The Comparative Phosphorus Requirements of Flooded and Non-Flooded Taro

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Abstract

Estimated levels of P in soil solutions were correlated with yield and leaf P percentage of *Colocasia esculenta* growing in flooded and non-flooded field plots. Phosphorus in submerged soils was estimated in soil solution extracted through ceramic filters and in non-flooded soils from phosphate sorption curves and saturation extracts. Approximately 0.02 ppm P in solution was required for 95 percent of maximum yield. Taro grown in flooded, unfertilized soil which supported 0.02 ppm P in solution did not respond to phosphate fertilization. Leaf P associated with near maximum production was about 0.4 percent. Although yield potential was greater for flooded taro, the external P requirement was not different from the non-flooded crop, probably because of greater cross-sectional area for diffusion of P to roots in flooded soils.

Introduction

Colocasia is an adaptable crop, it grows on a wide range of soil but for maximum growth fertile soils are required. When grown under less than ideal conditions, it responds to fertilization (Hodnett 1958, Plucknett and de la Peña 1971). Taro has responded to P fertilization both under flooded and non-flooded conditions in Hawaii (Plucknett and de la Peña 1971). P rates in their experiment ranged from 0-1120 kg/ha and optimum yields were obtained in the range 200-500 kg P/ha.

The chemistry and physics of flooded soils are usually more favorable to P solubility and P diffusion to roots than normally obtained in highly weathered soils that are freely drained. Thus, other things being equal, the external P requirement (estimated P concentration of the soil solution associated with a given level of production) should be less for flooded taro than for taro grown on well-drained soils. But things are not equal. The yield potential (at least in Hawaii) is greatest for flooded taro. Thus, the internal, quantitative requirement for P is also greater. To what extent these two features – greater internal requirement and greater intensity of the external supply – may be offsetting is one of the topics being considered in this paper.

Another related topic is the appropriateness of various procedures for evaluating the phosphorus status of soil – taro systems, and P fertilizer requirements for those systems which are deficient. The chemistry of well-drained soil changes so drastically upon flooding that the usual methods of evaluating the P status of soil will not apply to the new situation. The composition of the soil solution, *in situ,* should have universal application. While it may not be possible ever to determine the exact *in situ* condition, it is possible to approximate the conditions experimentally.

Materials and Methods

Non-flooded Experiment. A field test was sited on the island of Kauai. The soil was a Typic Gibbsihumox. Plots used had 10 levels of P established in 1971 in an augmented block design (Federer 1956). The plots were cropped repeatedly and P was applied before each crop to establish P levels in solution as follows: 0.002 (no P added), 0.003, 0.006, 0.012, 0.025, 0.05, 0.1, 0.2, 0.4 and 1.6 ppm (Fox and Kamprath, 1970). The concentration actually determined prior to establishing this test and the fertilization rates required to produce the desired levels are given in Table 1. The P plots were split with the pH adjusted on one half of each plot with $CaSiO_3$ and on the other half with $CaCO_3$. Soil pH was re-adjusted to 6.0 prior to the taro test. Liming materials, phosphorus as required, 100 kg K/ha as muriate of potash, and 50 kg N/ha as ammonium sulphate and 50 kg N/ha as urea were broadcast applied then rotovated into the surface 15 cm of soil before planting taro.

Three varieties of *C. esculenta* were planted in subplots: Lehua Maoli, the most common variety in Hawaii; Bun Long, a new chipping variety; and dasheen, locally called "Araimo." Three rows each of Lehua and Bun Long and two rows of dasheen at a spacing of 60 x 60 cm were planted in January 1978.

Leaf blades were sampled 3 months after planting, using as sample material the most recently fully expanded leaf. Root samples were also taken to determine the amount of vesicular arbuscular (VA) mycorrhizal infection in the root cortex. At this time another 100 kg/ha of N (urea) and K (KCl) were applied.

The dasheen matured early and was harvested during late September 1978. The varieties Lehua Maoli and Bun Long were harvested in late October 1978. Corms of the Lehua Maoli and Bun Long varieties were analyzed for nutrients and root samples were examined for VA mycorrhizae. Elemental analysis of leaf and corms samples were done (except for P) by x-ray fluorescence quantometer. The phosphorus contents of corms were determined in a 2:1 nitric perchloric acid digest (Blanchar 1965). Mycorrhizal infection was determined by the procedure of Phillips and Hayman (1970).

Flooded Experiment. The experimental design and phosphorus levels employed for the field test on flooded soil (Typic Tropaquept) were similar to those already described for the non-flooded experiment except that only $CaCO_3$ was used as liming material and a single variety, Lehua Maoli, was planted. Nitrogen (urea) and potassium (KCl) were uniformly applied at the rate of 200 kg/ha each. The test was planted Aug. 1972. Subsequent to planting, ceramic filter candles were inserted into the puddled zone. A length of surgical tubing was attached. The tube was closed off except when solution were being withdrawn from the filter candles. Samples of solution were withdrawn using a 25 ml syringe fitted with a slender semi-rigid plastic tube. This tube was inserted to the bottom of the filter candle so that the sample removed had minimum contact with the air. The initial samples were discarded and data from further samples were recorded only if they could be reproduced. The sampling detail is presented in Fig. 1. The sample withdrawn was immediately transferred to volumetric flasks containing acid molybdate solutions. The plastic tube through which the soil solution was withdrawn was kept beneath the acid solutions so that only the acidified solution came in contact with the atmosphere.

Leaf blades for foliar analyses were taken 9 months after planting. Corms were harvested 10, 12, and 14 months after planting.

Results

External P Requirements. According to the yield response curves presented in Figure 2, the external P requirement of all three varieties of *C. esculenta* was 0.02 ppm P in solution. Bun Long produced the highest yields with a maximum of 51 t/ha. Yield was 75 percent of the maximum attained at the lowest P level employed which was 0.002 ppm. (Bray 1 solution extracted less than one ppm P from the soil of this treatment). Lehua Maoli produced yields up to 37 t/ha. The response curve of Lehua Maoli and Bun Long were similar in shape while the curve for dasheen ascended more steeply although absolute yields were lower. The lowest P treatment produced only 50% of the maximum yield, indicating that this variety of dasheen was more sensitive to low P levels than the other varieties.

The unfertilized flooded soil supported a phosphorus concentration in the soil solution of 0.002 ppm P. Yield from this plot was 58 t/ha which was 92% of the yield plateau, 63 t/ha (Table 2). Thus, we have concluded that the external P requirements for flooded and non-flooded conditions were not appreciably different.

Internal P Requirements. The leaf P percentage of all three varieties grown in the non-flooded test increased with increasing P in solution (Table 3). About 0.40% P in the leaf blades was associated with 95% of maximum yield (Fig. 3). This critical level is almost identical with the level obtained under flooded conditions (Table 2).

Phosphorus concentration in corms was also a good indicator of the P status of taro (Fig. 4). Phosphorus percentage increased from 0.18 to 0.26 as P in solution increased from 0.002 to 0.012 ppm P in solution. Phosphorus percentage in Bun Long corms was lower and increased more gradually with increasing P in solution than in the case of variety Lehua Maoli.

The Contribution of Mycorrhizae to the P Nutrition of Non-flooded Taro. At three months of age, root samples of non-flooded taro were taken and inspected for VA mycorrhizal infection. At the low P treatments the percentage of the root cortex infected with mycorrhizae was approximately 10% for all three varieties. Infection was less at the highest P level and in the case of variety Lehua Maoli there was no infection.

At harvest, Bun Long and Lehua roots were inspected and the amount of infection was approximately constant for all the P treatments with Lehua roots having approximately 5 to 10%.

The Influence of P on Other Nutrients. Increased P fertilization did not influence the concentration of other nutrients in the leaves. Concentrations of other nutrients for a P treatment which produced near maximum yield, 0.012 ppm, are presented in Table 4.

Discussion

Taro yields were near maximum at 0.02 ppm P in soil solution. The external P requirement was independent of whether or not the soil was flooded and the variety of taro grown. Although yield potential was greater for flooded taro, the external P requirement was not different from the non-flooded crop, probably because of greater cross-sectional area for diffusion of P to roots in flooded soils. Internal P concentrations in the leaf blades of 0.40% are associated with 95% of maximum yield. Mycorrhizal infection was low in comparison with cassava and yams and it would appear to contribute only slightly to the P nutrition of the plant. Since taro is usually associated with wet soils, a strongly mycorrhizal plant should not be expected even under non-flooded conditions. In comparison with other root crops, taro has a similar external P requirement to that of yams (Vander Zaag *et al* 1980). However, cassava has a much lower external P requirement of approximately 0.006 ppm P in soil solution to attain 95% of maximum yield although 75% of maximum yield is obtained at 0.01 ppm P (Nishimoto *et al* 1977). Potatoes have a high P requirement of 0.2 ppm to obtain 95% of maximum yield (Vander Zaag *et al* 1979). Taro appears to have an extensive root system and this should be an important factor in the efficient utilization of relatively low levels of P.

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Table 1. Fertilizer P requirements to re-establish the desired P concentrations for the non-flooded taro experiment of Kauai (Typic Gibbsihumox)

Phosphorus Treatment	P Concentration Determined (ppm)	P Level Desired (ppm)	P Required (µg/g)	P Required (kg TSP/plot)*
1	.0020	—	0	0.
2	.0038	.003	0	0
3	.0025	.006	110	6.36
4	.0038	.012	120	6.94
5	.0050	.025	145	8.38
6	.0075	.05	185	10.69
7	.0150	.10	200	11.56
8	.0390	.20	215	12.42
9	.0590	.40	290	16.76
10	.4100	1.6	300	17.34

* plot size was 6 x 9 meters

Table 2. Yield response and percent P in leaf blades as influenced by P in solution for taro grown under flooded conditions at the Wailua Experiment Station, Kauai, on a typic tropaquept

Intended P Level* (ppm)	Determined P Level (filter candles) (ppm)	P in Leaf Blades + (percent)	Yield ‡ (T/ha)
None	.02	.35	58.3
.003	.05	.36	37.2
.006	.05	.42	59.0
.012	.07	.41	66.2
.025	.16	.41	61.8
.05	.07	.42	62.3
.1	.25	.45	62.7
.2	.30	.39	66.8
.4	.19	.46	63.9
1.6	.39	.42	62.6

*Levels established using P soprtion curves.

+Levels determined at 9 months after planting

‡Yields are means of harvests taken at 10, 12 and 14 months after planting

Table 3. P concentration in the leaf blades of three varieties of *C. esculenta* (non-flooded experiment) of P established in solution

P Level Maintained in the Soil (ppm)	Percent Lehua	Percent Bun Long	Percent Dasheen
.002	.29	.25	.24
.003	.37	.31	.33
.006	.39	.32	.36
.012	.38	.32	.34
.025	.41	.35	.34
.05	.45	.35	.36
.1	.47	.39	.37
.2	.56	.45	.39
.4	.59	.50	.45
1.6	.66	.58	.42

Table 4. Nutrient levels in leaf blades (3 months after planting) and in the corms at harvest for three varieties of *C. esculenta* for the 0.012 ppm P in solution treatment grown on Kuai (non-flooded experiment)

Variety	Percent					ppm			
	N	K	Ca	Mg	S	Mn	Fe	Cu	Zn
(leaves)									
Lehua	3.8	5.6	2.3	.20	.32	170	125	23	42
Bun Long	3.8	5.1	3.0	.38	.39	200	87	21	41
Dasheen	3.8	5.5	2.7	.29	.35	130	92	21	42
(corms)									
Lehua	.45	1.2	.20	.03	.02	–	–	–	–
Bun Long	.69	1.4	.13	.07	04	–	–	–	–

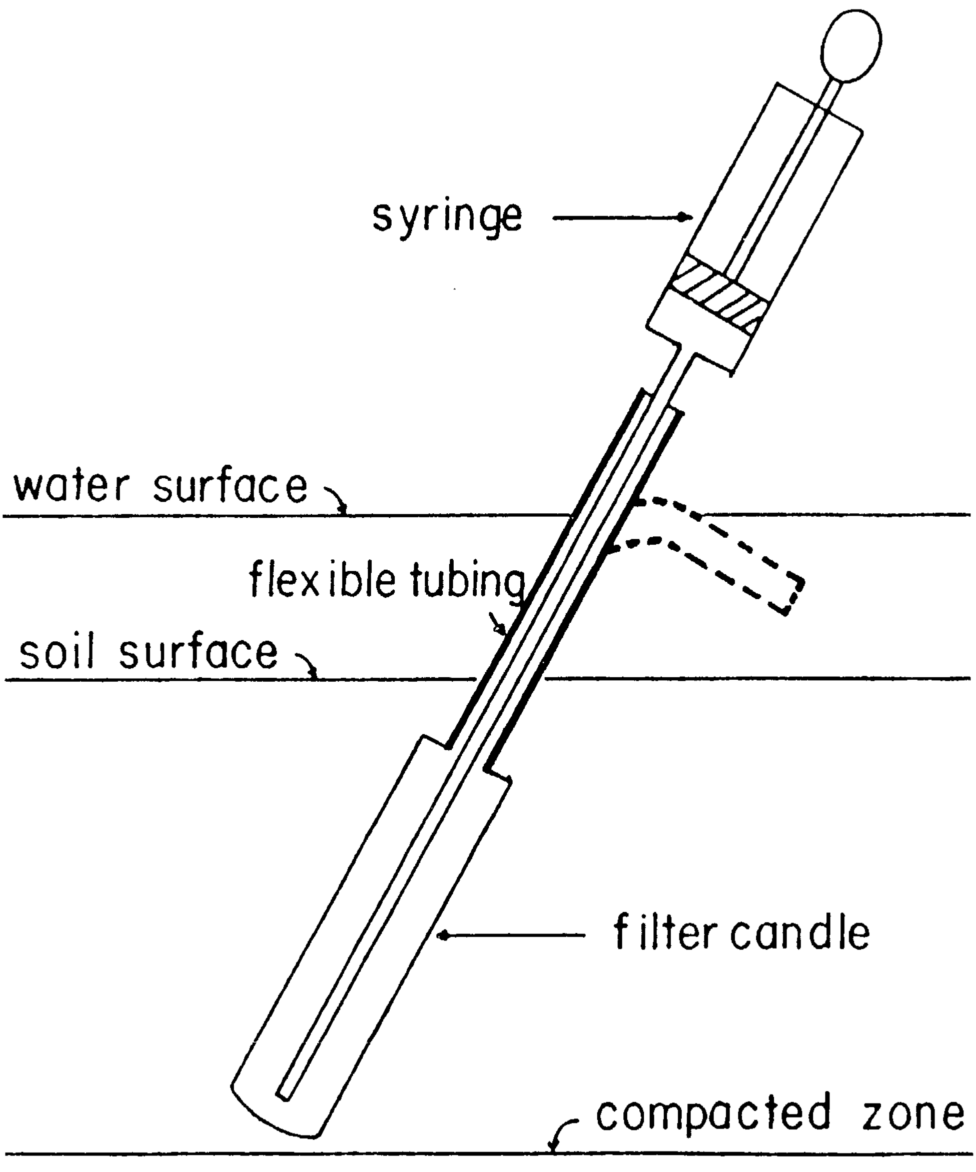

Figure 1. Position of ceramic filter candles in the soil and procedure for removing soil solution. Note that the sample is being withdrawn from the bottom of the filter candle to avoid oxygenating the sample and consequent precipitation of $Fe(OH)_3$ on which phosphate would be absorbed.

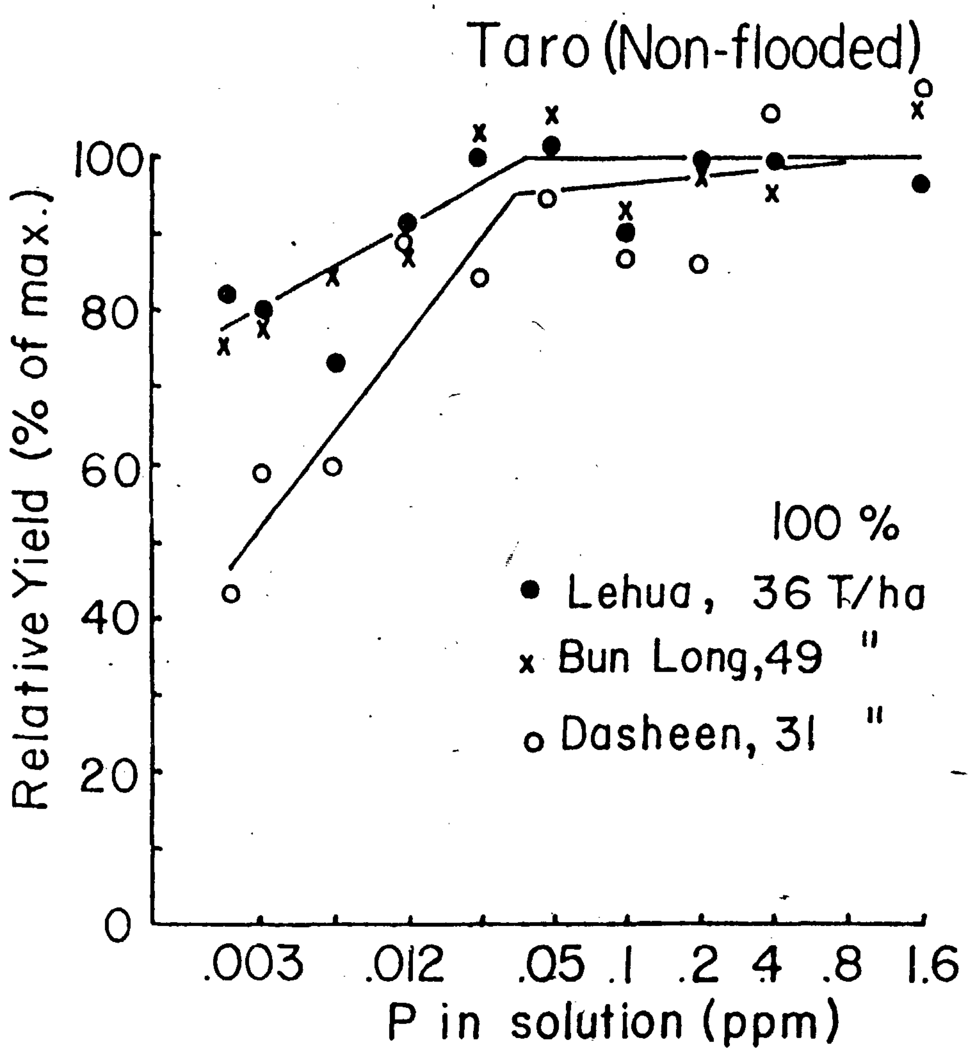

Figure 2. A composite yield response curve for the varieties Lehua and Bun Long and a yield response curve for dasheen as a function of P in solution. The correlation coefficients for the ascending portions of the 2 response curves are 0.89 and 0.94 for the Lehua and Bun Long varieties.

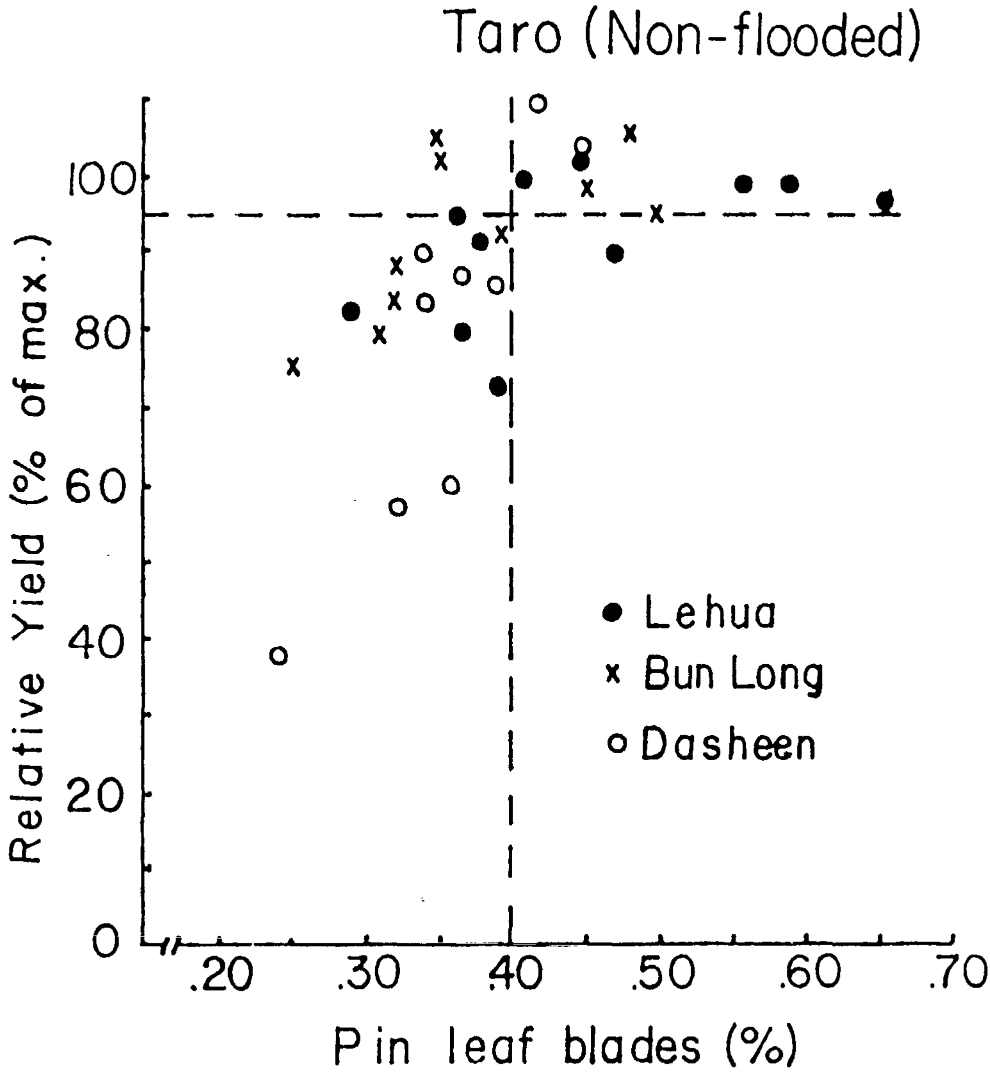

Figure 3. Relative yield of three varieties of taro grown on Kauai as influenced by the P concentration in the leaf blades samples at 3 months after planting.

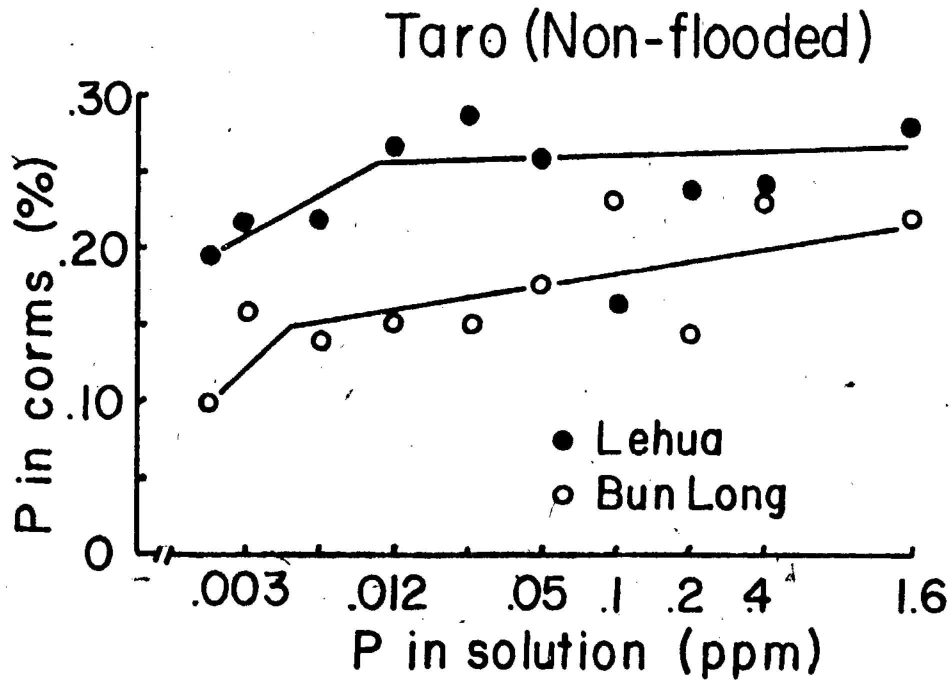

Figure 4. P concentration in the corms of two taro varieties grown on Kauai as influenced by the concentration of P in solution.