Managing Phosphorus to Optimize Potato Tuber Yield in the San Luis Valley

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Introduction

Soil phosphorus (P) contributes to early crop development and tuber initiation. Adequate soil P also enhances tuber maturation. Phosphorus fertilizer management of potatoes should aim to maximize profit as well as minimize the overuse of P to reduce environmental impacts. Potato responds to P application in soils with low P even though there have been reports of potato responding to P in soils with high P levels. Similarly, potato has been reported not to have responded to P application in some soils with low P levels. There are other factors apart from soil P level that may contribute to the availability of P to potato plants. Therefore, P fertilizer recommendations can vary considerably among regions. Generally, potato will normally not respond to P application in soils testing for high P levels. Poor growing season conditions such as cooler weather may also influence the response of potato to P application. It has been reported that potatoes respond to P fertilization, particularly in soils with high pH and plenty of free lime. Phosphorus deficiency can reduce tuber yield, tuber size, as well as tuber specific gravity. It is therefore important to pay attention to soil P levels in potato production.

Phosphorus Uptake

The amount of P in soil solution at a given time is between 0.01 to 0.3 ppm (less than 1 lb/A). Daily potato P uptake is very minimal (0.3 to 0.5 lb P/A/day), however, serious deficiencies can develop if available soil P concentrations are inadequate. Therefore, soil P need to be replenished constantly during the growing season from P labile sources that readily dissolve or mineralizes. Soil test P levels using the sodium bicarbonate extraction method is a good measure of soil available P to potatoes in high pH, calcareous soils.

Phosphorus Fertilizer Recommendations

Soil test P concentration and the amount of free or excess lime (calcium carbonate) are the primary basis for P fertilizer recommendation for potatoes. Excess free lime in the soil tends to precipitate available P and therefore makes P less available to the plant. Table 1 shows general guidelines for P application in potato production.

Table1. General guidelines for phosphorus application in potato production

	Soil Test Phosphorus (ppm)[1]			
Yield Goal (cwt/A)	0 – 10	11 – 25	26 – 50	> 50
	P_2O_5 to Apply (lb/A)			

400 - 500	150	100	50	25
> 500	175	125	75	25

[1] ppm x 2 = lb/A

Application of approximately 20 lb P_2O_5/A will increase soil test P level by 1 lb/A.

Phosphorus Placement for Maximum Plant Uptake

Phosphorus barely moves in the soil, and therefore it needs to be incorporated in the soil such that it will facilitate crop uptake. Phosphorus is not readily leached, but can be lost through runoff, where the soil is prone to erosion.

A rule of thumb in P placement is to get the fertilizer close to the seed or plant roots. Broadcasting and working the P fertilizer into the top six inches of soil pre-plant or banding the fertilizer two inches below and two inches to both sides of the seed tuber at planting is ideal. Banding gives the highest efficiency in P fixing soils. Fertilization rate can be reduced by 30% by banding compared to broadcasting if soil tests show low in P concentration. Broadcasting or banding fertilizers containing ammonium can increase P availability to the plant by reducing soil pH. For full season P availability, it is important to raise the soil test P concentration in the root zone to adequate levels by broadcasting P to provide the entire root system with ready access to available soil P. Liquid fertilizers such as ammonium polyphosphate (10-34-0) and dry fertilizers such as monoammonium phosphate (11-52-0) are equally effective P sources for potatoes.

In-Season P Management

Phosphorus application through the sprinkler can be done to correct P deficiencies during the growing season, but this method can be effective only when the roots are about two inches near the surface, since the applied P will not move more than two inches into the soil. Petiole P concentration usually respond about 10 to 14 days after P application. Therefore P through the sprinkler system should be applied prior to any development of P deficiencies.

Petiole Phosphorus Concentration

For a good indication of adequate P concentration in the plant, the total P concentration in the fourth petiole from the growing point should be maintained above 0.22%. Petiole sampling for P should begin shortly after tuber initiation and continue at weekly intervals through the tuber bulking phase. Petiole P concentration of 0.17% is considered low, 0.17 – 0.22% is marginal, and greater than 0.22% is sufficient.

CASE STUDY

Title: Response of Potato to Phosphorus Application Rate, Timing, and form of Application in the San Luis Valley

Experimental Procedure

The study was conducted at the San Luis Valley Research Center, Colorado State University. Selected soil chemical properties of the experimental site before potato planting are shown in Table 2. A factorial arrangement of P application rate (100, 150, 200 lb-P_2O_5/A), time of P application (100% pre-plant; 50% pre-plant and 50% at hilling;), and form of P application (liquid or dry application at hilling), were applied in a randomized complete block design. The treatments are summarized in Table 3. Each treatment was replicated three times. Seed tubers (2.5 to 3.0 oz seed wt.) were planted at a spacing of 11 inches within rows at 34 inches row spacing. Compound fertilizer – 75-50-50-1 (N-K-S-Zn), was applied pre-plant. The remaining 100 lb N was applied as Urea Ammonium nitrate in three split application between July 9 and 30.

Table 2 Selected soil chemical characteristics before planting

Nitrate Nitrogen	P	K	Zn	Fe	Mn	Cu
			ppm			
7.5	17.1	196.5	2.6	10.8	4.9	2.3

Petiole samples were collected from the fourth leaf beginning from the growing point between July 7 and August 4. Petioles were dried in a 60 ^oC oven and fine ground. Ground tissue was sent to the Colorado State University plant analysis lab for petiole P analysis.
Tubers harvested from each plot were weighed to record total field yield. Tubers from each plot were graded for external and internal defects (Growth cracks, knobs, misshapes, hollow heart and brown center). Tubers were separated into various size distribution groups based on weight. Ten large (10-16 oz) tubers were taken for hollow heart evaluation. Tuber specific gravity was measured using the weight-in-air/weight-in-water method.
Data were analyzed by analysis of variance, Waller-Duncan mean separation, and orthogonal contrasts using SAS software.

Table 3 Phosphorus application treatments.

Treatment (lb-P_2O_5/ac)	Treat. # used	--- Fertilizer phosphorus applied (lb-P_2O_5/ac)-- Pre-plant	At Hilling	Total	Form of Fertilizer Used
100	1	100	0	100	Liquid
150	2	150	0	150	Liquid
200	3	200	0	200	Liquid
100 (1/2 + 1/2)	4	50	50	100	Liquid
150 (1/2 + 1/2)	5	75	75	150	Liquid

	6	100	100	200	
200 (1/2 + 1/2)					Liquid
	7	50		100	
100(1/2+1/4+1/4)[1]			25 + 25		Liquid + Dry
	8	75		150	
150(1/2+1/4+1/4)[1]			37.5 + 37.5		Liquid + Dry
	9	100		200	
200(1/2+1/4+1/4)$_1$			50 + 50		Liquid + Dry

[1] Half of required fertilizer applied as liquid pre-plant, 1/4 applied as liquid and 1/4 as dry fertilizer at hilling

Results and Discussion

Tuber Yield and Tuber Size Distribution

Phosphorus application rate, timing, and form of application did not generally influence total tuber yield, except treatment 7 [100 (1/2+1/4+1/4)] which produced less tubers. Phosphorus management, however, influenced tuber size distribution (fig. 1 to 5). Treatment 1 and 9 (100 and 100+50+50 lb-P_2O_5/ac) produced fewer culls (fig 2) and more marketable size tubers (fig. 3 and 4), when compared to the other treatments. This observation indicates that application of 100 lb-P_2O_5/ac pre-plant with soil test of 17.1 ppm is more economical for maximum tuber yield. Treatment 1 (application of 100 lb-P2O5/ac), produced a total yield of 409 cwt/acre and 67% (276 cwt/A) of marketable tuber (4-16 oz) yield (fig 1 and 3). Phosphorus management did not influence tuber specific gravity in this study (data not shown).

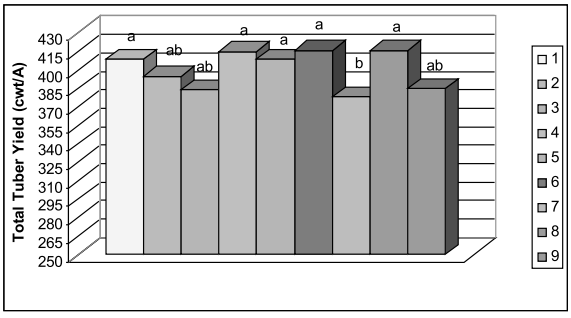


Fig 1 Effect of P management on total tuber yield of Russet Potato.

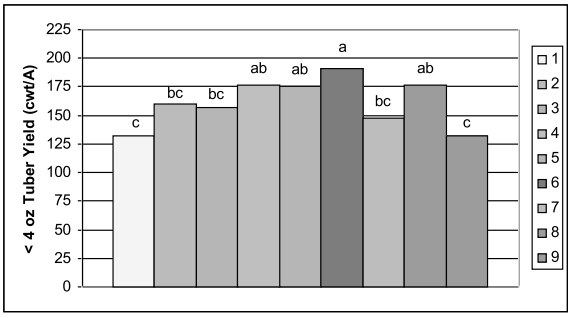


Fig 2 Effect of P management on the yield of < 4 oz tubers

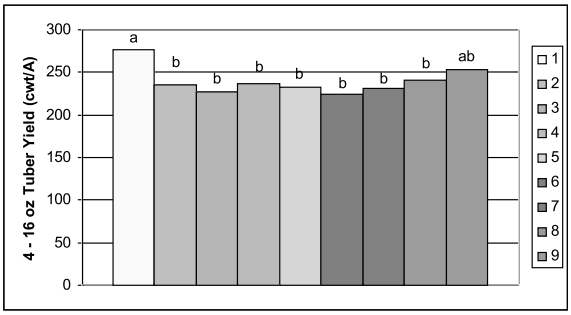


Fig 3 Effect of P management on marketable tuber yield of Russet Potato

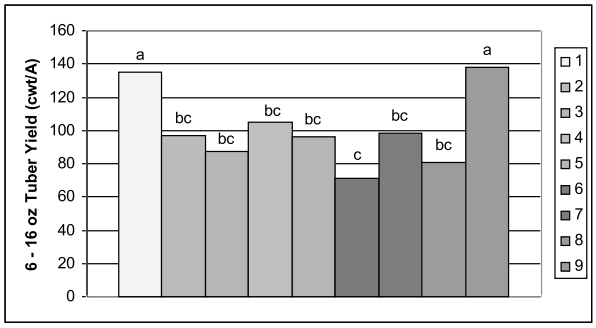
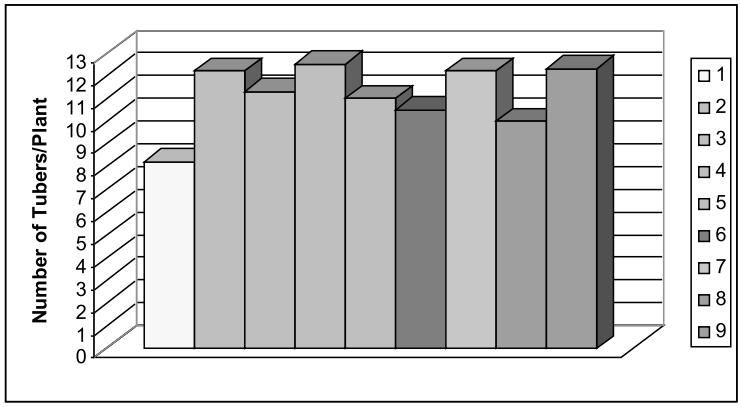


Fig 4 Effect of P management on yield of large marketable size tubers

Legend of Treatments (lb P_2O_5/A)
1 = 100; 2 = 150; 3 = 200; 4 = 100 (1/2 + 1/2); 5 = 150 (1/2 + 1/2); 6 = 200 (1/2 + 1/2);
7 = 100 (1/2 + 1/4 + 1/4); 8 = 150 (1/2 + 1/4 + 1/4); 9 = 200 (1/2 + 1/4 + 1/4)



Tuber Number (Tuber Set)

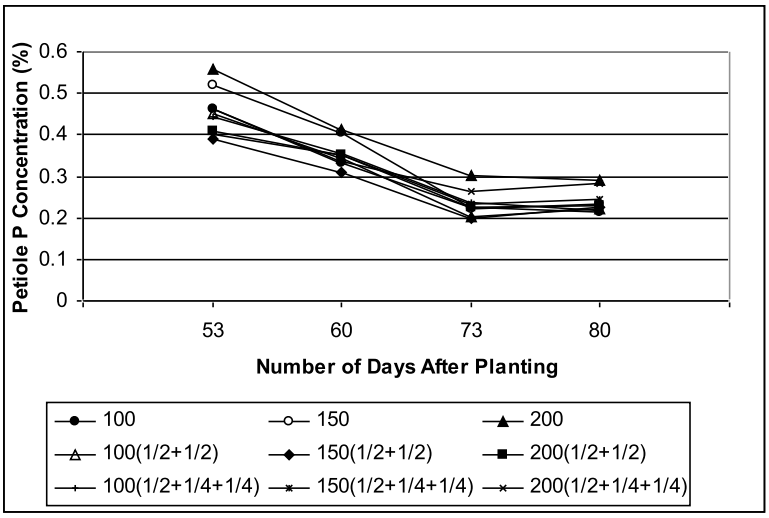
Phosphorus management influenced the number of tubers produced per plant (fig 5). Treatments 2, 4, 7, and 9, produced the largest number of tubers (12) per plant, while treatment 1 produced the least (8) tubers per plant. The eight tubers per plant produced did compensate for higher yield by producing bigger tubers (fig 3 and 4).

Legend of Treatments (lb P_2O_5/A)
1 = 100; 2 = 150; 3 = 200;
4 = 100 (1/2 + 1/2);
5 = 150 (1/2 + 1/2);
6 = 200 (1/2 + 1/2);
7 = 100 (1/2 + 1/4 + 1/4);
8 = 150 (1/2 + 1/4 + 1/4);
9 = 200 (1/2 + 1/4 + 1/4)

Fig 5 Effect of P management on tuber number of Russet potato

Petiole P Concentration

Petiole P concentration was measured at 53, 60, 73, and 80 days after planting (DAP) (fig 6). Petiole P concentration decreased in all treatments from 53 to 80 DAP. Petiole P concentration increased as P application rate increased. Petiole P concentration did not fall below 0.20% in all treatments. The optimum petiole P concentration for optimum tuber yield were observed to be, 0.46, 0.33, 0.23, and 0.21%, at 53,60, 73, and 80 DAP, respectively, when 100 lb P_2O_5/A was applied pre-plant. Phosphorus management practices that produced petiole P concentration above 0.5, 0.4, 0.3, and 0.28%, during the same sampling dates as the optimum concentration, produced fewer marketable tuber yield.



Legend of Treatments (lb P_2O_5/A)
1 = 100; 2 = 150; 3 = 200;
4 = 100 (1/2 + 1/2);
5 = 150 (1/2 + 1/2);
6 = 200 (1/2 + 1/2);
7 = 100 (1/2 + 1/4 + 1/4);
8 = 150 (1/2 + 1/4 + 1/4);
9 = 200 (1/2 + 1/4 + 1/4)

Fig 6 Effect of P management on petiole P concentration during the growing season

Summary and Conclusion

The main purpose of this study was to evaluate the effect of P application rate, application timing, and form of P application on tuber yield, tuber size distribution, quality, and petiole P concentration in Russet Potato. With soil test P of 17.1 ppm at pre-plant, an application of P fertilizer at the rate of 100 lb-P_2O_5/A pre-plant produced the maximum marketable tuber yield. The relatively low percentage (68%) of marketable tuber yield observed in this study was due to the narrow in-row seed spacing of 11 inches. Widening the in-row seed spacing to 12 inches, can increase the percentage of marketable size tubers.

Results of this study indicate that for maximum tuber yield, petiole P levels should not fall below 0.22% during tuber bulking, and should not go above 0.3% during the same period. Petiole P concentration should not go above 0.5% during the early stages of tuber formation. Optimum petiole P concentration during the growing season should be 0.46, 0.33, 0.23, and 0.21%, at 53, 60, 73, and 80 days after planting, respectively, to obtain maximum marketable tuber yield.