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Growth, Yield, Nutrient Content and Fruit Quality of *Carica papaya* L. Under Controlled Conditions. I. Nitrogen Effects[1]

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ABSTRACT

A sand culture greenhouse experiment was conducted with *Carica papaya* L., variety Blue Solo, to determine the effects of five (14, 28, 56, 112 (control) and 224 p/m) levels of nitrogen in the nutrient solution on the growth, fruiting and nutrient content. Nitrogen deficiency symptoms are described. Mineral content of blades, petioles and fruit are presented and discussed. The papaya has a high N requirement, (probably higher than the highest level of 224 p/m we supplied). Plant height, nodes in the stem, trunk diameter, leaf fresh and dry weights, total yield (fruits harvested) and fruit quality increased as the N supply was increased. Critical N level in the blade and petiole appears to be about 4 and 2%, respectively. Quality components of the fruits are discussed, based on a panel evaluation. Fruits from the lower N supply levels were of poorer flavor.

INTRODUCTION

Other than data on the Hawaii Solo variety, only limited information is available on the mineral nutrition of the commercial papaya, *Carica papaya* L., a fruit grown widely in the tropics and sub-tropics. N, P and K effects on growth and foliage of papaya have been reported in Hawaii (2, 3, 4, 5, 6) and limited field tests and recommendations are in the literature from Florida (19) Hawaii (11, 12), and India (20, 21). More recently, nutrient deficiency symptoms and mineral content studies were reported in Puerto Rico by Cibes and Gaztambide (8). Nutrient deficiency symptoms and studies of the foliar N and P trends also are available for a generic relative in Chile, known as the mountain papaya, *C. canda-*

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marcensis Hook f. (10, 13, 15, 16), which is hardy in southern California but with fruits of little commercial value (7).

The objective of this study was to determine the effects of different levels of N in greenhouse sand culture on growth, flowering, fruiting, fruit quality and mineral content of the leaves and fruit of *C. papaya* L.

MATERIALS AND METHODS

The experiment was initiated in greenhouse sand culture with five N levels (14, 28, 56, 112 and 224 p/m). Seed freshly removed from open-pollinated hermaphroditic fruits of the Blue Solo variety were germinated in flats. Two-month-old seedlings with 6 to 7 fully developed leaves were transplanted, one to a crock filled with fine white crystal silica sand. The seedlings were watered daily with a standard complete nutrient solution until they flowered. The N content of leaves of each plant were determined at the onset and found to be similar for all plants.

The five levels of N were replicated four times in a randomized complete block design, each replicated with one hermaphroditic and three female plants. Greenhouse temperatures averaged 24° C with a maximum range of 27–33° C and a minimum of 17–22° C. Daylength was kept at a minimum of 12 hours with supplemental lighting.

Differential N solutions were applied daily from flowering. Calcium nitrate as the main source of N was used from the low (14 p/m) to the high level (224 p/m) at 0.0005, 0.0010, 0.0020, 0.0040, 0.0040. Additional N at the 224 p/m level was supplied by magnesium nitrate (0.002 M) and potassium nitrate (0.002 M) which also provided part of the magnesium and potassium (0.002 M) needs. Trace elements were supplied in mg/l at: Zn-0.1, Cu-0.01, Mo-0.01, Cl-0.32, Mn-0.25, Fe 1.0 and B-0.1.

Growth data were taken 45, 105 and 225 days after treatments: trunk diameter at crock surface; height at the top terminal bud; total nodes on each plant; total fruits set; petiole diameter two to three centimeters from the blade; petiole at the stem attachment; fresh and dry weight of leaves; and total fruit yield. Three leaves per treatment were collected on the above mentioned days and separated into blades and petioles for mineral analyses.

The experiment was terminated 225 days after treatments started. At this date, two to three green fruits of comparable size were collected from each treatment, seeds removed, and fruits diced and dried for mineral analyses.

The nutrition Laboratory of Pennsylvania State University ran the analyses for P, K, Ca, Mg, Mn, Fe, Cu, B, Al and Zn. The N contents were determined by Nesslerization of Microkjeldahl digests.

Fruit acidity, pH, total solids, and soluble solids were analyzed by the A.O.A.C. specifications (1).

For flavor evaluation, mature fruits of comparable size were harvested on the same day and evaluated by a 15-member panel. The triple comparison procedure of Larmond (14) was used; the fruits from the 112 p/m N treatments were used as the control.

The Bio-Med 02V (revised) analysis of variance for factorial design was used; the means were ranked by the Tuckey H.S.D. test (18).

RESULTS

Within 2 weeks after differential N treatments were initiated, basal leaves on the low-N plants turned uniformly light green, a condition that gradually moved up the plant to the youngest leaves (fig. 1). Petioles were shorter, thinner and drooped downward on the deficient plants as Jones and Storey (11) also had noted. Low-N plants were shorter (110, 122, 156, 159, 163 cm) as Godoy et al. (10) and Cibes and Gaztambide (8) noted for *C. candamarcensis* and *C. papaya,* respectively, under controlled conditions. Under field conditions in a moderately fertile soil in Florida (19) and in Hawaii (11, 12); however, the rate of fertilizer (NPK) application did not seem to influence height noticeably. Similar results have been found in Puerto Rico by the senior author (unpublished data).

In low-N plants the number of nodes was less (63, 70, 77, 79, 77) and trunk-diameter was smaller (4.4, 5.4, 6.2, 6.6, 6.4 cm), as noted in Florida (19) with papaya under field conditions.

As the N supply was increased, the leaf blade and petiole fresh weights increased (10.5, 20, 25.5, 33.5, 34.5 g), as did the dry weights (12.5, 19, 26, 31, 33.5 mg).

Within 2 weeks after differential treatments were started, the plants with 14 p/m supply showed yellowing and dropping of most female flowers and buds. At 4½ weeks the plants supplied with 28 p/m showed heavy dropping of flowers. The number of fruits set per plant increased as the N increased (5a, 5a, 13b, 25c, 26c)[3] and total yield of fruits per plant likewise was increased (1.2a, 1.3a, 1.8ab, 3.0b, 4.0c). Traub et al. (19) in Florida and Pérez López (unpublished data) also found larger leaves and more fruit per plant as the fertilizer (NPK) was increased. Fruits of low-N plants were faded yellow with ooze droplets over the skin (fig. 1).

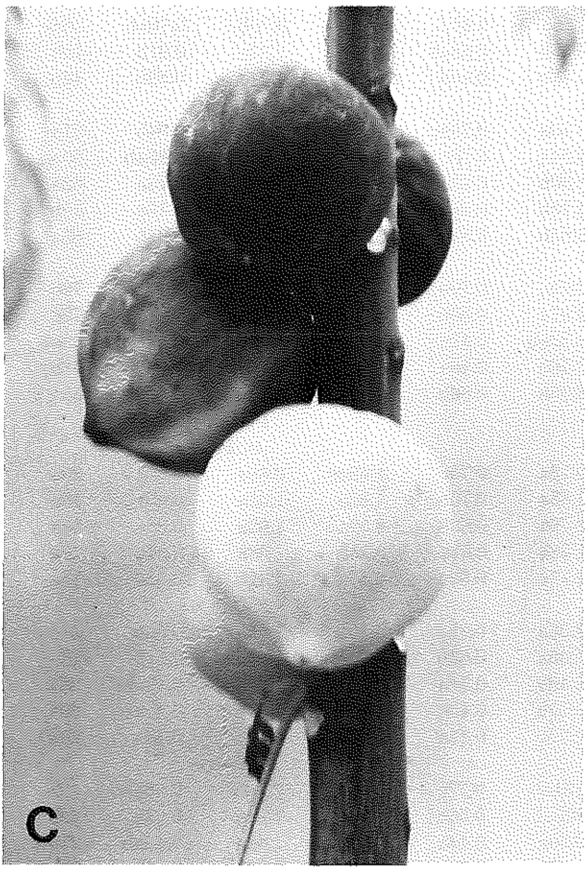
K, Fe, Al and Zn in the leaves and petioles were unaffected by an increase in the N supply. In the fruits the P, K, Mn, Fe, Cu, Al and Zn were found to be unaffected by the N supply. Results are summarized below and in table 1.

Generally speaking, the N content in the petioles appeared to be a more sensitive index of the N supply than the blade content, as also noted by Kocher and Villalobos (13) with *C. candamarcensis* in the greenhouse,

[3] Unless otherwise stated, differences given in the text are at the 0.05 level.

FIG. 1.—Effect of N levels in the nutrient solution on papaya (*Carica papaya* L.) plants and fruits. A. From left to right: from 224 to 14 p/m. B. 14 p/m; fruits showing a faded color. C. 112 p/m; Fruits showing a brighter color.

and Awada (12) with field grown papaya. N in the combined blades and petioles did not change significantly when the N supply was increased from 14 to 56 p/m, but beyond this supply the content increased sharply with N supply, as was found in the N percentage in the fruits (1.9a, 2.2ab, 2.0a, 2.8b, 2.6b). At the last sampling date, the amount of fruiting and perhaps growth may have diluted the N in the leaves and petioles; this situation may also apply with other nutrients.



With an increase in N supply the P content decreased in the petioles, while the data for the blades were irregular, indicating again that the petiole content appears to be a more sensitive index. Smith (17) has noted in Florida that a change in the N supply to citrus trees influences the P content of the tissues more than a change in the P supply.

The percent Ca increased in the petioles and blades (table 1) and in

TABLE 1.—*Influence of N levels (p/m) on nutrient contents of blades and petioles of papaya plants at the 45, 105 and 225 days after treatments*

N level	Nutrient contents							
	N	P	K	Ca	Mg	Mn	Cu	B
	%	%	%	%	%	p/m	p/m	p/m
				Blades				
				45 days				
14	4.62a[1]	0.61b	3.70a	0.74a	0.65a	38ab	9a	42b
28	4.51a	0.60b	3.79a	0.68a	0.66a	34a	8a	40b
56	4.88a	0.46a	3.44a	0.98b	0.76ab	38ab	9a	32a
112	5.45b	0.55ab	3.34a	1.33c	0.91b	45b	8a	28a
224	5.38b	0.65b	3.39a	1.72d	0.82b	44b	8a	26a
				105 days				
14	3.30a	0.75bc	4.73a	0.99a	0.94b	61a	10a	83d
28	3.54a	0.79c	4.78a	0.94a	0.85ab	60a	11a	70c
56	3.90b	0.62a	4.80a	1.11a	0.76a	62a	10a	50b
112	4.15b	0.66ab	4.72a	1.66b	1.16c	75b	10a	38a
224	3.84b	0.81c	5.13a	2.02c	0.98b	65a	9a	40a
				225 days				
14	287a	0.70b	3.78a	1.89b	1.17c	70c	16b	60d
28	2.97a	0.60b	3.75a	1.49a	0.95a	72c	12a	54c
56	3.32ab	0.47a	3.40a	1.92b	0.92a	63ab	10a	38b
112	3.56b	0.46a	3.50a	2.44c	1.08bc	68bc	11a	28a
224	3.75b	0.60b	3.42a	3.19d	0.96a	55a	12a	26a
				Petioles				
				45 days				
14	0.79a	0.75c	4.89ab	0.89a	0.39a	20a	6a	26a
28	0.85a	0.70bc	4.88a	1.02a	0.40a	18a	6a	25a
56	0.79a	0.63b	4.59ab	1.02a	0.35a	14a	5a	24a
112	1.58b	0.52a	5.25b	1.08a	0.37a	16a	5a	24a
224	2.17c	0.52a	4.57ab	1.42b	0.33a	15a	6a	24a
				105 days				
14	1.36a	0.75c	5.19a	1.58a	0.50b	28a	7a	34b
28	1.36a	0.63b	5.02a	1.64ab	0.53b	26a	7a	31ab
56	1.48a	0.54a	6.00b	1.54a	0.40ab	26a	7a	29a
112	2.10b	0.45a	6.31b	1.91b	0.45ab	22a	7a	28a
224	2.97c	0.46a	6.19b	2.36c	0.33a	23a	8a	29a
				225 days				
14	131ab	0.77c	4.49ab	2.16b	0.86c	33b	10b	34c
28	100ab	0.56b	3.83a	1.67a	0.47b	32b	6a	28b
56	0.98a	0.44a	5.18b	1.83a	0.43ab	25ab	6a	27ab
112	1.23b	0.36a	4.70b	2.29b	0.47b	27ab	7a	23a
224	2.22c	0.36a	4.44a	2.66c	0.29a	21a	6a	23b

[1] Means in columns with different letters do not significantly differ at the 0.05 probability level.

the fruits (0.23a, 0.37ab, 0.29ab, 0.53bc, 0.61c) with an increase in the N supply.

Mg decreased in the petioles with an increase in the N supply indicating that again the petiole content may offer a better index. Mg percentage in the fruit showed some increase with the N supply (0.18a, 0.23a, 0.23a, 0.4b, 0.32ab).

Mn and Cu in the blades and petioles decreased with an increase in N supply, a response found to be similar in the orange (9).

B content in the leaves, petioles and leaves + petioles decreased as the N supply increased. On the other hand, B in the fruits increased with N supply (fig. 2 and table 1.).

As the N supply was increased the quality components of the extracted juice were altered in a significant but limited way. Titratable acidity was slightly increased (0.32a, 0.38ab, 0.38ab, 0.61b, 0.58b). Unaffected were pH (4.96a, 4.96a, 5.00a, 5.16a, 5.23a) and percentage total solids (12.8a,

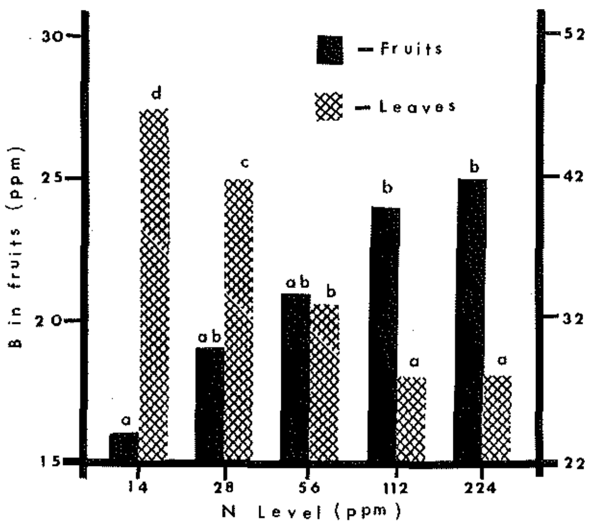


FIG. 2.—Effect of N levels in the nutrient solution on the B content of fruits and leaves of papaya plants at 225 days after initiation of treatments.

15.5a, 17.6a, 15.6a, 12.2a). Ratio of soluble solids to acidity decreased slightly as N supply increased (37.0bc, 35.3abc, 41.0c, 23.0ab, 19.3a), while the percentage of soluble solids showed a parabolic relationship (11.1a, 13.4ab, 15.4b, 13.6ab, 10.9a).

The panel of tasters rated low-N fruits as having poorest flavor. Panel scores for the low-to-high levels of N supply were: 6.1[4], 4.1, 5.4, 1.7 (control), and 3.6, respectively.

Panel preferences were at 14 p/m N supply, poorer than control; 28 p/m slightly poorer than control; 112 p/m control; 224 p/m slightly better

[4] Degree of difference from control on a scale of None=1 to extreme=9 (HSD 0.01=0.78).

than control. Traub et al. (20) on the other hand, found that taste quality under field conditions did not vary with fertilizer (NPK) rates.

RESUMEN

Un experimento bajo condiciones controladas se llevó a cabo en invernadero con la variedad "Blue Solo" de *Carica papaya* L. Se estudió el efecto de cinco niveles de nitrógeno (14, 28, 56, 112 (testigo) y 224 ppm) en el crecimiento, fructificación, calidad de las frutas y el contenido de nutrimentos en las hojas y las frutas. Se describen los síntomas carenciales de nitrógeno. Se da información sobre el contenido de nutrimentos de las hojas, pecíolos y frutas. La altura de la planta, número de nudos del tallo, diámetro del tronco, pesos verde y seco de las hojas, producción total y la calidad de las frutas a medida que se incrementó el N. El papayo, aparentemente, requiere una cantidad elevada de nitrógeno (probablemente un nivel más alto que las 224 ppm que nosotros aplicamos en este estudio). El nivel crítico de nitrógeno en la lámina y el pecíolo parece estar entre 4 y 2%, respectivamente. Un grupo de catadores que apreció la calidad de las frutas indicó que las de las plantas abonadas con poco N no tenían buen sabor y que las de plantas abonadas con la dosis más elevada de N (224 ppm) eran un poco más agradables que las de plantas abonadas con 112 ppm.

LITERATURE CITED

1. Association of Official Agricultural Chemists, 1950. Official methods of analyses, Washington, D.C. ed. 7 pp. 320, 329 and 495.
2. Awada, M. and W. S. Ikeda, 1957. Effects of water on nitrogen application on composition, growth, sugars in fruit, yield and sex expression of the papaya plants (*Carica papaya* L.), Hawaii Agric. Exp. Stn. Bul. 33.
3. ——, 1969. The selection of the nitrogen index in papaya tissue analysis, Proc. ASHS 94 (6): 687–90.
4. —— and C. Long, 1969. The selection of the phosphorus index in papaya tissue analysis, Proc. ASHS 94 (5): 501–4.
5. ——, 1977. Critical potassium level in petioles of papaya, Hawaii Agri. Exp. Stn. Tech. Bull. 99.
6. ——, 1977. Relation of nitrogen, phosphorus and potassium fertilization to nutrient composition of the petiole and growth of papaya, J. Am. Soc. Hort. Sci. 102 (4): 413–8.
7. Bailey, L. H., 1935. The standard encyclopedia of horticulture. Vol. 1, p. 164.
8. Cibes, H. and Gaztambide, S., 1978. Mineral deficiency symptoms displayed by papaya plants grown under controlled conditions. J. Agri. Univ. P.R. 62 (4): 413–23.
9. Del Rivero, J. M., 1964. Los estados de carencia en los agrios, Inst. Nac. Invest. Agron., Madrid, España, p. 383.
10. Godoy, J. D., Kocher, F. and Villalobos, A. 1969. Efecto de la fertilización nitrogenada en la curva anual de nitrógeno en papayos (*Carica candamarcensis* Hook, f). Agric. Téc. Santiago, Chile 20 (1): 9–14.
11. Jones, W. W. and Storey, W. B., 1941. Propagation and culture of the papaya, Hawaii Agric. Exp. Stn. Bull. 87.
12. Jones, W. W., Storey, W. B., Paris, G. K. and Holdaway, F. G., 1941. Papaya production in the Hawaiian Islands, Hawaii Agric. Exp. Stn., Univ. Hawaii, Bull. 87.

13. Kocher, F. and A. Villalobos, 1966. Comparación entre los constituyentes nitrogenados de hojas como indicadores del estado de nutrición nitrogenada de la planta. Agric. Téc. Santiago, Chile 26 (4): 155–58.

14. Larmond, E., 1967. Methods for sensory evaluation of food, Publ. 1284, Food Res. Inst., Central Exp. Farm Canada Dep. Agric., Ottawa, Canada.

15. Muñoz, I., Kocher, F. and Villalobos, A., 1968. Determinación de las concentraciones críticas de fósforo y boro para el crecimiento del papayo (*Carica candamarcensis* Hook f). Agric. Téc. Santiago, Chile 28 (3): 119–24.

16. Muñoz, M., Kocher, F. and Villalobos, A., 1966. Síntomas de deficiencias nutricionales en plantas de papayos (*Carica candamarcensis* Hook f.) Agric. Téc. Santiago, Chile 26 (3): 106–13.

17. Smith, P. and Reuther, W., 1966. In Citrus Nutrition, chapter in Fruit Nutrition—Temperate to Tropical, Hort. Publ., New Brunswick, N. J.

18. Steel, R. G. D. and Torrie, J. H., 1960. Principles and procedures of statistics, McGraw-Hill Book Co., New York.

19. Traub, H. P., Robinson, T. R. and Stevens, H. E., 1942. Papaya production in the United States, USDA Cir. 633.

20. Tripathi, R. D., 1957–59. A review of papaya manuring, Ann. Rep. Fruits Exp. Stn., Saharanpur, India.

21. ——, 1963. Effect of N, P and K fertilizers on papaya vigor. Hort. Absts. 33 (1): 18–7.