Figure 8. Nitrate concentrations in monitoring wells MW-F1, MW-F2, MW-F3, and MW–H.

flushing of applied fertilizer and the breakdown of organic matter may have had some impact upon nitrate concentrations in this monitoring well.

In 1998 two additional monitoring wells were installed at this site to characterize the vertical distribution of nitrate. Well construction was identical to those installed at MW-3 on-site at MCDC. The results from these nested wells indicate a rapid decrease in nitrate concentrations with depth. At the 1.5 - 3.0m depth average concentrations have typically been half that at the 0 - 1.5m depth and results from the 3.0 - 4.5m depth indicate nitrate concentrations at or near detection level (0.05 mg l^{-1} NO_3-N). In the spring of 1998, MW-H was installed in another field that would be irrigated for the first time (Figure 8). Well construction at this site was extremely difficult due to the grain-size of the formation at this location being very fine (borderline sand/silt). The installed well did not yield good sample volumes because of the length of recovery time after initial pumping. Although nitrate concentrations were relatively high initially (50 mg l^{-1} NO_3-N), it was thought that it may be due to the difficulties in construction and possible contamination of the borehole with organic material from the surface. It was hoped that after repeated sampling concentrations would decrease and stabilize. After a temporary decrease, nitrate concentrations in the well stabilized near 50 mg l^{-1} NO_3-N. Deep soil samples were taken at three locations within the field to determine if nitrates were moving downward through the soil profile into the aquifer. Results of these tests showed typically low levels of nitrate in the soil profile below the root zone. Due to the difficulty in sampling, MW-H was removed and is no longer part of the program.

Monitoring wells MW-E and MW-G, located in non-agricultural areas, have had nitrate concentrations near or below the detection level of mg l^{-1} NO_3-N since the beginning of the program.

The Expanded Groundwater Nitrate Monitoring program was initiated in 2000 to better characterize the magnitude and the distribution of nitrate concentrations in the ADA. The ADA is subdivided into 13 groundwater management sub-basins, with each basin behaving relatively independently. Two representative sub-basins were chosen, the Pine Creek North sub-basin and the Assiniboine River South sub-basin. Twenty-one monitoring wells were constructed in the Pine Creek North sub-basin and 24 wells in the Assiniboine River South sub-basin. The wells were sited such that a third of the wells were located in or adjacent to one of three different land uses, grassland or forages, traditional dry land crop production and irrigated crop production. The wells were constructed similar to those in the original monitoring program, i.e. sampling the top 1.5m of the water bearing layer (Figure 3).

The Pine Creek North sub-basin was sampled in March and May of 2000 and in May and October of 2001and 2002. The Assiniboine River South sub-basin was sampled in May and October of 2000, 2001 and 2002. While results indicate that in most wells the nitrate concentrations are relatively stable, some wells exhibit dramatic fluctuations in nitrate concentrations. The average nitrate-N concentrations in the Pine Creek North and the Assiniboine River South sub-basins are shown in Figures 9 and 10 respectively. The results indicate a relationship between elevated concentrations of nitrate and cultivated land use. However, there is less evidence that increased nitrate concentrations are a result of irrigated crop production specifically.

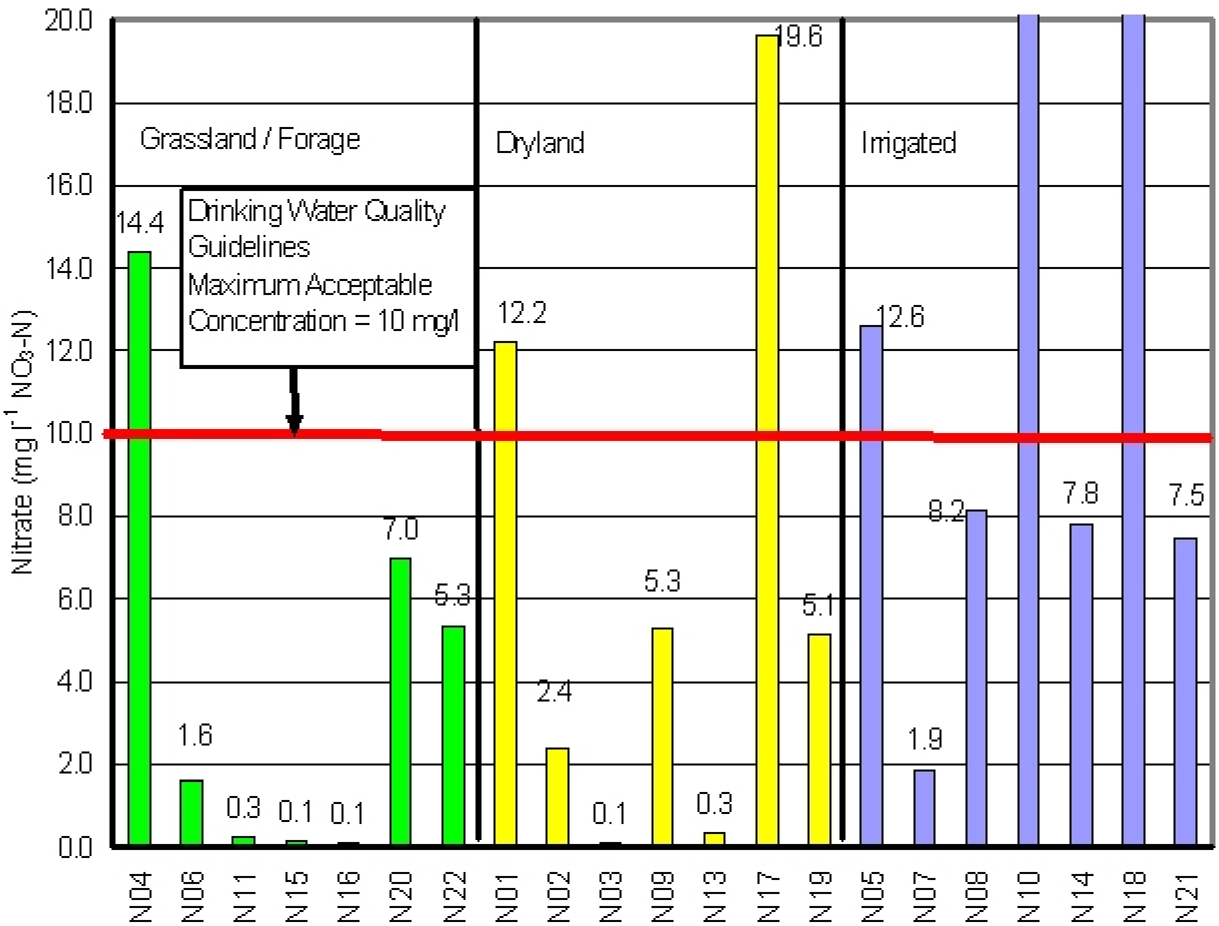


Figure 9. Average nitrate concentrations for Pine Creek North.

Conclusion

The Manitoba Crop Diversification Centre has completed the ninth year of the Assiniboine Delta Aquifer Monitoring Project. On site, soil nitrate concentrations have not had a statistically significant rise from levels determined in 1994. Below the root zone, they are very low, indicating no increase in nitrate leaching due to agronomic practices at the Centre. Ground water nitrate concentrations are relatively stable although there have been several examples of increasing levels. The expanded nitrate program has shown that both irrigated and dryland cropping have impacts upon water quality in the uppermost layers of the water table.

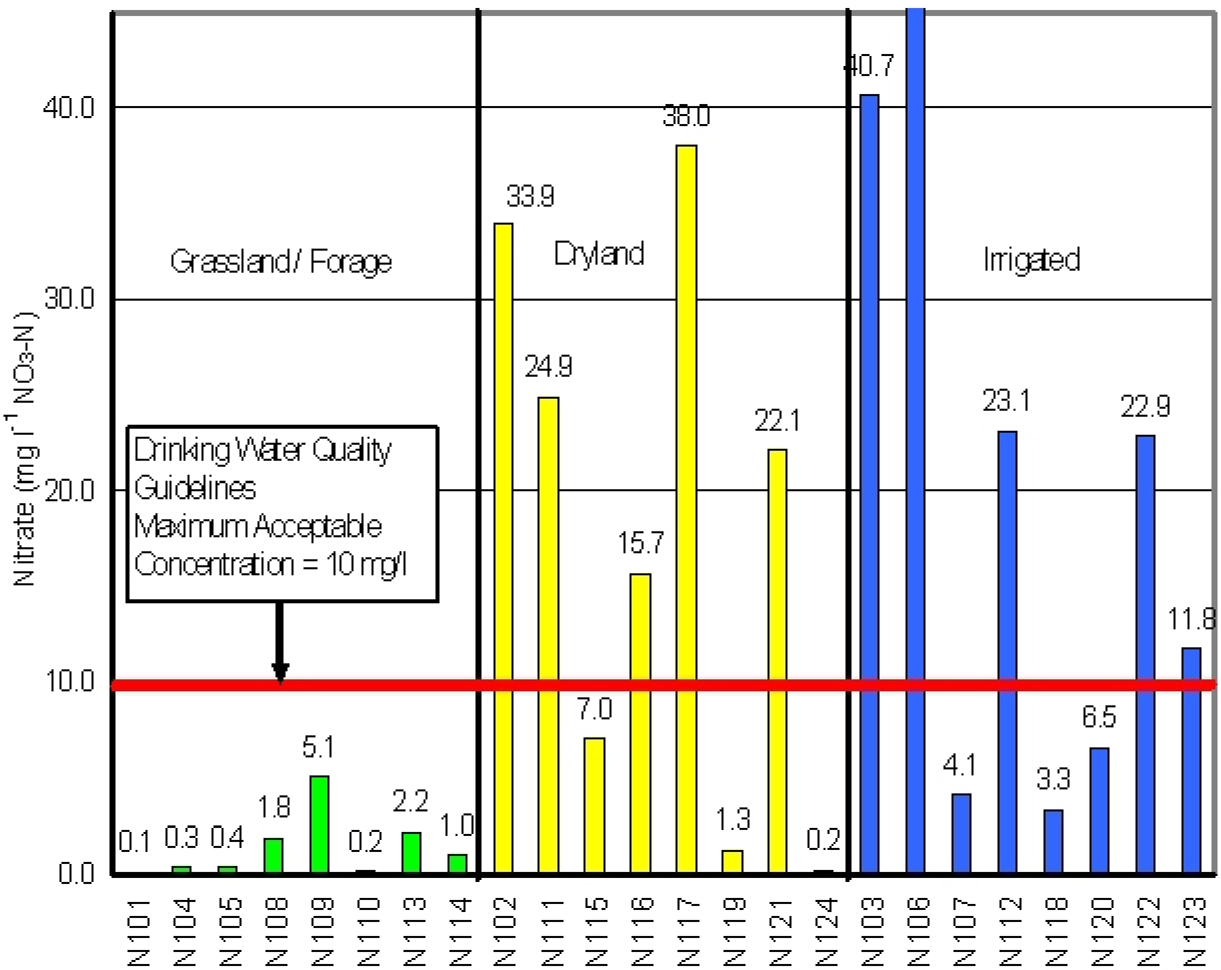


Figure 10. Average nitrate concentrations for Assiniboine River South.