Potato Yield and Tuber Quality Did Not Respond to Phosphorus Fertilization of Soils Testing High in Phosphorus Content

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SUMMARY. Phosphorus (P) fertilization studies were conducted on four commercial farms and at the University of Florida Institute of Food and Agricultural Sciences Hastings Research and Education Center in Hastings. All sites were in the potato (*Solanum tuberosum*) production area of northeastern Florida. Preplant Mehlich-1 soil test P was very low at one commercial site and very high at the other four sites. The yield of marketable size A tubers, the desired tuber category, did not respond to P fertilization from 0 to 66 lb/acre (74.0 kg·ha^{-1}) of P at any site. The average yield across all sites was 324 cwt/acre [16.2 ton/acre (36.3 t·ha^{-1})]. Leaf-P concentration at midseason did not respond to P fertilization. Leaf-P concentration averaged 0.38%, which was sufficient for potato. Potato tuber specific gravity averaged 1.075 and responded slightly to P fertilization only at one site.

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Potato is produced on 23,000 acres (9,300 ha) in the spring in northeastern Florida (Witzig and Pugh, 2000) and 80% of the potatoes are used for processing (potato chips). The St. Johns River Water Management District in northeastern Florida has concerns about the potential nutrient losses from the agricultural area to the St. Johns River (Livingston-Way et al., 1997), and one of the District's concerns was P runoff from potato fields. Potato growers tend to apply high rates (often in excess of recommended rates) of fertilizer in an effort to minimize risk of yield loss caused by leaching of fertilizer due to heavy rainfall. The soils used for potato production are sandy and are irrigated by subsurface irrigation from a perched or high water table. These sandy soils are typically high or very high [>30 ppm (mg·kg^{-1})] in Mehlich-1 soil-test P content from years of continuous P fertilization of potato crops. Although the soil is very high in residual P content, potato growers still apply P fertilizer because they feel routine fertilization replaces P removed by previous crops and minimizes risk of yield loss to inadequate fertilization. P fertilization is viewed as inexpensive crop insurance.

Very few reports of P research on potato could be found in the literature but there has been substantial research in Florida with P fertilization of potato. Yield of potato did not respond to P fertilization of a sandy soil continuously cropped for 60 years and testing high in P (65 ppm ammonium-acetate-extractable P). However, potato yield did respond to up to 70 lb/acre (78.5 kg·ha^{-1}) of P (1 lb P = 2.3 lb P_2O_5) on a soil testing low (8 ppm) in P (Hensel, 1962). Similar results were found for a sandy peat, on which there were 60 years of fertility trials (Boswijk, 1976). On another sandy soil in Florida testing 5 ppm Mehlich-1 P, potato yield responded to 50 lb/acre (56.0 kg·ha^{-1}) P (Rhue et al., 1981a, 1981b). However, on a site with soil testing 237 ppm Mehlich-1 P, potato yield did not respond to P fertilization. Yield response to residual P was quadratic with yield response leveling off when the Mehlich-1 soil test concentration of P was above the range of 25 to 35 ppm. These researchers concluded that 35 ppm Mehlich-1 P was sufficient for optimum potato growth and yield, and that no more than 50 lb/acre of P were needed on soils testing less than 30 ppm P. Other studies in Florida in the early 1980s documented no potato yield response to P fertilization of soils testing high in Mehlich-1 P and concluded that removal of P with the potato harvest would not deplete soil P to yield threatening levels for many years (Yuan et al., 1985a, 1985b). Therefore, in 1989, the P fertilization recommendations, based on the Mehlich-1 soil-test index, were revised. A maximum of 50 lb/acre of P was recommended for soils testing <10 ppm Mehlich-1 P (Kidder et al., 1989). Subsequently, these recommendations were tested in several on-farm demonstrations in the northeastern potato area of Florida in the early 1990s by Hochmuth et al. (1993). On several farms with soils testing very high in P content, yields with the zero-P program were the same as the yields with the grower P programs of up to 50 lb/acre P, confirming the revised P recommendations for potato. Although current P recommendations have been researched and demonstrated to farmers, there has been a reluctance to adopt reduced P applications by potato farmers in Florida for continued fear of reduced yields with reduced or zero-P fertilization. The objective of these trials was to evaluate the current P recommendations on several commercial farms across the potato-producing region of northern Florida.

Materials and methods

Replicated trials were established during 1999 on four commercial farms and on the University of Florida Institute of Food and Agricultural Sciences Research and Education Center farm at Hastings, in northeastern Florida. Specific test fields on the commercial farms were chosen by the farmer and researchers sampled the soil in the upper 6 inches (15 cm) for Mehlich-1 P concentration. The soil at the University of Florida Research and Education Center site was an Elsey fine sand, sandy, siliceous, hyperthermic, Arenic,

Table 1. Potato production information for five fields in northeastern Florida in 1999.

Production site[z]	Prefertilization Mehlich-1 soil test P index [ppm (mg·kg^{-1})]	N–K fertilization at planting (lb/acre)[y]	N–K fertilization total (lb/acre)	Planting date	Harvest date
One	234	170–145	270–280	11 Feb.	26 May
Two	5	110–125	270–215	8 Feb.	17 May
Three	146	100–100	240–190	9 Feb.	17 May
Four	250	20–200	240–230	17 Feb.	27 May
Five	376	65–230	230–230	18 Feb.	27 May

[z]Site one located at the University of Florida Institute of Food and Agricultural Sciences Hastings Research and Education Center, Hastings.
[y]1 lb/acre = 1.1 kg·ha^{-1}.

Ochraqualf. Soils at the commercial sites were not classified but were similar in nature to the soil at the Research and Education Center. In northeastern Florida, potatoes are grown on raised beds with 40 inches (1.1 m) between centers and grouped with 16 beds between irrigation/drainage ditches (Hochmuth et al., 1999). Florida potato growers apply fertilizer at several times in the potato-growing season, including before, during, and after planting. P and potassium (K) fertilizers are often broadcast before planting. Nitrogen (N), K, and additional P fertilizers are applied just before or at planting. More N and K fertilizers are banded in one or two applications later in the growing season.

All fields used for these studies had been planted in a sorghum-sudan grass cover crop [*Sorghum bicolor* X S. *arundinaceum* var. SX17, (Dekalb Genetics Corp., Dekalb, Ill.)] during the summer and fall between potato crops. The cover crop was incorporated into the soil with a disk and bedding machine one to two months before bed preparation for potato planting. At bed preparation, some growers banded preplant N and K in the bed, and a nematicide was injected in the soil. The experimental P was supplied from triple super phosphate and the treatments were 0, 11, 22, 44, and 66 lb/acre (0, 12.3, 24.7, 49.3, and 74.0 kg·ha^{-1}) P. The P was mixed with the at planting amounts of N and K (Table 1), and applied with a plot planter at all sites, except site four, by banding the fertilizer 2 inches (5 cm) deep and 2 inches to both sides of the seed piece. The preplant N and K fertilizers were applied by the grower at site four by incorporating the fertilizers in the bed. The P at site four was applied by the researchers with the plot planter. The variable N and K fertilization practices used by the growers led to differential amounts of N and K applied for potatoes at each site. Seed pieces of 'Atlantic' potato were cut to a target size of 2.5 oz (71 g) and planted during February 1999 (Table 1). Plots consisted of four rows of potatoes each 25 ft (7.6 m) in length. Treatments were replicated four times in a randomized complete-block design at each site.

The potato crop was irrigated by subsurface irrigation from an elevated water table to keep the soil moisture tension in the root zone near –10 centibars (kPa) throughout the season. An application of an N and K fertilizer mixture was made when the plants were 4 inches (10 cm) in height by injecting liquid (mixtures of urea/ammonium nitrate/potassium chloride/potassium sulfate) fertilizer into the sides of the beds. Foliar diseases and insects were controlled by applications, made by the grower, of labeled pesticides. Samples of most-recently-matured whole potato leaves were taken from plants in each plot during early bloom for P analyses. Leaves were oven-dried at 160 °F (70 °C) and P concentration in the samples was determined by dry-ashing followed by P analyses by inductively coupled plasma emission spectroscopy.

Potatoes from the inner two rows were harvested mechanically during May 1999 (Table 1) and tubers were washed and graded into five size categories. Marketable potatoes included size B [1.5 inches (3.8 cm) to 1.9 inches (4.8 cm)] and four classes of size A [1.9 to 2.5 inches (6.4 cm), 2.5 to 3.0 inches (7.6 cm), 3.0 to 3.75 inches (9.5 cm), and >4.0 inches (10.2 cm)] tubers. Damaged, decayed, or misshapen tubers were classified as unmarketable. A random sampling of size-A potatoes was made from each plot for determination of tuber specific gravity (ratio of weight-in-air to weight-in-water). Planting dates, soil P concentration, and production practices differed for each site, therefore all data were separately analyzed for each site with analysis of variance.

Results and discussion

The preplant Mehlich-1 soil-test P concentrations ranged from 5 ppm (very low) to 375 ppm (very high) across the five sites (Table 1), with responses to P fertilization expected for soils testing below 31 ppm P (Hochmuth and Hanlon, 1995). Thus, yield response was expected only for site two. Soil pH, measured in a 2 water : 1 soil mixture was 6.9, 6.1, 5.3, 5.7, and 6.0 for sites one through five, respectively, all acceptable for potato production in Florida.

Leaf-P concentration at early blooming did not vary with P fertilization (Table 2). Leaf P concentrations with all P fertilization treatments were sufficient for normal potato growth (Hochmuth et al., 1991; Kunkel et al., 1973; Locascio and Breland, 1963).

Yields of size A tubers did not respond to P fertilization at any production site (Table 2). Size A tubers typically make up the bulk of potato yields and comprise the most desirable category of commercial tubers. All yields were above the Florida average yield of 286 cwt/acre (32.1 t·ha^{-1}) cited by Witzig and Pugh (2000), except for site three. This farm has very coarse-sandy soil and yields in other research trials at this farm have tended to be lower than yields at many other farms in the potato production area of northeastern Florida (G. Hochmuth, personal communication). The lack of yield response for site two was not expected since the soil P concentration was very low. Rhue et al. (1981a,

Table 2. Size-A marketable potato yield, tuber specific gravity, and leaf phosphorous concentration responses to phosphorous fertilization for five sites in northeastern Florida.

Production site[z]	P rate (lb/acre)[y]	Yield size A tubers[x] (cwt/acre)[y]	Tuber specific gravity[w]	Midseason leaf P concn (%)
One	0	334	1.074	0.34
	11	336	1.074	0.37
	22	361	1.074	0.38
	44	352	1.075	0.41
	66	366	1.073	0.38
	F test (P)	NS (0.1458)	NS	NS
Two	0	352	1.074 bc	0.40
	11	363	1.073 c	0.40
	22	367	1.076 a	0.48
	44	371	1.076 a	0.45
	66	376	1.075 ab	0.40
	F test (P)	NS (0.5094)	*	NS
Three	0	221	1.081	0.36
	11	213	1.078	0.35
	22	196	1.079	0.39
	44	229	1.082	0.40
	66	236	1.080	0.35
	F test (P)	NS (0.5170)	NS	NS
Four	0	367	1.073	0.38
	11	377	1.073	0.36
	22	346	1.074	0.37
	44	371	1.074	0.34
	66	378	1.073	0.43
	F test (P)	NS (0.2802)	NS	NS
Five	0	302	1.073	0.36
	11	312	1.074	0.38
	22	308	1.073	0.40
	44	317	1.073	0.38
	66	339	1.073	0.37
	F test (P)	NS (0.0676)	NS	NS

[z]Site one located at the University of Florida Institute of Food and Agricultural Sciences Hastings Research and Education Center, Hastings.
[y]1 lb/acre phosphorus = 2.3 lb/acre phosphate (P_2O_5), 1 lb/acre = 1.1 kg·ha^{-1}, 1 cwt/acre = 0.05 ton/acre = 0.11 t·ha^{-1}.
[x]Size A tubers are those >1.9 inches (4.8 cm) diameter. CV values were 6%, 5%, 15%, 6%, and 5% for sites one through five, respectively.
[w]Values followed by the same letter within a column do not differ significantly according to the Waller-Duncan k ratio t test, k = 100 (P = 0.05).
[NS,*]nonsignificant or significant at $P < 0.05$, respectively.

1981b) observed a yield response on a soil testing as low as 5 ppm Mehlich-1 P. A second soil test was made on unfertilized plots at site two in midseason to check for inadvertent P fertilization by the grower during the season. The second soil test value was 10 ppm, confirming the low soil test values obtained before planting and largely eliminating the possibility of inadvertent P fertilization during the growing season. This yield result could indicate that the current soil test recommendations are conservative at low Mehlich-1 values, and may result in a recommendation of P when no P would be required.

Yield of size B tubers was not affected by P fertilization (data not shown) averaging 20 cwt/acre (2.2 t·ha^{-1}). Yields of unmarketable tubers were low, ranging from 0 to 10 cwt/acre (1.1 t·ha^{-1}) for all sites (data not shown).

The lack of tuber yield responses on the four farms with soils testing very high in P content was expected, and supports the results of Hochmuth et al. (1993) and those of Rhue et al. (1981a, 1981b). These field tests confirmed the current potato P fertilization recommendations for used by the University of Florida are adequate for soils testing high in P concentration.

Potato tuber specific gravity is a measure of chipping quality of potato tubers. Higher specific gravity indicates higher-value tubers because more potato chips will result per unit weight of tubers, compared with tubers of lower specific gravity. Average potato tuber specific gravity in this study was very high for Florida-grown potatoes. Specific gravity responded to P treatment only at site two where higher specific gravities resulted with intermediate rates of P (Table 2).

Potato growers can refrain from routinely applying P fertilizers to potatoes being produced on sandy soils with >30 ppm Mehlich-1 residual P. More research on soils testing very low in P would be needed to confirm current University of Florida recommended amounts of P for potato production on soils with <30 ppm Mehlich-1 P. Those recommendations currently are for up to 50 lb/acre P for soils testing very low in P, with up to 10 lb/acre (11.2 kg·ha^{-1}) P as starter P banded at planting for planting in cool soils of any Mehlich-1 P content. These results would likely apply to many potato-producing areas in the southeastern United States with similar sandy soils and high levels of residual P.

Literature cited

Boswijk, A. 1976. The effect of fertilizers on the yields of industrial potatoes in an intensive cropping plan on sandy peat. Ann. Agron. 27:771–780.

Hensel, D. 1962. Phosphorus fertilization of potatoes on Ona fine sand. Soil Crop Sci. Soc. Fla. Proc. 22:130–134.

Hochmuth, G.J. and E.A. Hanlon. 1995. IFAS standardized fertilization recommendations for vegetable crops. Fla. Coop. Ext. Serv. Circ. 1152.

Hochmuth, G., E. Hanlon, G. Kidder, D. Hensel, W. Tilton, J. Dilbeck, and D. Schrader. 1993. Fertilization demonstrations for the tri-county potato production area of northeast Florida. Proc. Fla. State Hort. Soc. 106:190–198.

Hochmuth, G, D. Maynard, C. Vavrina, and E. Hanlon. 1991. Plant tissue analysis and interpretation for vegetable crops in Florida. Fla. Coop. Ext. Serv. Spec. Ser. SS-VEC-42.

Hochmuth, G.J., D.N. Maynard, C.S. Vavrina, W.M. Stall, T.A. Kucharek, P.A. Stansly, T.G. Taylor, S.A. Smith, and A.G. Smajstrla. 1999. Potato production in Florida, p. 201–208. In: D.N. Maynard and G.J. Hochmuth (eds.). Vegetable production guide for Florida. Fla. Coop. Ext. Serv. Circ. SP-170.

Kidder, G., E.A. Hanlon, and G.J. Hochmuth. 1989. IFAS standardized fertilization recommendations for vegetable crops. Fla. Coop. Ext. Serv. Spec. Ser. SS-SOS-907.

Kunkel, R., N. Holstad, and T.S. Russell. 1973. Mineral element content of potato plants and tubers vs. yields. Amer. Potato J. 50:275–282.

Livingston-Way, P., G. Hochmuth, E. Hanlon, A. Tilton, D. Bottcher, B. Reck, and J. Konwinski. 1997. Assessment of agricultural BMPs in the tri-county agricultural area of northeast Florida. Univ. Fla. Coop. Ext. Serv. Misc. Publ.

Locascio, S.J. and H.L. Breland. 1963. Irish potato yield and leaf composition as affected by dolomite and phosphorus. Soil Crop Sci. Soc. Fla. Proc. 23:95–99.

Rhue, R.D., D.R. Hensel, T.L. Yuan, and W.K Robertson. 1981a. Response of potatoes to soil and fertilizer phosphorus in northeast Florida. Soil Crop Sci. Soc. Fla. Proc. 40:58–61.

Rhue, R.D., D.R. Hensel, T.L. Yuan, and W.K Robertson. 1981b. Ammonium orthophosphate and ammonium polyphosphate as sources of phosphorus for potatoes. Soil Sci. Amer. J. 45:1229–1233.

Witzig, J.D. and N.L. Pugh. 2000. Florida agricultural statistics. Vegetable summary. Fla. Agr. Stat. Serv., Orlando.

Yuan, T.L., D.R. Hensel, R.S. Mansell, and R.D. Rhue. 1985a. Yield and nutrient content of potato on a sandy Humaquept with high levels of accumulated Ca and P. Soil Crop Sci. Soc. Fla. Proc. 44:68–71.

Yuan, T.L., D.R. Hensel, and R.S. Mansell. 1985b. Nutrient status of a sandy Humaquept under long-term potato cultivation. Soil Crop Sci. Soc. Fla. Proc. 44:93–97.

Stratification Improves and Is Likely Required for Germination of *Aconitum sinomontanum*

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Additional index words. monkshood, sexual propagation, dormancy, herbaceous landscape plants

Summary. ***Aconitum sinomontanum*** **is a robust perennial monkshood native to China that shows promise as a cultivated ornamental. However, nothing has been reported about the germination requirements of the species, and little is known about the requirements of the genus as a whole. The objective of this study was to test the influence of stratification (moist prechilling) on germination of *A. sinomontanum* seeds. The seeds were from wild-collected plants of identical provenance growing at the Arnold Arboretum (Jamaica Plain, Mass.). After harvest and before stratification, seeds were stored dry at 38 °F (3.3 °C) and percentage germination was assessed after seeds were stratified, also at 38 °F, for 0, 21, 42, or 84 days. It is likely that stratification is required for seeds of this species to germinate, as unstratified seeds failed to germinate through the duration of the experiment (73 days). The highest level of germination (90.8%) was achieved after 84 days of stratification, and as length of stratification increased, so did percentage germination and indices of peak value and germination value. Days to maximum germination decreased with additional days of chilling. Growers wishing to germinate seed of this species should stratify seed for 3 months to achieve the highest level of germination.**

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Herbaceous perennial plants have increased in popularity and use in the ornamental landscape, particularly in the past 2 decades. Coincident with the surge of interest, many promising, new herbaceous species have been released, some successfully brought into cultivation from the wild for the first time, such as several clones of the blue corydalis (*Corydalis flexuosa*) from Sichuan, China (Rix, 1993).

Species of monkshood (*Aconitum* spp.) are valued in the horticultural trade for their late summer and autumn dark blue to purple floral displays and finely textured, divided leaves reminiscent of delphinium (*Delphinium*) also in the Ranunculaceae. While the genus contains about 100 species of annual, biennial and perennial herbaceous plants, only a few are found in cultivation. Native to Europe, the common monkshood (*A. napellus*) may be the most frequently grown of the species, having the general attributes and characteristics of the genus and reaching about 4 ft (1.2 m) in height. Others encountered include the asian azure monkshood (*A. carmichaelii*), the european yellow wolfsbane (*A. lamarckii*) and the hybrid bicolor monkshood (*A. ×cammarum*).

In September 1994, during a North America China Plant Exploration Consortium (NACPEC) expedition, several plants of *A. sinomontanum* were found on Wudang Shan, Hubei Province (lat. 32°23'43" N, long.111°00'13" E), at an altitude of 4272 ft (1302 m), growing among wild english or persian walnut (*Juglans regia*), chinese chestnut (*Castanea mollissima*), and *Lindera obtusiloba*. As the fruit had not yet matured, several young plants from the same population were collected under the number WD 067. Although this species was described in 1935 (Nakai, 1935), this collection likely represents its only introduction to cultivation.

Some of these original plants (394-95 MASS) are growing at the Arnold Arboretum of Harvard University. The species shows potential for introduction as a cultivated ornamental, particularly after further evaluation and selection. While plants on Wudang Shan were observed to be only 3.3 ft (1 m) in height, plants under cultivation at the Arnold Arboretum ultimately produce erect stems up to 7.2 ft (2.2