University of Idaho
College of Agriculture

Cooperative Extension System
Agricultural Experiment Station

Current Information Series No. 903

Phosphorus Nutrition of Potatoes

Terry A. Tindall, Dale T. Westermann, Jeffrey C. Stark, John C. Ojala and Gale E. Kleinkopf

Phosphorus (P) is an essential nutrient required by potatoes and all other plants. Potato plant roots readily absorb P in the form of phosphate from the soil (water) solution. The absorbed phosphate moves upward and downward in the plant. Phosphorus-deficient potato plants transfer P from older tissues to actively growing, younger tissues.

Symptoms of P deficiency include darker green, stunted, spindly leaves with younger leaflets that turn upward or curl. With prolonged deficiency, plants are small and have reduced leaf area.

Phosphorus uptake

Maximum potato yield occurs when sufficient P is available during early vegetative development and the entire period of tuber growth. Total plant P uptake increases rapidly during tuber initiation, levels off to a constant rate during tuber bulking, and ceases with plant maturation (Fig. 1). Tuber P uptake during maturation occurs primarily through the transfer of P reserves from the vine and roots.

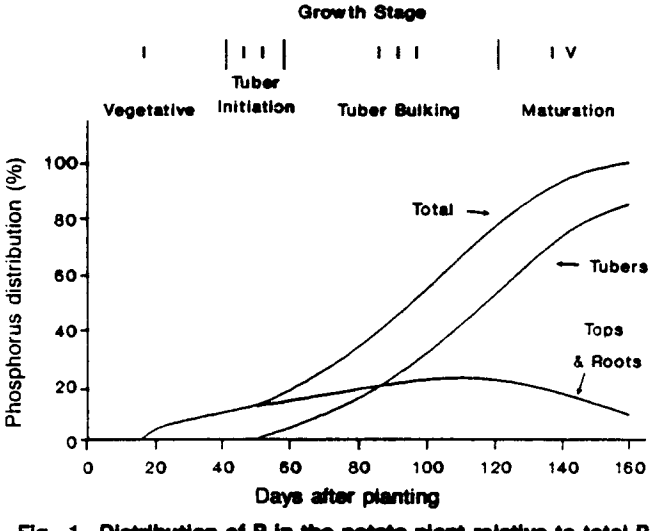

Fig. 1. Distribution of P in the potato plant relative to total P at maturation (Russett Burbank variety).

Phosphorus uptake by potatoes is relatively low compared with uptake of potassium or nitrogen but similar to uptake of sulfur. Potato crops yielding 300 cwt and 500 cwt per acre take up approximately 28 pounds P per acre (64 lb P_2O_5) and 40 pounds P per acre (91 lb P_2O_5), respectively.

Phosphorus availability in soil

The amount of P in the soil solution that is readily available for plant uptake is very small compared with the total amount of P in the soil. The calcium in Idaho soils combines quickly with P fertilizer, causing reduced P availability to plants and very restricted P mobility in soil. Therefore, P fertilizer use efficiency is quite low compared with that of most other available fertilizers.

Preplant P fertilizer

The accepted soil extraction method for measuring P availability in Idaho soils is sodium bicarbonate

Table 1. Recommended preplant P fertilizer application rates based on soil test P concentration and free lime content.

Soil test P[1] (0 to 12 inch sample depth)	Free lime content[2]		
	Less than 5%	10%	15% or more
(ppm P)	(pounds P_2O_5 per acre)		
0	240	354	466
5	160	280	400
10	80	200	320
15	0	120	240
20	0	40	160
25	0	0	80
30	0	0	0

[1]Soil extractant for P is sodium bicarbonate ($NaHCO_3$); ppm = parts per million.

[2]Free lime is measured as calcium carbonate equivalent (CCE).

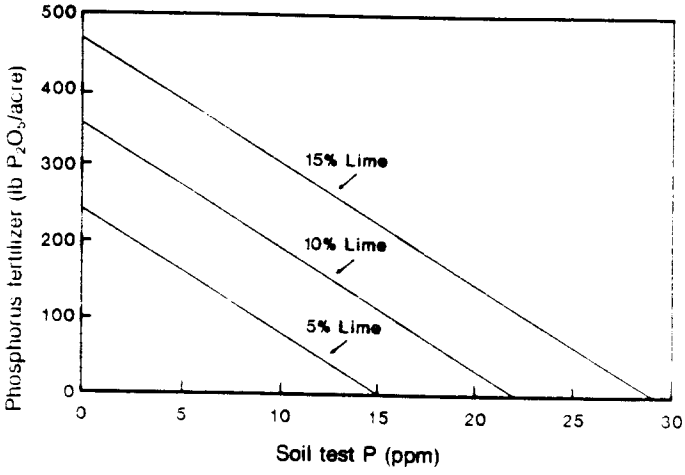

Fig. 2. Phosphorus fertilizer recommendations based on soil test P and soil lime content.

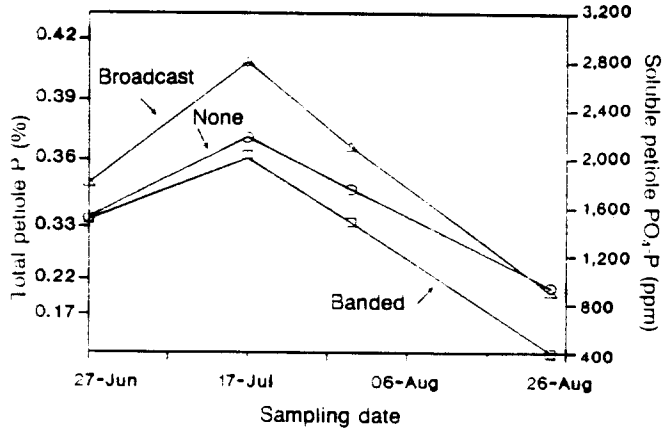

Fig. 3. Petiole P concentration as influenced by fertilizer placement. (Soil test P was 27 ppm.)

($NaHCO_3$). Potatoes produced in soil containing little free lime (less than 5 percent calcium carbonate equivalent or CCE) and soil test P less than 15 parts per million respond to P fertilizer with improved yield and quality (Table 1). Potatoes growing in soil containing high amounts of free lime (15 percent or more) respond to P fertilizer application when soil test P is less than 30 ppm. In most soils, the P fertilizer application rates given here (Table 1, Fig. 2) should provide adequate P from early plant growth through maturation. About 15 pounds of P_2O_5 per acre will raise the soil test P level by 1 part per million.

Fertilizer placement

Phosphorus availability is influenced by fertilizer placement and timing. Field research trials in south-central Idaho compared banding and broadcasting preplant P fertilizer. Greatest petiole P concentrations occurred when P fertilizer was broadcast and tilled into the seedbed (Fig. 3). Likewise, broadcasting P then incorporating it into the soil resulted in greater yields (Table 2). This is probably because broadcasting provides a greater opportunity for roots to come in contact with P fertilizer and to absorb it. Do not place P fertilizer below the active root zone of potatoes.

Table 2. Influence of P fertilizer placement on total yield of potatoes.

Placement method	Phosphorus fertilizer rate (lb P_2O_5/acre) 0	68	272	682
	(cwt/acre)			
None	364	---	---	---
Banded	---	389	441	---
Plowed	---	464	473	489
Disked	---	415	490	---

Place starter fertilizer materials above the seed piece at planting (directly in front of the hilling disks). Rates should not exceed 100 pounds of fertilizer material per acre.

Fertilizer type

Most types of P fertilizer provide similar amounts of available P when applied at equivalent rates. Liquid P solutions have P availabilities similar to solid, granular materials. However, field trials by the USDA Agricultural Research Service at Kimberly, Idaho, demonstrated that potatoes treated with acid urea phosphate had lower tuber yields and petiole P concentrations than potatoes treated with ammonium polyphosphate (10-34-0). Starters should not be based on diammonium phosphate.

Table 3. Influence of preplant and mid-season P fertilization on potato tuber yield and size distribution.

P rate: Preplant P	P rate: Mid-season P[1]	Tuber yield: Total	U.S. No.1: Total	U.S. No.1: >10 oz	U.S. No. 2	U.S. No.1 and 2 >10 oz
(lb P_2O_5/acre)		(cwt/acre)				
0	0	467	298	92	130	150
136	0	460	383	130	30	143
136	45	485	405	142	47	165
136	91	520	434	195	45	217
136	182	494	406	185	53	208

[1]Applied as 10-34-0 or 12-62-0 on 25 July.

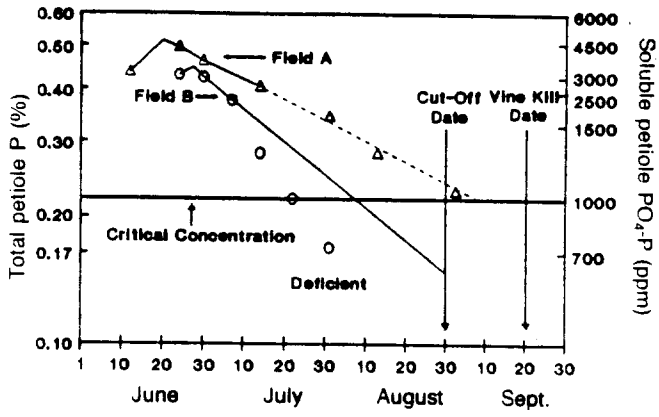

Fig. 4. Evaluating mid-season plant P adequacy from petiole P concentrations.

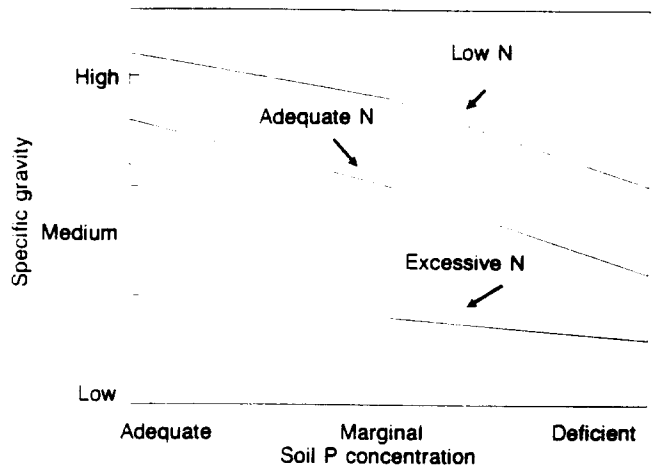

Fig. 5. The effects of P and N on potato specific gravity.

Mid-season P application

Mid-season P fertilizer application to potentially P deficient, healthy potato crops can significantly improve potato yield and quality (Table 3). However, fertilizing potato crops infested with root pathogens will probably improve yield and quality less, if at all.

Petiole P concentration is a good indicator of plant P status. Maintain P concentration in the fourth petiole from the growing tip above 0.22 percent total P (1,000 ppm soluble P) from tuber bulking until the beginning of maturation or until 20 days before vine kill (Fig. 4). Petiole P concentrations higher than 0.22 percent provide enough P for maximum vegetative and tuber growth.

The need for a mid-season fertilizer application can be determined using a technique for predicting future P concentrations in petioles. Take petiole samples shortly after the petiole P concentration has peaked and every 10 days afterward. As a general rule, collect the first petiole sample when the tubers are about 1 inch in diameter. Three or four sample dates will improve the accuracy of the prediction.

An example of predicting the need for additional P is presented in Fig. 4. Early-season petiole samples (solid symbols) for two fields are plotted on semilogarithmic graph paper. A line is drawn through the data points to the cut-off date (20 days before vine kill). If the line remains above this critical P concentration of 0.22 percent then no additional P fertilizer will be needed during the growing season. In the example, Field A has sufficient P for the entire growing season. Field B does not and requires a mid-season P fertilizer application.

If additional P is needed, P fertilizer may be injected through irrigation lines. An injection rate of 40 pounds per acre P_2O_5 in early to mid July will often satisfy mid-season petiole P deficiencies. Application should coincide with the presence of fine roots near the surface of the potato hills to ensure maximum P uptake. Be sure that the fertilizer and irrigation water are compatible to avoid plugging the nozzle with fertilizer salts.

Phosphorus uptake and environmental stress

Many environmental stresses influence plant P uptake during the growing season. These include Verticillium wilt, blackleg, *Fusarium* and other diseases of roots; root pruning during cultivation; cool soil temperatures; and soil properties such as low available P, lime content, restrictive layers, and pH. Petiole P may fall below the critical concentration even though adequate P was applied or present in soil tests. Excessive preplant P fertilization may slightly improve P uptake during some stresses, but is generally expensive and inefficient. A better solution is to prevent pathogens from infesting potato roots by careful management.

Phosphorus and potato quality

Phosphorus-deficient potato crops may have lower specific gravity. Specific gravity declines with greater P deficiency and greater nitrogen availability (Fig. 5). To keep specific gravity high, maintain adequate soil P concentrations.

Phosphorus and nitrogen also influence net development (skin set) on tubers. Phosphorus deficiency reduces netting when nitrogen levels are adequate or excessive. Maintain adequate P to lessen the reduction in net development.

Summary

- Preplant P fertilizers should be broadcast and disked into the upper 4 to 6 inches of soil or plowed under. Banding or sidedressing preplant P fertilizer during marking, planting or hilling generally results in lower plant uptake and tuber yield. If P is adequate according to the soil test, placement probably has little effect.
- Starter fertilizer containing P should be placed above the seed piece.
- The availability of P in most solid granular and liquid P fertilizer materials is similar when the materials are applied at equivalent rates.
- Monitor petiole P concentrations at regular intervals throughout the early and mid-tuber bulking stages of potato development. Mid-season P fertilizer need can be determined by plotting early season petiole P concentrations on semi-logarithmic graph paper and predicting late season P concentrations.

About the authors

Terry A. Tindall is Extension soil specialist at the University of Idaho District 3 Extension office at Twin Falls. Dale T. Westermann is research soil scientist with the USDA Agricultural Research Service at Kimberly, Idaho. Jeffrey C. Stark is research agronomist at the UI's Aberdeen Research and Extension Center. John C. Ojala is Extension potato specialist at the UI District 4 Extension office at Idaho Falls. Gale E. Kleinkopf is research agronomist at the UI's Kimberly Research and Extension Center.

Issued in furtherance of cooperative extension work in agriculture and home economics, Acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture, LeRoy D. Luft, Director of Cooperative Extension System, University of Idaho, Moscow, Idaho 83843. We offer educational programs, activities and materials without regard to race, color, religion, national origin, sex, age or disability, in accordance with state and federal laws.

3,000, 10-91

35 cents per copy