

Phosphorus management for irrigated potato production in Manitoba

by Dr. Ramona Mohr and Dr. Dale Tomasiewicz. Reprinted from *Better Crops with Plant Food*, with permission of International Plant Nutrition Institute (IPNI)

Extensive research shows impact on yield and quality.

Results of a set of field experiments evaluating potato response to recommended rates of P fertilizer demonstrated yield benefits in two of four 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 adaptation for Manitoba.

Manitoba has become a major contributor to potato production in Canada, with output of more than 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 40lbs/ac. 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 postharvest 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 six-inch depth were 43, 24, 34 and 19lbs/ac 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 lbs of P_2O_5 per acre as MAP) was established. Individual plots were typically 52 feet long, and ranged from six to nine rows wide. Row spacing was 37 inches and within-row spacing was typically 15 inches. 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

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broadcast, 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 feet of the centre 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 90lbs of

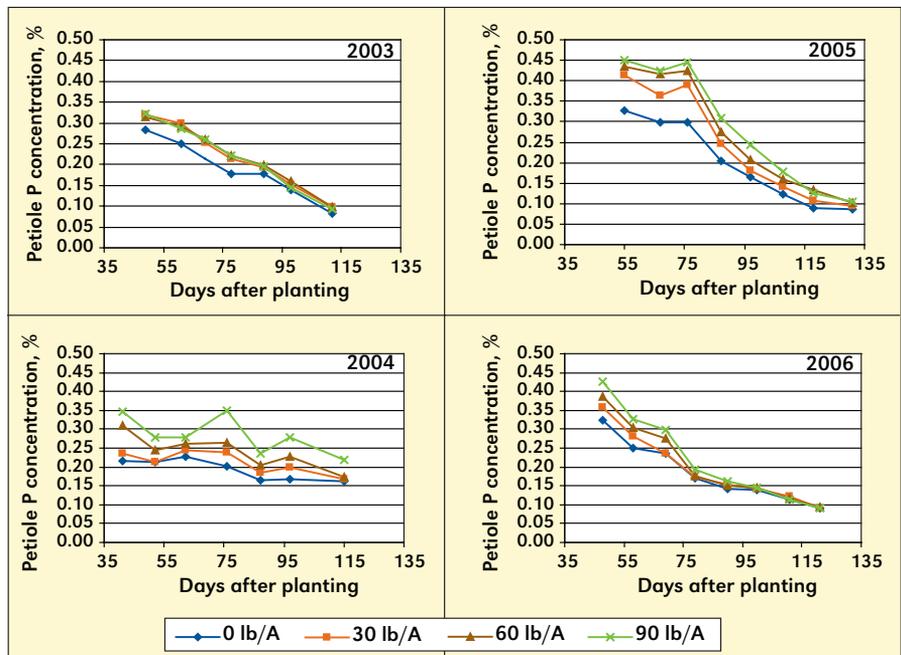


Figure 1. Effect of rate of P fertilizer (lbs P₂O₅/ac applied as broadcast MAP) on total P concentration in petioles of irrigated Russet Burbank potato in Manitoba (2003-2006).

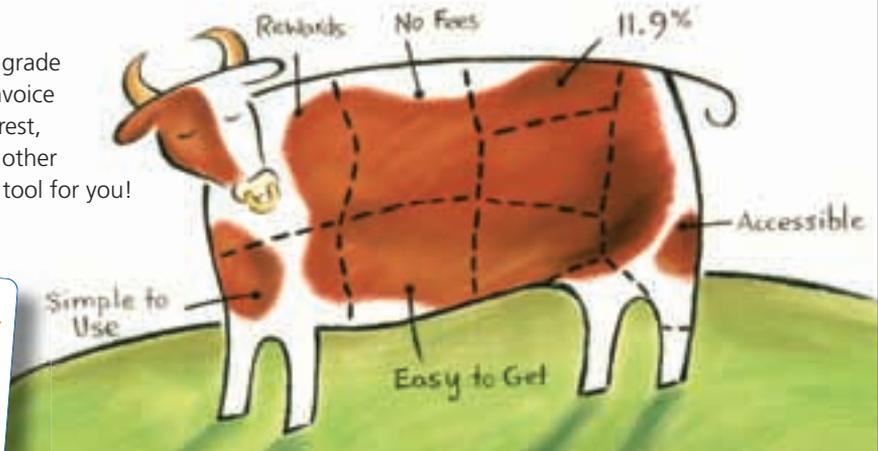
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Table 1. Effect of rate of P fertilizer application on yield and tuber size fraction of irrigated Russet Burbank potato for four years in Manitoba.

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

Table 2. Effect of rate of P fertilizer application on Olsen P level (lb/A) for the six inch 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

P₂O₅ per acre 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 per acre 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 revealed that the treatment receiving 30lbs of P₂O₅ per acre 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 centre averaged 15.2 percent, 15.1 percent, 9.5 percent and 2.1 percent 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 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 less than 0.17 percent were considered low, 0.17 to 0.22 percent marginal, and greater than 0.22 percent sufficient for the fourth petiole



Timing of plant counts, mid-June 2005.

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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 percent 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 northwestern US ranged from 0.22 to 0.62 percent in early July, from 0.20 to 0.50 percent in late July, and from 0.16 to 0.40 percent 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 percent 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 percent in mid-August only in treatments receiving 60 and 90lbs of P_2O_5 per acre, 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 16lbs of P per acre in 2004 and 2006, and 20lbs of P per acre in 2005. This estimate included vines, tubers, and recoverable roots plus stolons. Average P uptake in tubers was 12, 16 and 13lbs of P per acre in 2004, 2005 and 2006, respectively. Increasing P fertilizer rate did not result in a statistically significant (P greater than 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 per plot to six inches) 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 90lbs of P_2O_5 per acre treatment and the control ranged from 8lbs of extra P per acre in 2003 to 42lbs of extra P per acre in 2004.

Increasing P fertilizer rate resulted in a significant linear increase in marketable (greater than 3.0 ounces) 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 110lbs of P_2O_5 per acre for soils containing less than 10 ppm Olsen P, 70 to 80lbs of P_2O_5 per acre for soils containing greater than 10 and less than 15 ppm P, and 60lbs of P_2O_5 ac for soils containing greater than 15 ppm P, assuming broadcast incorporation (Manitoba Agriculture, Food and Rural Initiatives, 2007). It should be noted, however, that P fertilizer recommendations for potato vary considerably 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 (15lbs of P_2O_5 per acre) and 2006 (75lbs of P_2O_5 per acre) 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 (less than 100 ppm P, Bray 1), 250lbs of P_2O_5 per acre is recommended for a potato crop yielding 351 to 450 cwt per acre; for soils testing low in P (100 to 160 ppm P), 180lbs of P_2O_5 per acre is recommended (Laboski et al., 2006). Based on the Wisconsin guidelines, the probability of a yield increase to applied nutrients is greater than 90 percent 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 zero to six inches. ■



Southern Manitoba P and potato research site, August 2005.