Phosphorus Fertilization for Caladium Tuber Production on Organic Soil

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SUMMARY. Phosphorus is considered a major pollutant of lakes in central Florida, and growers producing crops in the Lake Okeechobee watershed are being challenged to reduce use of P fertilizer. Caladium (*Caladium ×hortulanum* Birdsey) tubers are produced on organic soils within this area. This study was done to determine if current commercial P fertilization rates could be reduced or eliminated, since these organic soils have high levels of water extractable P (P_w). Two farms were selected with low (Farm A 19 lb / acre; 21 kg·ha^{-1}) or high (Farm B 59 lb / acre; 66 kg·ha^{-1}) preplant P_w levels. Production of caladium tubers with the standard grower P fertilization practice (Farm A = P at 39.2 lb / acre; 43.9 kg·ha^{-1}, or Farm B = P at 15.9 lb / acre; 17.8 kg·ha^{-1}) was compared to production with either one-half the standard grower rate of P or no P. The percentage of harvested tubers in each of five grades and the estimated harvested tuber value index were similar irrespective of the amount of P fertilizer used on either farm. These results indicate that P could be eliminated from the fertilization program for caladium tuber production on organic soils.

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Caladium tubers are produced on organic soils (Histosols) in central Florida and are irrigated with surface waters from canal systems connecting a series of lakes. Phosphorus is considered a major pollutant in these surface waters, and agricultural enterprises are always challenged to reduce use of P fertilizers to minimize the impact from P in the Lake Okeechobee watershed (Izuno et al., 1991). The potential for P pollution from organic soils is common in other areas of the United States and Canada as well since organic soils are often linked to environmentally sensitive wetlands; drainage and farming practices often lead to mineralization of P and other nutrients (Cogger and Duxbury, 1984; Lucus, 1982).

The effect of rates of complete (N–P–K) fertilizers on caladium tuber production have been reported (Harbaugh and Overman, 1983), but reports dealing with the ratio of N to P to K to optimize caladium tuber production under field conditions are unknown. Fertilization practices have often developed for ornamental crop production without detailed studies on the effects of the ratio of N to P to K. This may be due to several factors including 1) the total fertilization cost is generally <3% of the variable production cost (Taylor et al., 1990), 2) the ratio of P in the macro nutrient mixture has a relatively insignificant effect on total fertilization costs, 3) the crop value is high compared to many crops, and 4) the crop response (yield and / or crop quality) can be greatly influenced by fertilization. Consequently, there has been a tendency to overfertilize with one or all three of the primary macro nutrients on high-value ornamental crops. Recognition of the potential pollution of surface or ground water sources, however, has led to the desire to develop more precise and conservative fertilization practices on many ornamental crops, including caladiums.

Phosphorus mineralization rates from central Florida organic soils ranged from 34 to 164 lb / acre (38 to 184 kg·ha^{-1}) per year (Reddy, 1983), and from 5 to 64 lb / acre (5.6 to 72 kg·ha^{-1}) for drained soils or 32 to 78 lb / acre (35.8 to 87.4 kg·ha^{-1}) for flooded South Florida organic soils (Diaz et al., 1993). Before this study, we randomly sampled soil from several caladium fields that had been farmed for at least 20 years; P_w soil levels ranged from 19 to 55 lb / acre (21 to 62 kg·ha^{-1}) (B.K. Harbaugh, unpublished data). These P_w soil levels were generally well above levels shown to be adequate for root or tuberous vegetable crops on organic soils (Sanchez, 1990). For example, the critical P_w value for radishes and potatoes was 14 lb / acre (16 kg·ha^{-1}) and 16 lb / acre (18 kg·ha^{-1}) for carrots. We hypothesized, therefore, that caladiums could be produced with lower rates of P fertilizer than were currently being used. This study was conducted to determine if P applications could be reduced or eliminated compared to current fertilization practices for caladium tuber production.

Materials and methods

Three soil samples from several commercial farms were analyzed for P_w, and two farms were selected to represent low (Farm A, 19 lb / acre; 21 kg·ha^{-1}) or high (Farm B, 59 lb / acre; 66 kg·ha^{-1}) P_w soil levels for the caladium production area. Farm A had been in production for >20 years with P generally surface-broadcasted with the N and K fertilizer. Farm B had been in production for >30 years with various rates of P applied as granular single superphosphate (0N–8.7P–0K) incorporated preplant in the soil and / or surface broadcast postplant in a macronutrient fertilizer.

Caladium tuber production with the standard P fertilization practice for each farm was compared to production with no P or one-half the standard grower rate of P. Three side-by-side 0.2-acre (0.08-ha, Farm A) or 2-acre (0.8-ha, Farm B) plots were used for these tests with each plot serving as an experimental unit. The experimental design was a randomized complete block with three 1-year replications in time. Statistical analyses were performed on data using analysis of variance, and means separated where appropriate using Fisher's protected $LSD_{0.05}$ (PROC ANOVA, SAS Inst., Cary, N.C.).

Land preparation, planting (mid to late April), culture during the growing season, and harvesting practices (mid to late January) were unchanged from normal operations on both farms and were performed by the managing growers. The standard fertilization practice utilized for Farm A was three surface applications of a granular 8N–3.5P–6.6K at 375 lb / acre (420 kg·ha^{-1}) mid

Table 1. Effect of P fertilization practices on the percentage of tubers in each of five commercial marketing categories, value of harvested tubers, and P removed in harvested tubers for two commercial farms.[z]

P applied[y] (lb/acre)	Tuber size category (%) No. 3	No. 2	No. 1	Jumbo	Mammoth	Tuber value index[x]	P removed (lb/acre)[w]
				Farm A			
39.2	32	29	31	8	---	43,004	18.1
19.6	29	29	34	9	---	45,464	18.1
0.0	32	30	31	7	---	45,632	19.2
Significance	NS	NS	NS	NS	NS	NS	NS
				Farm B			
15.9	35	29	29	6	1	423,080	16.9
8.0	37	29	26	7	1	402,520	15.8
0.0	37	30	27	5	1	373,480	14.6
Significance	NS	NS	NS	NS	NS	NS	NS

[z]Farm A = 0.2-acre (0.08-ha) and Farm B = 2-acre (0.8-ha) plots.
[y]Standard grower P fertilization rate: Farm A = 39.2 lb / acre (43.9 $kg \cdot ha^{-1}$) and Farm B= 15.9 lb / acre (17.8 $kg \cdot ha^{-1}$); 1.0 lb / acre = 1.12 $kg \cdot ha^{-1}$.
[x]An estimated tuber value index was calculated using the following formula: (n No. 3) + (1.5n No. 2) + (3n No. 1) + (6n Jumbo) + (9n Mammoth), where n is the number of tubers in that grade.
[w]The estimated P removed from the field in harvested tubers, (root and leaf tissue remain in the field and are plowed under).
[NS]ANOVA treatment effects nonsignificant at $P \leq 0.05$.

to late June, July, and August depending on weather and soil moisture. On Farm B, the standard practice was to surface broadcast 365 lb / acre (409 $kg \cdot ha^{-1}$) of a 10N–2.2P–12.4K fertilizer the last week of June and 397 lb / acre (445 $kg \cdot ha^{-1}$) of a 10N–2.2P–12.4K fertilizer during August. Both farms relied upon subirrigation for the main source of irrigation, but Farm B could apply irrigation overhead if water levels in the canal systems were less than satisfactory for optimal soil moisture.

For farm A, the one-half P rate was achieved by surface application of a granular 8N–1.7P–6.6K at the same N and K rates and on the same dates as the standard practice. The one-half P rate on Farm B was accomplished by surface application of a 10N–0P–12.4K for the June application and the normal 10N–2.2P–12.4K in August. An 8N–0P–6.6K or 10N–0P–12.4K was used for the no-P treatment applied at the same N and K rates and on the same dates as the standard fertilizers used for Farm A and B, respectively.

Soil and leaf samples were taken around the third week of June, July, August, September, and October, but always before any fertilization was done for that month. Sampling was discontinued at this time since leaves abscise and foliage is minimal after October. Soil samples were taken as three 6-inch (15-cm) deep cores from three locations within each plot. Soil was analyzed for water extractable P by the Murphy-Riley, molybdate-ascorbic acid, single-solution method (Sanchez, 1990). These organic soils are acidic with an average pH of 4.7, even after liming. Thus P_w and acid extractable P levels are very similar. About 10 caladium leaf blades were sampled from three locations within each plot. Leaf P was determined using an inductively coupled argon plasma spectrometer (Hanlon et al., 1994).

'Candidum', the most widely grown caladium cultivar (Bell et al., 1998), was used for these experiments. Harvested tubers were graded into commercial grade categories of No. 3, 0.75 to 1.5 (1.9 to 3.8); No. 2, 1.5 to 2.5 (3.8 to 6.4); No.1, 2.5 to 3.5 (6.4 to 8.9); Jumbo, 3.5 to 4.5 (8.9 to 11.4); and Mammoth, >4.5 (11.4) inches (cm) in diameter. An estimated tuber value index was calculated using the following formula: (n No. 3) + (1.5n No. 2) + (3n No. 1) + (6n Jumbo) + (9n Mammoth) where n equals the number of tubers harvested in that grade. The tuber value index was used to reflect crop value, as prices change from year to year and grower to grower, but the differences in tuber value between grades usually remain constant. Ten harvested tubers for each size category from each plot were also analyzed for P utilizing the same method described for leaf tissue.

Results and discussion

On both farms, the percentages of tubers in each size category were similar regardless of the amount of phosphorus applied (Table 1). The harvested tuber value indexes were also similar. Both factors are important since different enterprises may have markets that demand certain sizes of tubers, but the total tuber value per acre could be similar due to plant spacing or other factors.

On Farm A, the soil P_w was significantly greater for the standard grower practice compared to the no-P rate, with the one-half P rate resulting in intermediate P_w levels for July, August, and September samples (Table 2). For June, where samples were taken before fertilizer application and thus represent the base line for each treatment, and October soil samples, P_w levels were similar. On Farm B, there were similar P_w soil levels for all sampling dates. This farm had a very high initial P_w, so the applied P appeared to have little influence on P_w soil levels throughout the year.

Leaf tissue P levels were higher for September and October samples for leaves from both the standard grower practice and the one-half P rate compared to the no-P rate on Farm A (Table 2). On Farm B, there were no differences in leaf tissue P levels due to P fertilization treatments. Interestingly, leaf tissue P levels were similar for both farms even though P_w soil levels were two to three times higher on Farm B than on Farm A.

Optimal P_w soil levels have not been reported for caladium tuber production, but for September and October sampling dates for Farm A , P_w soil levels were near or below critical values reported for radishes and potatoes on muck soils (Sanchez, 1990). However, leaf tissue levels were never below

Table 2. The effect of P fertilization practices[z] on P_w soil levels and tissue P levels during the growing season on two farms.

P applied	Soil P_w (lb/acre)					Leaf tissue P (% dry wt)				
(lb/acre)	June	July	Aug.	Sept.	Oct.	June	July	Aug.	Sept.	Oct.
					Farm A					
39.2	19	26 a[y]	30 a	18 a	13	0.59	0.65	0.64	0.62 a	0.70 a
19.6	19	22 ab	26 ab	16 b	12	0.61	0.64	0.63	0.63 a	0.69 a
0.0	19[NS]	17 b	18 b	11 c	10[NS]	0.61[NS]	0.62[NS]	0.60[NS]	0.53 b	0.59 b
					Farm B					
15.9	59	60	69	53	49	0.52	0.61	0.57	0.62	0.65
8.0	59	62	64	51	48	0.52	0.63	0.57	0.61	0.63
0.0	57[NS]	64[NS]	62[NS]	52[NS]	47[NS]	0.55[NS]	0.62[NS]	0.58[NS]	0.61[NS]	0.65[NS]

[z]Standard grower P fertilization rate: Farm A = 39.2 lb / acre (43.9 $kg\cdot ha^{-1}$) and Farm B= 15.9 lb / acre (17.8 $kg\cdot ha^{-1}$); 1.0 lb / acre = 1.12 $kg\cdot ha^{-1}$.
[y]For each farm, mean separation within columns by Fishers's protected $LSD_{0.05}$.
[NS]Nonsignificant.

0.52% P on either farm for any sampling date. Leaf tissue P of 0.52% was determined optimal for caladium tuber production in studies on potted caladiums (Harbaugh, 1987). Thus, even though there were relatively low P_w soil levels, the high leaf tissue P and the lack of differences in tuber yields due to P fertilization practices indicated there was adequate soil P available for tuber development and high yields.

From the tuber tissue analyses, we estimated that 14.6 to 19.2 lb / acre P (16.4 to 21.5 $kg\cdot ha^{-1}$) was removed in the harvested tubers for both farms (i.e., lb / acre = oz of P per tuber grade multiplied by the number of tubers per grade per acre). Although we have not performed tests to determine the potential release of nutrients from this organic soil, the amount of P removed in the harvested tubers was well below the potential mineralization rates of 34 to 164 lb / acre (38 to 184 $kg\cdot ha^{-1}$) reported by Reddy (1983) for central Florida soils. In addition to mineralization of the peat, caladium leaves and roots are left in the field at harvest and their decomposition also could contribute to replacement of P removed in the tubers each year. Even without additional P fertilizer, it appears that sufficient levels of soil P become available in these organic soils to maximize caladium tuber yields.

These results indicate that at present, even in caladium fields with relatively low P_w soil levels, no additional P would be required for optimal caladium tuber yields. If P fertilization was eliminated from caladium tuber production, soil levels could be monitored over the years to determine if levels would fall below those seen in this study. If soil P_w levels drop due to changes in fertilizer practices, subsidence, or other factors which may occur in future years, experiments could then be designed to regress P rates on yield for fields with residual P_w levels below those used in this test. Until or if these changes occur, eliminating P in the fertilizer would be a welcome practice by both the caladium growers and the water management agencies. The potential danger of P entering surface water as a result of farming practices related to caladium tuber production would be reduced without compromising tuber yields.

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