Calcium Nutrition of Taro *(Colocasia Esculenta* (L.) Schott

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Abstract

Calcium deficiency symptoms on taro, *Colocasia esculenta* (L.) Schott. cv. 'Lehua maoli,' grown in nutrient culture for 7 weeks, were leaf blade interveinal chlorosis and necrosis, failure of the leaf blades to unfurl, collapse of petioles, die-back of roots, and ultimately death of the growing point. The critical level of calcium in the leaf blades was 0.4% on a dry weight basis for 7 week-old plants. The best indicator tissue was the blade of the third or fourth leaf because of its greater sensitivity to changes in calcium levels.

Introduction

Taro (*Colocasia esculenta* (L.) Schott.) contains relatively high amounts of calcium (Plucknett and de la Peña, 1971). Miller (1927) calculated that the daily adult requirement of calcium would be more than adequately met when taro comprised the bulk of the diet. The strong skeletons and excellent teeth of the ancient Hawaiians, despite a diet lacking in milk, provide additional evidence that taro can supply the required calcium for human needs (Potgieter, 1940).

The presence of calcium oxalate crystals in taro has long been recognized (Black, 1918), and the structure of the calcium oxalate raphides was described recently by Sakai and Hanson (1974). The function of calcium oxalate crystals is not known, but Arnott and Pautard (1970) suggested that storage of calcium in an inactive form allows certain plants to tolerate high levels of calcium.

Taro has a high calcium requirement and liming is beneficial in soils low in calcium (Plucknett and de la Pena, 1971; Kay, 1973). Chew (1971) reported increased tuber yields when acid peat soils were limed and he concluded that this response was partly due to the calcium and magnesium made available by the lime.

Low levels of soil calcium have been found in taro growing areas in Hawaii by the Soil Testing Service of the University of Hawaii, Manoa. Although liming is recommended, little research has been done on the growth response of taro to calcium. This study was designed to characterize calcium deficiency symptoms and plant tissue levels of calcium in taro.

Materials and Methods

This experiment was conducted from July to August, 1978 in a greenhouse whitewashed to reduce light intensity to 70% of full sunlight. The taro plants were grown in

glazed 10 liter ceramic crocks using a modified Hoagland's solution (Hoagland and Arnon, 1938). Micronutrients one-fourth strength and iron was supplied from Geigy Sequestrene 330 Fe.

The experimental design was a randomized complete block with 7 Ca levels and 3 replicates. Within each block, the taro 'hulis' (vegetative propagating material consisting of approximately the upper 0.5 cm of the corm plus 20 cm of the petioles) were selected for uniformity on the basis of fresh weight. The seven levels of Ca were 0.05, 0.10, 0.20, 0.50, 1.00, 4.00, and 20.00 parts per million (ppm) in the modified Hoagland's solution. In solutions where the concentration of Ca was less than 20 ppm, nitrogen was maintained by substituting NH_4NO_3 for $Ca(NO_3)_2$.

One-tenth strength modified Hoagland's solution was continuously dripped into the crocks from a 50 l reservoir at a rate of 2.4 l per day. A constant head device maintained a fairly constant flow rate of nutrient solution and flow rates were checked daily. Overflow tubes maintained a constant level as air was continuously bubbled through the solution.

The taro cultivar grown in this experiment was 'Lehua maoli,' the primary commercial cultivar in Hawaii. 'Hulis' were supported on 2 crossed rubber strips that were suspended in the nutrient solution.

Plants were harvested after 7 weeks of growth at which time the shoot tips of several plants had died in the low calcium solutions. Plant tissue analyses were carried out at the Plant Tissue Testing Lab at the University of Hawaii, Manoa. Tissue nitrogen was measured using the micro-Kjehldal method of Suehisa and Deputy (1979). Plant tissue levels of P, K, Ca, Mg, S, Si, Na, Cl, Mn, Fe, Cu, and Zn were determined with an Applied Research Laboratories vacuum x-ray fluorescence quantometer, model 72000.

Results

Calcium deficiency symptoms were observed on taro grown in solutions containing 1.0 ppm Ca or less. With mild Ca deficiency (1.0 ppm Ca), a slight interveinal chlorosis was evident on the leaf blades. As Ca concentrations in the solution decreased, plant tissue levels decreased (Fig. 1) and visual deficiency symptoms increased in severity (Fig. 3). The leaf blades of moderately Ca-deficient plants (0.50 ppm Ca) were extremely chlorotic in interveinal areas with some necrosis and the blades appeared cup-shaped (Figs. 3A, 4A). With severe Ca deficiency (0.05 to 0.20 ppm Ca), the leaf blades failed to unfurl and the growing point died in several plants. (Fig. 4B).

Calcium deficiency symptoms of taro were also marked by severe stunting of the plant, and drooping of the petioles at the lower Ca levels (Figs. 3A, 4B). Calcium deficiency also resulted in die-back of the roots and reduced mother corm size. The mean number of cormels increased significantly with Ca in solution from 2 at 0.05 ppm Ca to a maximum of 5 to 4.0 and 20.0 ppm Ca (Table 1). Total dry weight of the plant increased with Ca in solution to a maximum at 4.0 ppm, which corresponded to a Ca concentration of 0.57% dry weight in the leaf blades (Fig. 2) Total dry weight decreased slightly at 20.0 ppm Ca in solution (Table 1).

Calcium concentration in plant tissues increased linearly with increasing Ca in solution (Fig. 1). Leaf blades had the highest rate of increase in Ca concentration with increasing Ca in solution, petioles were intermediate, and roots the lowest. Calcium concentration in the petiole increased with age of the petiole (Table 2). Petiole 1 was

from the youngest fully unfurled leaf, while petiole 4 was from the oldest.

The concentration of many nutrient elements was found to decrease with increasing Ca in solution. However, it was necessary to separate actual Ca interference effects from dilution effects due to increased growth. Comparisons were limited to plants grown with 4.0 and 20.0 ppm Ca in solution, because no significant difference was found in the growth of taro at these Ca levels (Table 1) and Ca concentration in the plant tissues was significantly higher in plants grown with the higher level of Ca.

Magnesium was the only element that decreased significantly in both leaves and petioles of plants as Ca in solution increased from 4.0 to 20.0 ppm (Table 3). Magnesium concentration in the roots increased significantly with increasing Ca in solution.

Discussion

Calcium deficiency symptoms of taro are typical of such symptoms found on other plants (Arnott and Pautard, 1970; Spense and Ahmad, 1967). The inability of leaf blades to unfurl, wrinkling of leaf blades due to bands of necrotic tissues, collapse of petioles, die-back of roots, and death of the growing point are commonly described Ca deficiency symptoms.

Luxury consumption of Ca was demonstrated with taro at 7 weeks. As Ca concentration in the leaf blades increased from 0.57 to 2.09% (dry weight), total dry weight of the plants decreased slightly (Fig. 2). The high levels of Ca in the plant tissues seems to have interfered with translocation of Mg, and this could account for the slightly decreased growth. Other experiments have shown that Ca interferes with Mg transport to the shoot, while Mg accumulation by root tissue is less affected (Jackson, 1967). The data for taro are in agreement with those from previously reported experiments.

An inadequate supply of soil calcium could reduce commercial yields of taro by reducing mother corm size and number of cormels. Tissue sampling could be used to diagnose this problem in the field. The leaf blades are probably the best index tissue because of their greater sensitivity to changes in Ca levels in the external solution (Fig. 1). The data of this experiment show that petiole numbers 3 and 4 have the highest concentrations of Ca and therefore are the best leaves to sample (Table 2).

The critical level of Ca in the leaf blades was determined by plotting two perpendicular lines, one parallel with the x-axis and the other with the y-axis, so that a miminum number of observations were in the upper left and lower right quadrants (Cate and Nelson, 1965). The critical concentration of 0.4% Ca on a dry weight basis was estimated by the point of intersection of the 2 lines. However, further work in the field needs to be done to correlate commercial yields with plant tissue analyses at different plant ages.

Tissue analysis of leaf blades of field-grown plants at the time of harvest (12-14 months) in Hawaii had Ca concentrations which ranged from 0.6 to 1.4% dry weight. No visual symptoms of Ca deficiency have been observed by the authors in taro fields. Further experiments are in progress to assess plant Ca levels in a wider range of fields to see if incipient Ca deficiency occurs in taro-growing areas in Hawaii. The tissue levels obtained in this study will provide guidelines to determine whether 'hidden hunger' exists in taro fields of Hawaii.

References

ARNOTT, H. J. and F. G. E. PAUTARD. 1970. In *Biological Calcifications: Cellular and Molecular Aspects* (ed. H. Schraer), pp. 375-446. Appleton-Century Crofts, NY, NY.

BLACK, O. F. 1918. *Am. J. Bot.* 5: 447-451.

CATE, R. B. and L. A. NELSON. 1965. *Inter. Soil Test. Ser. Tech. Bull. 1* N. Carolina State Univ. Agric. Exp. Sta., Raleigh.

CHEW, C. W. 1971. *Malaysian Agric. J.* 48: 142-157.

HOAGLAND, D. R. and D. I. ARNON. 1938. *Calif. Agric. Exp. Sta. Circ. 347.*

JACKSON, W. A. 1967. In *Soil Acidity and Liming* (ed. R. W. Pearson and F. Adams), pp. 43-123. Amer. Soc. Agron., No. 12 Ser. Agron., Madison, Wisconsin.

KAY, D. E. 1973. *Root Crops,* pp. 71-75, 168-179. Trop. Products Inst., London, England.

PLUCKNETT, D. L. and R. S. DE LA PEÑA. 1971. *World Crops.* 23: 244-249.

POTGIETER, M. 1940. *J. Am. Diet. Assoc.* 16: 536-540.

SAKAI, W. S. and M. HANSON. 1974. *Ann. Bot.* 38: 739-748.

SNEDECOR, G. W. and W. G. COCHRAN. 1967. *Statistical Methods, 6th ed.,* pp. 272-273. Iowa State Univ. Press, Ames, Iowa.

SPENCE, J. A. and N. AHMAD. 1969. In *Int. Symp. Trop Root Crops, Trinidad, 1967, Proc.* 1(2): 61-69.

SUEHISA, R. A. and J. C. DEPUTY. 1979. In *Sugarcane Crop Logging and Crop Control* (ed. H. F. Clements). Univ. Hawaii Press, Honolulu, Hawaii.

Table 1. Effects of Ca on taro mean total dry weight and cormel number

Ca in solution. ppm	Total dry weight, g*	Number of cormels
0.05	7.5a	2.0a
0.10	8.3a	3.0ab
0.20	8.6a	3.3ab
0.50	14.0ab	4.0ab
1.0	16.5ab	3.7ab
4.0	27.4b	5.0b
20.0	22.1ab	5.0b

*Numbers followed by the same letter are not significantly different (95% probability level) as determined by the Studentized Range Test (Snedecor and Cochran, 1967).

Table 2. Calcium concentration in petioles of taro grown with 4.0 ppm Ca

Petiole Number	1	2	3	4
Ca, % dry weight*	0.20a	0.26a	0.35b	0.37b

*Numbers followed by the same letter are not significantly different (95% probability level) as determiend by the Studentized Range Test (Snedecor and Cochran. 1967).

Table 3. Effect of calcium in solution on plant magnesium levels of taro

Ca in solution ppm	Dry weight, %			Total, mg		
	Blade	Petiole	Root	Blade	Petiole	Root
4.0	0.51	0.43	0.29	50.58	36.85	22.62
20.0	0.41	0.34	0.74	21.94	17.37	42.70
	*	*	*	*	*	n.s.

*Significantly different (95% probability level) as determined by analysis of variance

n.s. Not significantly different