

Phosphorus Management for Irrigated Potato Production in Manitoba

By Ramona Mohr and Dale Tomasiewicz

Results of a set of field experiments evaluating potato response to recommended rates of P fertilizer demonstrated yield benefits in 2 of 4 years, and consistent increases in post-harvest Olsen P levels. Findings suggest that petiole critical nutrient concentrations developed in other potato-growing areas may require regional adaption for Manitoba.

Manitoba has become a major contributor to potato production in Canada, with output of over 12 million cwt of processing potatoes valued at \$97.3 million in 2001. While P is routinely applied to most potato fields in Manitoba, much of the research regarding potato responses to P in Manitoba was conducted in the 1960s. More recently, Geisel (1995) and Tomasiewicz (1994) conducted field trials to assess P response in irrigated potato. In five field trials conducted from 1991 through 1994, Geisel (1995) reported significant yield increases with P application in two of five trials, with yield increases evident only where soil test P levels were less than 40 lb/A. In a one-year study, Tomasiewicz (1994) found no effect of P application on potato yield or quality for a site that, based on the soil P level, would have been expected to respond to P fertilization most of the time. The objective of this study is to determine the effect of recommended rates of P fertilizer on tuber yield and quality, petiole P concentration, and post-harvest Olsen P levels for irrigated processing potato.

Four field experiments were conducted in Manitoba from 2003 through 2006 to assess the impact of P fertilizer rate on irrigated Russet Burbank potato. Field experiments were conducted on Orthic Black Chernozem soils near Carberry in 2003, 2004, and 2005 (pH 5.6 to 6.2) and near Douglas in 2006 (pH 6.8). Sodium bicarbonate extractable P (Olsen P) levels for the 6 in. depth were 43, 24, 34 and 19 lb/A in 2003, 2004, 2005, and 2006, respectively. A randomized complete block design consisting of four replicates of four P fertilizer rates (0, 30, 60, and 90 lb P_2O_5 /A as MAP) was established. Individual plots were typically 52 ft. long, and ranged from 6 to 9 rows wide. Row spacing was 37 in. and within row spacing was typically 15 in. Blanket applications of N, K, and S-containing fertilizers were made as required to ensure nutrients were non-limiting at all sites. Nitrogen applications were adjusted for each P rate to account for N applied in the MAP in order to ensure that all treatments received equal rates of fertilizer N. All pre-plant fertilizer was surface broadcast,



Southern Manitoba P and potato research site, August 2005.

and then thoroughly incorporated. In select years, additional N was top dressed and incorporated at hilling. Potato (cv. Russet Burbank) was planted between late April and late May depending upon the year. Approximately 36 to 39 ft. of the center two rows of each plot were harvested the third week of September each year. Pests were effectively managed and irrigation water applied as required.

In the spring prior to plot establishment, soil samples were collected and the Olsen P concentration determined. Petiole samples were collected at approximately 10 day intervals throughout the growing season. Shortly before tuber harvest, whole plant samples were collected and separated into vines, recoverable roots plus stolons, and tubers. In 2005 and 2006, whole plant samples were collected in all treatments; in 2004, only the 0 and 90 lb P_2O_5 /A treatments were sampled.

Growing season conditions varied among years. Cool conditions prevailed throughout the 2004 growing season and, in 2005, precipitation levels were above-normal in the early part of the growing season. Total tuber yield varied among years, averaging 380, 306, 463, and 422 cwt/A in 2003, 2004, 2005, and 2006, respectively. The comparatively lower yields obtained in 2004 were due in part to cooler growing season conditions, including frost in August.

Phosphorus fertilization appeared to have limited effects on tuber yield and quality although the experimental sites selected would have received a recommendation for P fertilizer based on the "Manitoba Soil Fertility Guide" (Manitoba Agriculture, Food and Rural Initiative, 2007). Total tuber yield increased linearly ($p = 0.02$) with increasing P fertilizer rate only in 2005 (**Table 1**). Phosphorus rate had no effect on total tuber yield in 2003 and 2006. In 2004, P rate tended ($p = 0.07$) to influence total tuber yield. Closer examination of the data

Abbreviations and notes for this article: N= nitrogen; P = phosphorus; cwt = 100 wt or 100 lb; MAP = monoammonium phosphate; K = potassium; S = sulfur; $NaHCO_3$ = sodium bicarbonate; ppm = parts per million.



Timing of plant counts, mid-June 2005.

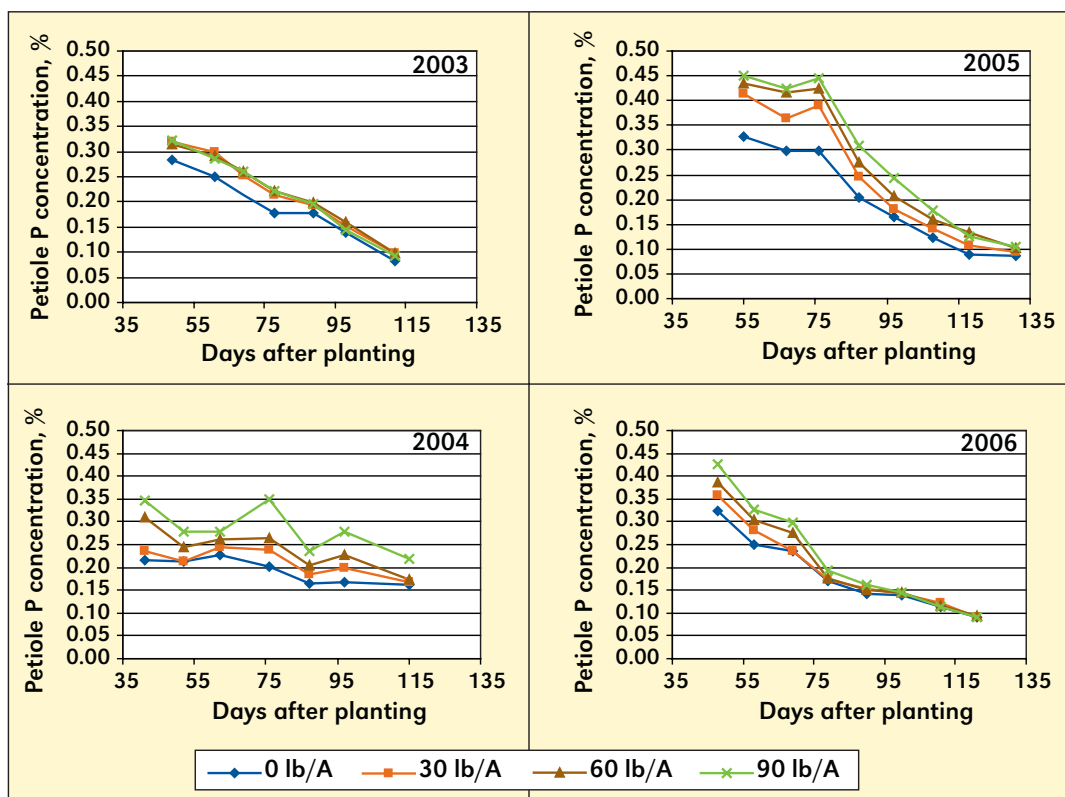
Table 1. Effect of rate of P fertilizer application on yield and tuber size fraction of irrigated Russet Burbank potato for 4 years in Manitoba.

Year	P ₂ O ₅ rate, lb/A	Total yield	< 3 oz	3-6 oz	6-10 oz	10-12 oz	> 12 oz	Marketable
-----cwt/A-----								
2003	0	378.6	22.9	97.6	144.6	37.9	75.6	355.7
	30	390.1	22.1	114.0	130.4	42.9	80.7	368.0
	60	374.1	20.0	85.2	146.1	42.5	80.3	354.1
	90	379.1	22.2	104.3	146.2	56.6	49.6	356.8
	Pr>f	NS	NS	NS	NS	NS	NS	NS
2004	0	312.0	23.5	89.0	106.5	29.7	63.3	288.5
	30	283.5	33.0	93.5	93.9	31.1	32.0	250.5
	60	311.8	28.6	101.2	112.3	32.1	37.7	283.2
	90	316.3	26.1	85.5	112.5	37.3	54.9	290.2
	Pr>f	0.070	0.100	NS	NS	NS	NS	0.029
2005	0	441.8	29.0	119.2	177.2	55.0	61.3	412.6
	30	459.8	35.8	129.8	163.7	49.6	87.4	430.4
	60	466.3	31.5	117.2	177.7	59.0	81.1	435.0
	90	483.0	34.4	113.9	145.0	70.0	119.6	448.5
	Pr>f	0.100	NS	NS	0.080	NS	0.006	NS
2006	0	421.0	36.0	124.8	128.2	50.0	82.2	385.1
	30	423.5	23.9	118.4	160.9	43.7	76.4	399.4
	60	441.5	23.9	108.3	155.3	49.9	104.0	417.6
	90	403.3	35.6	95.9	150.2	49.7	71.9	367.7
	Pr>f	NS	0.009	NS	NS	NS	NS	0.060

revealed that the treatment receiving 30 lb P₂O₅/A had a numerically lower yield than any other treatment, although the reason for this effect is unclear. In 2005 and 2006, increasing P rate increased marketable yield (**Table 1**). A significant linear effect was evident in 2005 ($p = 0.03$), and a significant quadratic effect was evident in 2006 ($p = 0.02$). In part, a somewhat higher soil test P level in 2003—and poor growing season conditions that restricted crop growth in 2004—may have limited crop responses to fertilizer application in those years.

The rate of P fertilizer applied had limited effects on tuber quality (data not shown). Specific gravity was not affected by P rate except in 2004 when increasing P rate resulted in a statistically significant linear increase in specific gravity. In 2003, P rate tended to influence specific gravity, but increasing P rate had inconsistent effects. The occurrence of defects such as rot and greening was generally very low throughout the course of the study, while the occurrence of hollow heart/brown center averaged 15.2%, 15.1%, 9.5%, and 2.1% of the tubers assessed (on a weight basis) in each of 2003, 2004, 2005, and 2006, respectively. Preliminary analysis suggests that P rate had limited effects on hollow heart.

Petiole P concentration generally declined over the course of the growing season (**Figure 1**). In 2004 and 2005, increasing P rate increased petiole P concentration for each sampling date. In 2006, increasing P rate also increased petiole P concentration in the early part of the growing season, but this effect was not evident for later sampling dates. In 2003, P fertilization similarly

**Figure 1.** Effect of rate of P fertilizer (lb P₂O₅/A applied as broadcast MAP) on total P concentration in petioles of irrigated Russet Burbank potato in Manitoba (2003-2006).

increased or tended to increase petiole P concentration at most sampling dates, but effects were not as pronounced as in 2004 and 2005. In an extension bulletin from the University of Idaho, petiole P concentrations of <0.17% were considered low, 0.17 to 0.22% marginal, and >0.22% sufficient for the fourth petiole of Russet Burbank potatoes during tuber bulking (Stark et al., 2004). In the current study, petiole P concentration in most treatments at most sites fell below 0.22% as the season progressed. However, increasing P rate increased marketable yield only in 2005 and 2006.

Woods et al. (2002) reported that the adequate range for petiole P based on standards used in the northwest U.S. ranged from 0.22 to 0.62% in early July, from 0.20 to 0.50% in late July, and from 0.16 to 0.40% in mid-August. Using these criteria, the petiole P concentration in all treatments in all site-years fell within the adequate range in early July. Petiole P concentration also fell within the adequate range in late July in all years except 2006 where petiole P concentration fell below 0.20% by the July 20th sampling date. In 2003 and 2004, petiole P concentrations were also adequate in mid-August, suggesting that P was not limiting (increasing P rate did not increase yield at these sites). In 2005 and 2006, petiole P concentration in some treatments fell below the adequate range in mid-August. However, petiole P concentration in some treatments did not consistently predict when yield responses to P application would occur at these two sites. In 2005, petiole P concentrations were greater than or equal to 0.16% in mid-August only in treatments receiving 60 and 90 lb P₂O₅/A, suggesting that P was not deficient in these treatments. However, a linear yield response was evident at this site with marketable yield increasing across the range of P fertilizer rates. Additional site-years of data are required to further assess petiole P criteria for Manitoba conditions.

Estimated P uptake by the potato plant shortly before tuber harvest averaged 16 lb P/A in 2004 and 2006, and 20 lb P/A in 2005. This estimate included vines, tubers, and recoverable roots plus stolons. Average P uptake in tubers was 12, 16, and 13 lb P/A in 2004, 2005, and 2006, respectively. Increasing P fertilizer rate did not result in a statistically significant ($p > 0.05$) increase in P uptake in 2005 and 2006 where all treatments had been sampled.

Detailed sampling of each plot (based on 10 cores/plot to 6 in.) following tuber harvest revealed a significant linear increase in Olsen P content in all years (**Table 2**). However, treatment effects were not always statistically significant using this sampling method. The difference in Olsen P level between the 90 lb P₂O₅/A treatment and the control ranged from 8 lb extra P/A in 2003 to 42 lb extra P/A in 2004.

Increasing P fertilizer rate resulted in a significant linear increase in marketable (> 3 oz) and total yield only in 2005, and a quadratic increase in marketable yield in 2006, even though all experimental sites would have received a recommendation to apply P fertilizer based on Manitoba guidelines. In the current study, the range of P fertilizer rates applied reflected provincial guidelines in Manitoba which recommend application of 90 to 110 lb P₂O₅/A for soils containing ≤ 10 ppm Olsen P, 70 to

Table 2. Effect of rate of P fertilizer application on Olsen P level (lb/A) for the 6 in. depth measured following tuber harvest in Manitoba.

P ₂ O ₅ rate, lb/A	Year			
	2003	2004	2005	2006
0	37	31	32	28
30	45	43	45	35
60	43	58	62	39
90	45	73	64	42
Pr>f	0.0518	0.0001	0.0006	0.0366

80 lb P₂O₅/A for soils containing >10 and ≤15 ppm P, and 60 lb P₂O₅/A for soils containing >15 ppm P, assuming broadcast incorporation (Manitoba Agriculture, Food and Ru-

ral Initiatives, 2007). It should be noted, however, that P fertilizer recommendations for potato vary considerable among regions. Based on North Dakota guidelines (Dahnke et al., 1992), for example, P fertilizer would have been recommended in the current study only in 2004 (15 lb P₂O₅/A) and 2006 (75 lb P₂O₅/A) given the Olsen P level and average total yield at experimental sites. Comparatively higher P recommendations exist in other regions. In Wisconsin, for example, for fine- to medium-textured soils categorized as very low in P (<100 ppm P, Bray 1), 250 lb P₂O₅/A is recommended for a potato crop yielding 351 to 450 cwt/A; for soils testing low in P (100 to 160 ppm P), 180 lb P₂O₅/A is recommended (Laboski et al., 2006). Based on the Wisconsin guidelines, the probability of a yield increase to applied nutrients is >90% for soils in the very low category. In the current study, P application typically increased petiole P concentration at a given sampling date, however, petiole P criteria developed in potato-growing regions outside of Manitoba did not appear to consistently identify when positive yield responses to P application would occur. At all sites, increasing P rate also resulted in a linear increase in post-harvest soil test P levels in the surface 0 to 6 in. **BC**

Dr. Mohr (rmohr@agr.gc.ca) is a research scientist with Agriculture and Agri-Food Canada, Brandon, Manitoba. Dr. Tomasiewicz is research manager of the Canada-Manitoba Crop Diversification Centre, Carberry, Manitoba.

- Dahnke, W.C., C. Fanning, and A. Cattanaach. 1992. Fertilizing potato. [Online] Available: <http://www.agndsu.edu/pubs/plantsci/soilfert/sf715w.htm> [2008 Feb.07].
- Geisel, B.P. 1995. p. 17-23 *In* Keystone Vegetable Producers Association and Nestle-Simplot Foods Ltd. 1994 Potato Research Report.
- Laboski, C.A.M., J.B. Peters, and L.G. Bundy. 2006. Nutrient application guidelines for field, vegetable and fruit crops in Wisconsin. 70 pp.
- Manitoba Agriculture, Food and Rural Initiatives. 2007. Manitoba Soil Fertility Guide. 73 pp.
- Stark, J., et al. 2004. Bulletin 840. University of Idaho College of Agricultural and Life Sciences. 12 pp.
- Tomasiewicz, D.J. 1994. Effects of phosphorus fertilization on potato production and petiole test levels. p. 31-33 *In* Manitoba Crop Diversification Centre Annual Report 1994.
- Woods, S.A., et al. 2002. Report from the Crop Diversification Centre South, AAFRD, Brooks, AB.
- Western Potato Council. 2003. Guide to Commercial Potato Production.