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MID-SEASON P FERTILIZATION EFFECTS ON POTATOES [1/]

D. T. Westermann [2/]

Final potato tuber yields are a function of tuber growth rates and the duration of the tuber growth period, particularly for the indeterminate potato varieties. Nutrient uptake should be continuous until the start of normal plant maturation since the tubers function as major nutrient sinks during their growth. Nutrient uptake rates less than those required for tuber growth will cause the mobile nutrients to be translocated from the other plant parts to the tubers, eventually causing a premature canopy senescence. Final tuber yields will be reduced if this senescence starts when the environmental conditions are still favorable for growth. Nutrient uptake rates can slow or stop during the maturation growth stage since tuber growth during this period mainly comes from the translocation of dry matter and nutrients from the vegetative portions of the plant to the tubers.

The adverse effect a low P concentration in potato plants during tuber growth on final tuber yields and the relationships of the petiole P concentrations to the P balance between the tubers and the other vegetative portions were recently reported (12). It was also suggested that the soluble petiole PO_4-P concentration should be maintained above 1000 µg/g for a favorable plant P balance until about 20-30 days prior to scheduled vine kill. Examining the petiole PO_4-P concentrations in 81 Idaho potato fields sampled from 1977 to 1981 showed that 42 fields had less than 1000 µg/g PO_4-P in the petioles after August 15-20 (unpublished data, D. T. Westermann; and (9)). All of these fields had a sufficient soil test P concentration (8). These data suggest that potato plants may not always be able to take up sufficient P because of plant diseases and other factors causing plant deterioration.

Management practices that might be used to raise low plant P concentrations are (a) the application of foliar sprays directly to the plants and (b) applying P fertilizers either dry or through the irrigation system. Attempts to supply the total P and Zn fertilizer needs of corn by sprinkler applications were more successful on a loamy sand than on a clay loam soil (4). Surface applications of inorganic P materials during the growing season are generally not considered feasible because of P immobility in most soils (3). Some organic P compounds are capable of moving through several centimeters of soil before being hydrolized to the orthophosphate ion. Glycerophosphate and orthophosphate had equivalent availabilities to growing tomato plants, but the glycerophosphate moved farther into the soil at equivalent P application rates when applied by a drip irrigation system (10). The objectives of this report were to evaluate the effects of a mid-season P fertilizer application on total plant P uptake and potato tuber yields.

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2/ Soil Scientist, Snake River Conservation Research Center, USDA-ARS, Kimberly, Idaho 84321

METHODS AND MATERIALS

The results presented here for the Russet Burbank potato variety came from one main field experiment at Kimberly and from 12 smaller replicated experiments on potato growers' fields in southern Idaho. All experiments included at least a (a) control, (b) preplant P fertilizer, and (c) preplant P fertilizer plus a mid-season P fertilizer application as treatments. The Kimberly experiment also compared P fertilizer source and rates (Table 1). Only the 12-62-0 material was used for the mid-season P fertilizer application on the growers' fields. All the mid-season applications were applied as close as possible before a sprinkler irrigation from 19 July in western Idaho to 28 July in eastern Idaho. The Na-form of glycerophosphate was applied on 3 August at Kimberly. Nitrogen contained in the P source was balanced by an equivalent N application as NH_4NO_3. Emphasis was placed on measuring the petiole and total plant P uptake changes in all experiments; the final tuber yields were also measured in the Kimberly experiment.

Table 1. Experimental Characteristics - 1983

Location (expts.)	Preplant STPC ppm	P mid-season Sources	P Rates: Preplant†	P Rates: Mid-Season
			lbs P/A	lbs P/A
Kimberly (1)	5.1	12-62-0 10-34-0 glycerophosphate	0,60	0,20,40, 80
Growers (12)	4.3-39.6	12-62-0	0,50-120	0,60-80

† Applied as 0-45-0

Culture and complete fertilization practices are not available for the growers' fields, however, standard practices were followed at Kimberly (6, 8). Sprinkler irrigations at Kimberly were scheduled according to tensiometers placed in the row at the seed-piece depth, allowing a 40 to 50% depletion of the available soil water between irrigations.

The dry weight of whole plants was determined on 5-foot row sections taken from each plot on about a 14-day and 21-day interval at Kimberly and on each grower's field, respectively, starting at early tuber set until mid-September. Easily recoverable roots and all tubers were separated and washed before determining fresh weights. All plant parts were dried, weighed, ground to pass a 40-mesh sieve, and analyzed for total P (5) after digestion in $HClO_4$ and HNO_3 acids. Petioles from the most recent fully expanded leaf (usually fourth from growing tip) were also taken at the same time for soluble PO_4-P analysis (1) and for monitoring other nutrients. Final tuber yields were measured at Kimberly by harvesting two rows, each 30 or 40 feet long, from each plot. Tubers were evaluated for uniformity and size distribution. Specific gravity was determined on about 10 lbs USDA #1 tubers from their weights in air and water.

RESULTS

<u>Kimberly location</u>

The 60 lbs of P/A preplant fertilizer application did not significantly increase total tuber yields but did significantly increase total USDA #1, the #1 > 10 oz, and reduced USDA #2 tubers (Table 2). The effects on yields from the mid-season P applications from both 12-62-0 and 10-34-0 were similar. Both sources increased total USDA #1, #1 > 10 Oz, and (#1+#2) > 10 oz tubers at the 40 lbs of P/A fertilization rate. Total USDA #2 and < 4 oz tubers were not influenced by either 10-34-0 or 12-62-0. Total tuber yields were slightly greater with glycerophosphate, however, USDA #1 tubers were not increased while #2 tubers were increased, particularly the #2 > 10 oz tubers (data not shown). Specific gravity was generally improved from P fertilization, with most of the improvement from the preplant P application. It should be indicated that this experiment was largely disease-free and that 60 lbs of P/A preplant would generally not be adequate for maximum tuber yields at this soil test P concentration (Table 1). Tuber yields in other companion treatments (data not shown) adequately supplied with preplant P were equivalent to that from the 40 lbs of P/A mid-season treatment using the 12-62-0 source.

Table 2. Effect of P fertilization on potato tuber yields, size distribution, and specific gravity in 1983 Kimberly experiment

	Controls		Mid-Season P Fertilizer Source: 12-62-0			10-34-0		glycerophosphate		LSD %5
	lbs P/A									
Preplant P	0	60	60	60	60	60	60	60	60	
Mid-Season P	0	0	20	40	80	20	40	20	40	
	cwt/A									
Total tuber yields	467	460	486	550	494	483	491	523	520	34
#1 Total	298	383	403	450	406	407	418	402	393	56
> 10 oz	92	130	139	186	185	149	204	133	148	34
#2 Total	130	30	46	57	53	50	32	82	79	47
< 4 oz	28	38	37	42	35	26	40	39	46	N.S.
(#1+#2)>10 oz	150	143	159	211	208	171	222	178	193	31
Specific gravity	1.081	1.084	1.083	1.083	1.085	1.084	1.082	1.085	1.085	N.S.

The P uptake data were combined across fertilizer sources at equivalent P rates since there were no significant differences between P sources. All mid-season P applications significantly increased the total P uptake 4 to 5 lbs of P/A at the August samplings, while only the 40 lbs of P/A mid-season rate was significantly greater than the preplant treatment at the September sampling (Fig. 1). The P uptake from 80 lbs of P/A as 12-62-0 was only slightly higher than the 40 lbs of P/A rate at all samplings (data not shown). All P applications (preplant and mid-season) significantly increased the P uptake at all samplings over the non-fertilized treatment (Fig. 1). The total P uptake in September was increased approximately 11 lbs of P/A by the preplant 60 lbs of P/A application.

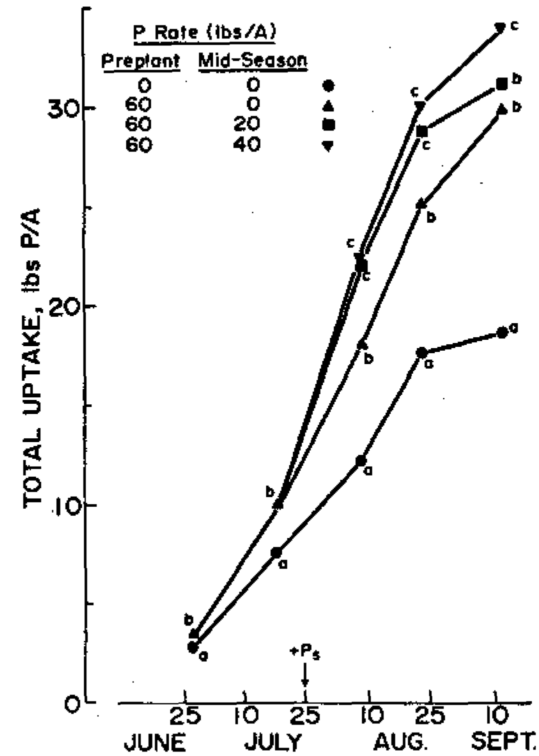

Fig. 1. Effect of preplant and mid-season P fertilization on total plant P uptake for 1983 Kimberly experiments. Phosphorus sources were combined by rate. Data points within a sampling date with different letters significantly different at the 95% probability level.

The soluble petiole PO_4-P concentrations in the preplant 60 lbs of P/A treatment was significantly greater than the non-fertilized treatment at all sampling dates (Fig. 2). Petiole PO_4-P concentrations were below 1000 µg/g by 8 August in both treatments, indicating that the total P uptake rates were less than those needed for the tuber growth rates (12). The petiole PO_4-P concentrations for all mid-season P sources were similar at equivalent P fertilization rates. Both the 20 and 40 lbs of P/A mid-season rates were different from each other and had significantly higher petiole PO_4-P concentrations than the other treatments. Both these rates effectively prevented the petiole PO_4-P concentration from dropping below 1000 µg/g during late tuber growth (August samplings). The 80 lbs of P/A treatment as 12-62-0 did not have a significantly larger petiole PO_4-P concentration than the 40 lbs of P/A treatment at any sampling. All petiole PO_4-P concentrations were below 1000 µg/g during the maturation growth stage (September sampling).

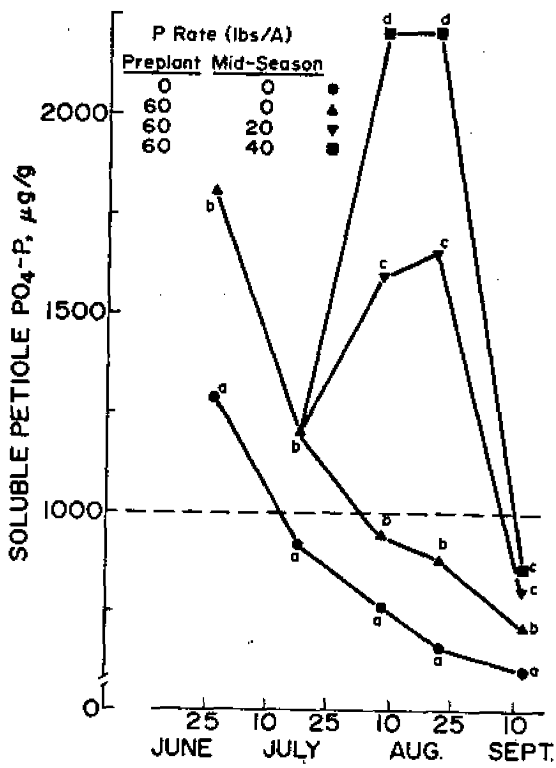

Fig. 2. The effect of preplant and mid-season P fertilizer applications of petiole PO_4-P concentrations in the 1983 Kimberly experiments. Phosphorus sources were combined by rate. Data points within a sampling date with different letters are significantly different at the 95% probability level.

Growers locations

The median increase in P uptake at the September sampling from the mid-season P fertilizer application on the growers' fields was about 5.8 lbs of P/A, ranging from 2.6 to 11.1 lbs of P/A. The increase was statistically significant at the 95% probability level on 10 out of the 12 fields. There was a tendency for larger increases on the coarser textured soils and lower lime-containing soils.

The average petiole PO_4-P concentration increase on the growers' fields from the mid-season P application was 900 μg/g approximately three weeks after application (mid-August sampling). None of the petiole PO_4-P concentrations on the growers' fields were less than 1000 μg/g because of the growers' supplemental fertilization practices.

DISCUSSION AND SUMMARY

It should be possible to predict the time required for the petiole PO_4-P concentration to decrease to 1000 μg/g if its decline follows a functional relationship. This approach was successful for NO_3-N concentrations in sugarbeet petioles (2). The equation used in that approach was $N = N_o e^{\underline{ct}}$, where N was the NO_3-N concentration at time (t), N_o was the concentration at the first sampling date after the peak NO_3-N concentration occurred, and (c) was a constant for any treatment on grower's field. This equation was used to calculate coefficients of linear determination (r) using the petiole PO_4-P concentrations and elapsed time from our data and published data (7, 11) where P fertilizers were not applied during the crop's growth. These coefficients (r) varied between -0.81 and -0.99 for 31 data sets with a median of almost -0.99. This indicates that future petiole PO_4-P concentrations could be reliably estimated by plotting the P concentration on semi-logarithmic paper, with the P concentration on the log scale (y-axis) and time (t) on the linear scale (x-axis), e.g., Fig. 3. The elapsed time interval from the first petiole sampling to when the PO_4-P concentration reached 1000 μg/g could then be estimated by extrapolating a straight line between the PO_4-P concentrations of the first and second samplings (between 10 and 20 days) down to the 1000 μg/g concentration (Fig. 3).

The predicted time interval (day) from the first petiole sampling to when the PO_4-P concentration reached 1000 μg/g was estimated for a number of examples following the procedure outlined in the previous paragraph and as illustrated in Fig. 3. This interval was then compared with the actual time interval (day) obtained from graphing all the petiole data for the entire growing season (Fig. 4). This relationship indicates that it is possible to predict when additional P fertilizer materials should be applied to a growing potato crop. The predicted time interval under-estimated the actual time interval by about 9%. Additional petiole samples past the first two samplings would also tend to increase the accuracy of the prediction.

The data presented in this paper indicate that a mid-season application of a high water soluble P fertilizer material can maintain an adequate P status of potato plants until normal maturation. A single application of 20 to 40 lbs P/A increased total P uptake by 4 to 5 lbs of P/A and maintained adequate petiole PO_4-P concentrations during all

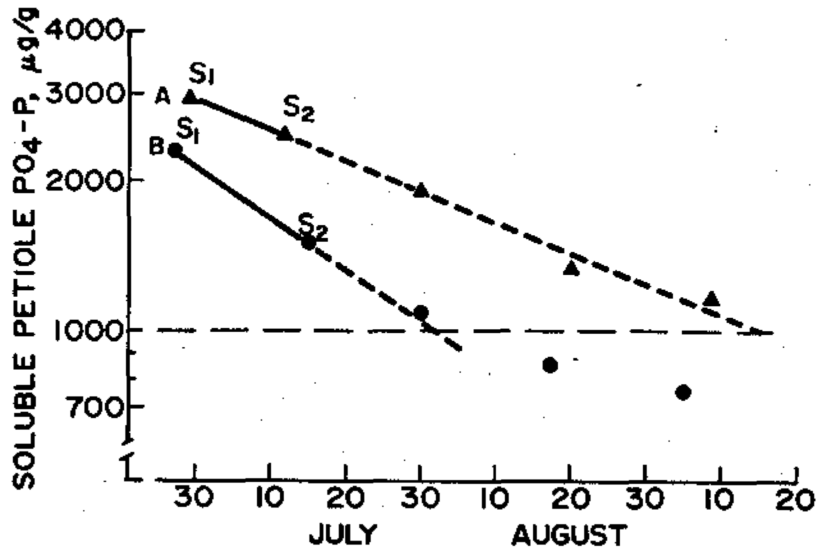

Fig. 3. Two examples of estimating future petiole PO4-P concentrations from two initial petiole samples on semi-logarithmic paper. S_1 and S_2 are the first and second PO_4-P concentrations, respectively, following the peak PO_4-P concentrations. The dashed line was extrapolated to 1000 μg/g PO_4-P by drawing a straight line between S_1 and S_2. Additional P fertilizer would need to be applied to field B, but not to field A.

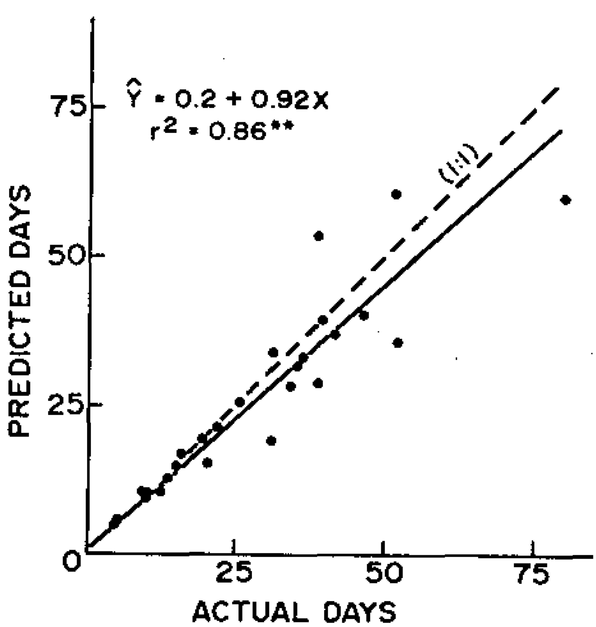

Fig. 4. Relationship between the actual days and the days predicted from the first two petiole samplings for the petiole's soluble P concentration to decline to 1000 mg kg^{-1} after the first sampling.

of the tuber growth stage. Final tuber yields, total USDA #1, and the (#1+#2) > 10 oz were also increased. An additional 3 lbs of P/A assimilated by the plant and used for tuber growth could increase final tuber yields 70 cwt/A if P was limiting during late tuber growth.

This study was not a rigorous comparison of sources, rates, methods, or timing of the mid-season application. As used in this study, both the 10-30-0 and 12-62-0 materials appeared to be equally effective and slightly better than the glycerophosphate source when measured in terms of tuber yields and quality. The optimum single mid-season application rate was between 20 and 40 lbs of P/A. The timing of this application may be predicted in advance because the decline in petiole PO_4-P concentration follows a definite functional relationship. In any situation, the P fertilizer material, if needed, should be applied to a healthy growing crop for the greatest response and benefits. An economic response from an application would not be anticipated once the potato plants are in their natural maturation growth stage, or within 20 to 30 days before scheduled vine kill. Growers are encouraged to first use a reliable preplant soil testing and fertilization program and then use the nutrient concentrations in the potato petioles to (a) monitor nutritional status and (b) schedule mid-season fertilizer materials when needed for maximum total yields and quality.

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