Effect of Nitrogen and Boron Applications on *Carica papaya* L. II. Petiole and Fruit Nutrient Content and N and B Index for Leaf Tissue Analysis[1]

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ABSTRACT

Four levels of N (0, 57, 170 and 340 kg/ha) and 4 levels of B (0, 2.3, 4.5 and 6.8 kg/ha) were applied to the P.R. 7-65 papaya variety, growing on an Oxisol. Treatments were initiated when the transplanted seedlings were 3 months old, and were repeated every 6 weeks.

Increments of N and B levels increased the petiole and fruit contents of these elements. Except at the highest N application, the leaf content of N decreased as the B supplied was increased; the fruit content of all elements, except P, decreased as the fruit matured; the Ca content of leaves and fruits increased directly with the N and B levels supplied to the soil; Mg increased and Mn decreased significantly in recently matured fruits as the N and B supplies to the soil were increased; the N and B levels associated with the highest yield (24 kg/plant) were 1.48% and 64 p/m, respectively; the petioles contained less N, P, Mg and B, and higher Ca and Mn, and about the same K as the fruits; the B, Ca, Mg and Mn contents decreased as the fruits ripened.

INTRODUCTION

Literature on papaya fertilization is limited. Reports from Hawaii (1, 2, 3, 4) on papaya fertilization are mainly applicable to the Solo variety. Research in Puerto Rico on fertilization of this fruit has been carried out to determine deficiency symptoms of several nutrient elements (5, 10, 11, 12, 13).

Boron deficiency symptoms described by Cibes and Gaztambide (5) and the effect of levels of this element, studied under controlled conditions by Pérez-López and Childers (11), demonstrated the papaya's need of this nutrient. Therefore, an experiment was carried out on a Coto clay (an Oxisol) at the Isabela Station to study the effects of four levels of N (0, 57, 170 and 340 kg/ha) and four levels of B (0, 2.3, 4.5, 6.8 kg/ha) on the P.R. 7-65 papaya variety.

MATERIALS AND METHODS

This research was performed as part of a previous report (12); therefore, the materials and methods such as soil type, variety, seedbeds, fertilizer treatments, experimental design and data recorded have been reported elsewhere (12).

[1] Manuscript submitted to Editorial Board August 8, 1982.

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The healthiest petioles between the 13th and 16th leaves, counting basipetally, were sampled to determine the N, P, K, Ca, Mg, Mn, and B content. These same nutrients were also determined on fruits at three stages of development: petal fall, fully developed, and mature.

Petioles and fruit samples were washed thoroughly with a mild detergent and distilled water, dried to a constant weight in a forced-air oven

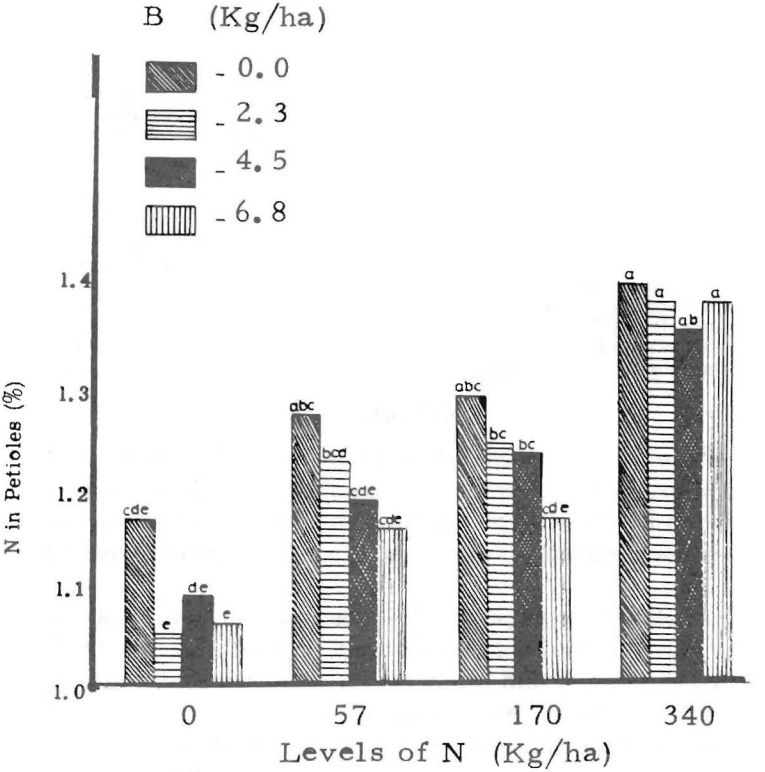

FIG. 1.—Effect of N and B levels on the nitrogen content of papaya petioles. Mean values in all figures followed by one or more letters in common do not differ significantly at the 0.05 probability level.

at 70° C, and ground in a semimicro-Wiley mill fitted with a stainless steel sample funnel and a 20-mesh stainless steel screen. The ground samples were stored in labeled plastic bottles for chemical analyses.

Two grams per sample (replicated 2 times) were digested in 35 ml concentrated nitric acid and 7 ml of concentrated perchloric acid, according to the Herwitz (8) method.

All digested samples were stored in 100-ml clear plastic polyethylene bottles, and the K, Ca, Mg and Mn were determined by flame atomic

absorption according to the Perkin-Elmer method (14); N by the Kjeldahl method; and P and B, colorimetrically, according to the methods of Matt (9) and Hatcher and Wilcox (7), respectively.

The N and B critical levels were determined by Spiegel's method (15). These levels were found by comparing these nutrient contents with the total amount of fruit harvested when the plants were 10 months old. The quadratic equation was fitted to the data to show that the critical levels

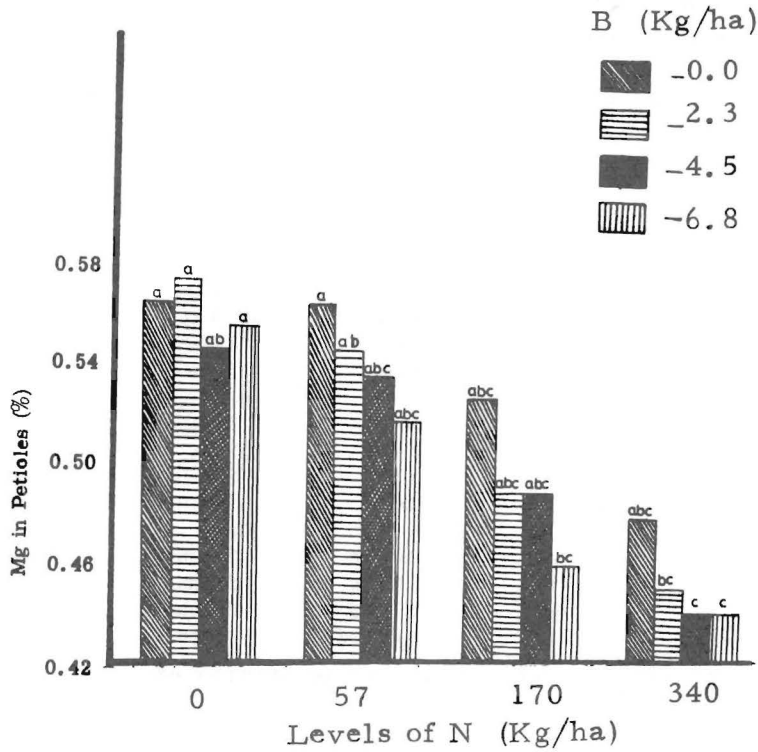

FIG. 2.—Effect of N and B levels on the boron content of papaya petioles.

of N and B was $Y = A_0 + A_1X + A_2X^2$, where A_0, A_1, and A_2 were determined by solving the normal equations system for fitting the curve by the method of least squares.

The critical level for each nutrient was found by following the Ulrich method (16), which consisted of equalling the first derivative to zero $\left(\frac{dy}{dx} = 0\right)$. The probable production of fruits per each increment of N and B was determined by means of this equation.

The coefficient of determination (R^2) was determined to show the goodness of fit of the curve to the data.

RESULTS AND DISCUSSION

NITROGEN

Figure 1 shows that as the N supplied to the soil was increased the petiole N content increased significantly. The figure also shows that at the 57 and 170 kg/ha levels of N there was a reduction in the N content in the petiole as the B levels were increased. This reduction in the N

TABLE 1.—*Effect of N and B levels on the nitrogen content of papaya fruits during three stages of development*

Boron levels	Nitrogen levels (kg/ha)			
	0	57	170	340
kg/ha	%	%	%	%
			Petal fall	
0.0	3.30d[1]	3.78bc	3.91abc	4.17a
2.3	3.76bc	3.79bc	3.95abc	3.98ab
4.5	3.68c	3.78bc	3.97ab	3.98ab
6.8	3.76bc	3.76bc	3.89abc	3.98ab
			Fully developed	
0.0	2.02d	2.57abc	2.63ab	2.81a
2.3	2.21cd	2.69a	2.69a	2.76a
4.5	2.30c	2.31c	2.56ab	2.68a
6.8	2.39bc	2.67ab	2.64ab	2.68a
			Ripe	
0.0	1.73de	2.06abc	2.09ab	2.30a
2.3	1.77cde	2.02abc	2.12abc	2.17ab
4.5	1.62d	1.92bcd	2.07abc	2.31a
6.8	1.88bcde	2.01abcd	2.16ab	2.24a

[1] Means in all tables followed by one or more letters in common do not differ significantly at the 0.05 probability level.

content could be due to the heavier petioles encountered in these treatments as published in our previous report (12). Another reason to account for a reduction in the N content of petioles could be the high accumulation of B in the leaf as the B levels supplied to the soil were increased (fig. 2).

Table 1 shows that the N content in the fruits during the 3 stages of development increased significantly as the N supplied to the soil was increased. This table also shows that fruit N content decreases as the age increase in the papaya fruits and that this reduction is more dramatic in trees that received no N.

Ripe fruits contained significantly more N than the petioles. This fact accounts for the high N fertilization required by papaya.

PHOSPHORUS AND POTASSIUM

Tables 2 and 3 show that the P and K content in the leaf petioles and fruits at the three stages of development were not affected significantly by the N and B levels supplied to the soil.

Table 2 shows that the P content of the fruits during the 3 stages of development was twice that of the petioles. Table 3 shows that the K content in the recently developed fruits was significantly higher than that of mature and ripe fruits and that the difference in K content of the latter three plant parts sampled was nonsignificant.

TABLE 2.—*Effect of N and B levels on the P content of papaya fruits during three stages of development, and on the petioles*

Boron levels	Nitrogen levels (kg/ha)			
	0	57	170	340
kg/ha	%	%	%	%
			Petal fall	
0.0	0.41a	0.40a	0.41a	0.41a
2.3	0.41a	0.42a	0.41a	0.43a
4.5	0.41a	0.41a	0.41a	0.44a
6.8	0.40a	0.40a	0.42a	0.43a
			Fully developed	
0.0	0.39a	0.38a	0.37a	0.38a
2.3	0.39a	0.39a	0.38a	0.37a
4.5	0.40a	0.39a	0.37a	0.37a
6.8	0.40a	0.39	0.37a	0.37a
			Ripe	
0.0	0.38abc	0.39ab	0.39ab	0.34c
2.3	0.37abc	0.39ab	0.40a	0.35bc
4.5	0.37abc	0.40a	0.36abc	0.35bc
6.8	0.38abc	0.40a	0.35bc	0.35bc
			Petiole	
0.0	0.21ab	0.20ab	0.19ab	0.18ab
2.3	0.23ab	0.20ab	0.18ab	0.17b
4.5	0.24a	0.20ab	0.18ab	0.17b
6.8	0.23ab	0.19ab	0.19ab	0.18ab

CALCIUM

Table 4 shows that the Ca content in fruits during the three stages of development increased significantly in direct proportion as the N and B levels were supplied to the soil. However, the effects were more dramatic on mature and recently developed fruits. Table 4 also shows that the N and B supplied to the soil did not affect significantly the Ca content of the petiole.

MAGNESIUM AND MANGANESE

Tables 5 and 6 show that in fruits at the petal fall stage, Mg increased while Mn decreased significantly in direct proportion to the supply of N.

These same tables and figures 3 and 4 show that in fully developed and ripe fruits and in petioles the opposite occurred.

These results can be explained in the following way, Mg is immobile in papaya. The response in recently mature fruits may be promoted by new roots formed as a consequence of the high N supply. Those roots are responsible for higher Mg absorption, which will be accumulated directly in developing fruits.

A previous report (12) showed that leaf weight increased in direct

TABLE 3.—*Effect of N and B levels on the K content of papaya fruits during three stages of development, and on the petioles*

Boron levels	Nitrogen levels (kg/ha)			
	0	57	170	340
kg/ha	%	%	%	%
			Petal fall	
0.0	3.14ab	3.15ab	3.09ab	3.02ab
2.3	3.10ab	3.10ab	3.06ab	3.35a
4.5	2.92ab	3.06ab	3.37a	3.07ab
6.8	3.00ab	3.07ab	3.21ab	2.80b
			Fully developed	
0.0	2.66bc	3.18a	2.76abc	2.40c
2.3	2.91ab	2.84abc	2.59bc	3.02ab
4.5	2.76abc	2.88ab	2.93ab	2.43c
6.8	2.85abc	2.41c	2.44c	2.96ab
			Ripe	
0.0	2.10d	2.93bc	3.02ab	2.77bc
2.3	2.66bc	2.71bc	2.52c	2.87bc
4.5	3.03ab	3.05ab	2.72bc	2.86bc
6.8	2.60bc	2.94bc	2.85bc	3.40a
			Petiole	
0.0	2.98b	2.81bcd	2.49de	2.35e
2.3	3.40a	2.90bc	2.37e	2.46de
4.5	3.32a	2.57cde	2.52de	2.35e
6.8	2.82bcd	2.52de	2.67bcde	2.32e

proportion to the N and B supply; therefore, the reduction of Mg on the leaf and in mature and ripe fruits could be due to a dilution by growth of those parts of the plant.

Mg was not affected significantly and Mn decreased in fruits of the three stages of development as the B supply was increased (tables 5 and 6).

BORON

The results for the B content of fruits during the three stages of development (table 7) and for petioles (fig. 5) show that this nutrient

TABLE 4.—*Effect of N and B levels on the Ca content of papaya fruits during three stages of development, and on the leaf petiole*

Boron levels	Nitrogen levels (kg/ha)			
	0	57	170	340
kg/ha	%	%	%	%
			Petal fall	
0.0	0.88g	1.12ef	1.16de	1.17de
2.3	1.02f	1.17de	1.34c	1.81b
4.5	1.17de	1.21de	1.29cd	1.77b
6.8	1.17de	1.24cde	1.30cd	2.10a
			Fully developed	
0.0	0.56fg	0.71de	0.84cd	0.99ab
2.3	0.48g	0.73de	0.92bc	1.01ab
4.5	0.49g	0.69def	0.80be	1.11a
6.8	0.61efg	0.75de	1.10a	1.10a
			Ripe	
0.0	0.35d	0.35d	0.37d	0.40cd
2.3	0.35d	0.36d	0.35d	0.56bc
4.5	0.31d	0.37d	0.37d	0.45bcd
6.8	0.36d	0.43bcd	0.59b	0.82a
			Petiole	
0.0	1.30a	1.31a	1.46a	1.38a
2.3	1.48a	1.45a	1.51a	1.65a
4.5	1.33a	1.45a	1.58a	1.47a
6.8	1.39a	1.46a	1.62a	1.65a

TABLE 5.—*Effect of N and B levels on the Mg content of papaya fruits during three stages of development*

Boron levels	Nitrogen levels (kg/ha)			
	0	57	170	340
kg/ha	%	%	%	%
			Petal fall	
0.0	1.47de	1.65abc	1.62abcd	1.71ab
2.3	1.43e	1.52cde	1.57bcde	1.63abcd
4.5	1.56bcde	1.58bcde	1.65abc	1.73ab
6.8	1.67abc	1.68abc	1.70abc	1.78a
			Fully developed	
0.0	1.28a	0.95bc	0.81cd	0.75cd
2.3	1.30a	1.05b	0.79cd	0.76cd
4.5	1.31a	0.82cd	0.75cd	0.70d
6.8	1.26a	0.79cd	0.76cd	0.70d
			Ripe	
0.0	0.63bc	0.71a	0.57bcd	0.58bc
2.3	0.64bc	0.53cd	0.53cd	0.51cd
4.5	0.69ab	0.63bc	0.54cd	0.52cd
6.8	0.79a	0.56bcd	0.55cd	0.44d

TABLE 6.—*Effect of N and B levels on the Mn content of papaya fruits during three stages of development*

Boron levels	Nitrogen levels (kg/ha)			
	0	57	170	340
kg/ha	*p/m*	*p/m*	*p/m*	*p/m*
			Petal fall	
0.0	82a	84a	78ab	65bcd
2.3	86a	85a	63cd	62cd
4.5	76abc	80ab	66bcd	54d
6.8	73abc	62cd	63cd	56d
			Fully developed	
0.0	26b	25b	18d	21cd
2.3	39a	23bc	21cd	21cd
4.5	25b	24bc	18d	18d
6.8	20cd	19d	18d	17d
			Ripe	
0.0	19ab	20ab	20ab	22a
2.3	21ab	20ab	20ab	16abc
4.5	20ab	19ab	19ab	15bc
6.8	19ab	21ab	20ab	13c

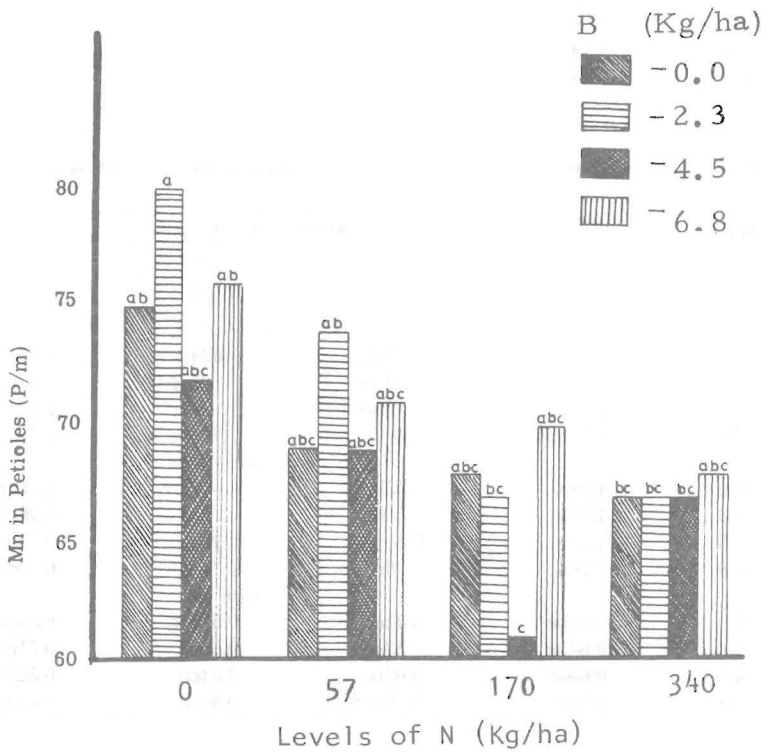

FIG. 3.—Effect of N and B levels on the Mg content of papaya petioles.

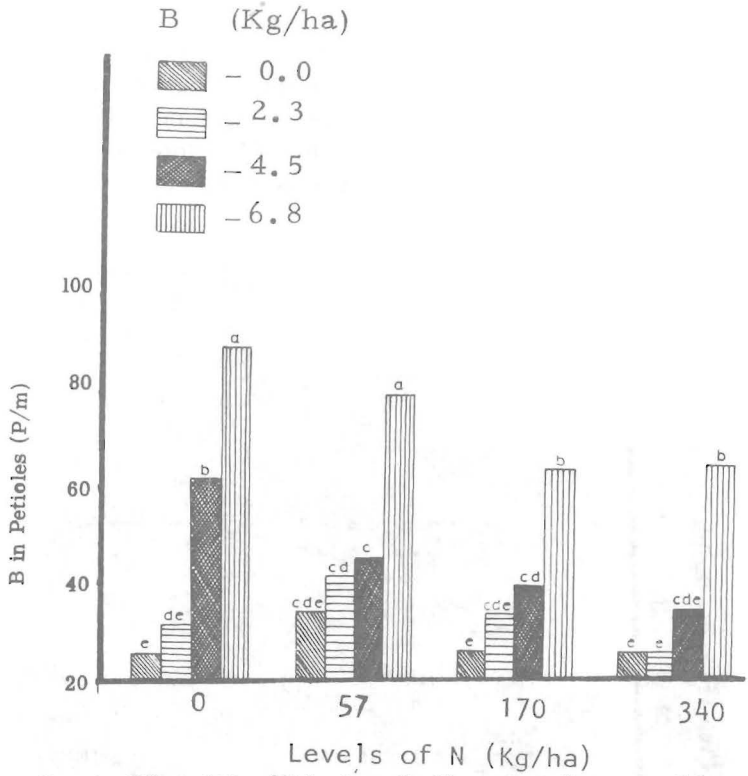

FIG. 4.—Effect of N and B levels on the Mn content of papaya petioles.

TABLE 7.—*Effect of N and B levels on the B content of papaya fruits during three stages of development*

Boron levels	Nitrogen levels (kg/ha)			
	0	57	170	340
kg/ha	*p/m*	*p/m*	*p/m*	*p/m*
			Petal fall	
0.0	40b	48h	51h	95ef
2.3	69g	74g	81fg	100cde
4.5	98de	95de	108cde	115bc
6.8	110bcde	125b	112bcd	162a
			Fully developed	
0.0	39f	39f	65bcd	46ef
2.3	52def	38f	72abc	50ef
4.5	53def	44f	76ab	51def
6.8	59cde	47ef	80a	80cde
			Ripe	
0.0	39cd	28d	41bcd	29d
2.3	41bcd	32d	52ab	33d
4.5	40bcd	33d	54a	34d
6.8	49abc	34d	56a	38cd

element increased significantly and consistently with the N and B supplied. Figure 2 also shows that at the 4.5 and 6.8 kg/ha B treatments, the B content of petioles decreased significantly when the N supply was increased from 0 to 157 kg/ha. This decrease suggests that there is a N × B interaction between these two elements. Therefore, the response to N by papaya may be affected by the B status of the plant.

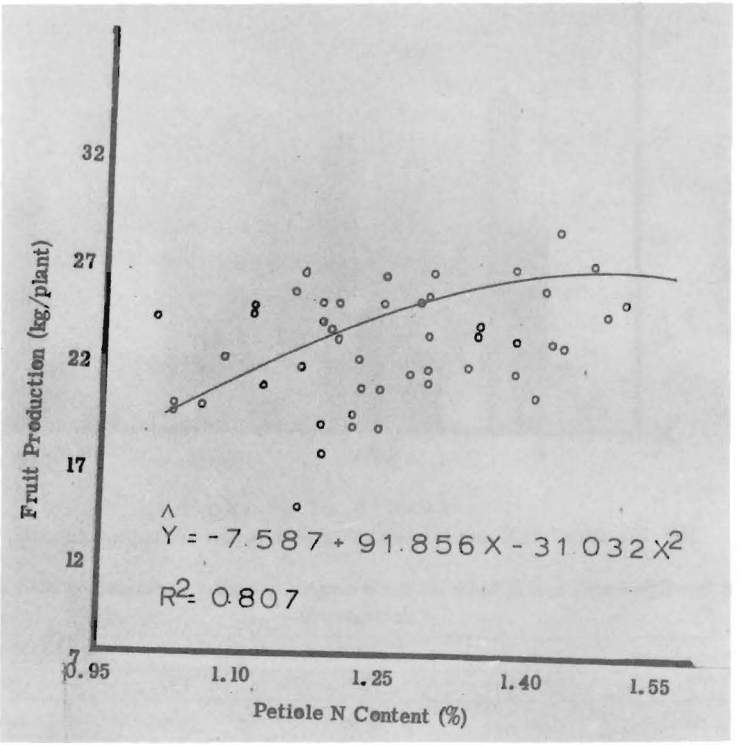

FIG. 5.—Curvilinear relationship of fruit production and % N in the petiole of papaya leaf.

NITROGEN AND BORON INDEX

Figures 5 and 6 show the relationship between the petiole N and B content and fruit production. The two quadratic curves that demonstrate the equations for these nutrient elements respectively were as follows:

$$Y = -7.587 + 91.856\ X - 31.032\ X^2\ R^2 = 0.807, \quad \text{and} \quad Y = 21.572 + 1.153\ X - 0.009\ X^2\ R^2 = 0.895.$$

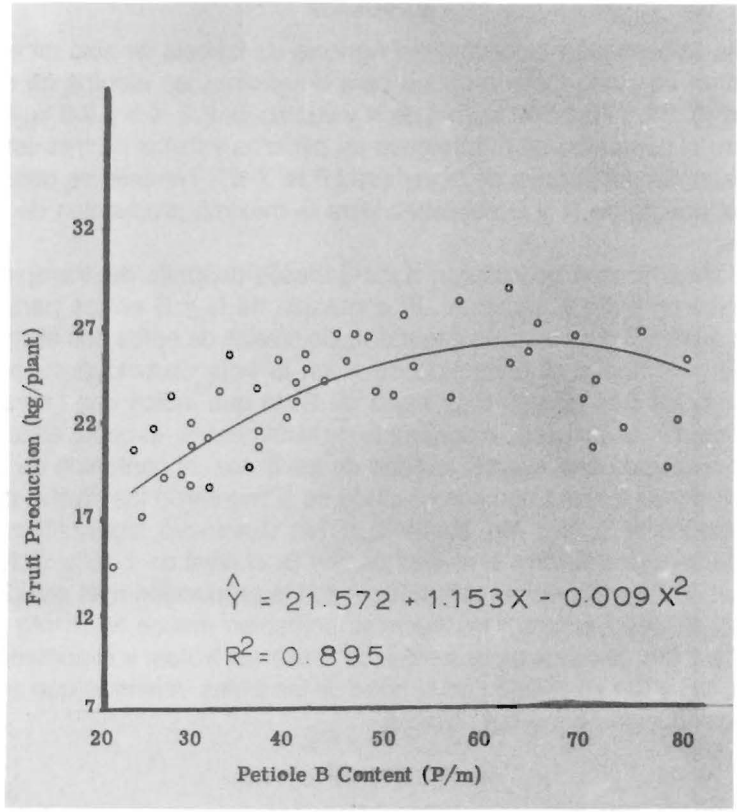

FIG. 6.—Curvilinear relationship of fruit production and p/m B in the petiole of papaya leaf.

According to these best fitting equations, the maximum yield of 24 kg of green fruits per plant could be obtained when the N leaf petiole content was 1.48% and that of B was 64 p/m. The result for the nitrogen content is in agreement with that for Solo papaya found by Awada (1), who reported that 1.45% N content was required in Hawaii for the maximum yield of that papaya variety; and with that of Godoy et al. (6), who reported that the optimum N content for *C. candamarcensis* in Chile was between 1.4% and 1.7%. The optimum B content appears to be close to that of *C. candamarcensis*, which is between 30 and 70 p/m (6).

The high R^2 values denote that the curves fit well to the data, better in the case of B than with N, because the R^2 of the former was higher.

RESUMEN

En la Subestación Experimental Agrícola de Isabela se hizo un experimento en un suelo Coto arcilloso para determinar los efectos de cuatro niveles (0, 57, 170 y 340 kg/ha) de N y cuatro (0, 2.3, 4.5 y 6.8 kg/ha) de B sobre el contenido de nutrimentos en pecíolos y frutas en tres estadios de desarrollo del papayo de la variedad P.R. 7-65. También se determinó el nivel óptimo de N y B necesario para la máxima producción de frutas verdes.

Los tratamientos se iniciaron a los 3 meses después del transplante y se repitieron cada 6 semanas. El contenido de N y B en los pecíolos y frutas aumentó cuando se aumentaron los niveles de estos dos elementos aplicados al suelo; el contenido de N en la hoja disminuyó cuando se aplicaron los tres niveles más bajos de B, lo que indica una interacción entre los dos elementos; el contenido de nutrimentos, excepto el de P, se redujo a medida que avanzó la edad de los frutos; el contenido de Ca en las hojas y en la fruta aumentó cuando se aumentaron los niveles de N y B aplicados al suelo; Mg aumentó y Mn disminuyó significativamente cuando se aumentaron los niveles de N y B; el nivel de 1.48% de N y de 64 ppm de B en el pecíolo coincidieron con la producción más alta (24 kg/planta), respectivamente; los pecíolos contenían menos N, P, Mg y B y más Ca y Mn, pero igual porcentaje de K que las frutas; y el contenido de B, Ca, Mg y Mn se redujo con la edad de las frutas, mientras que en N, P y K la reducción no fue tan notable.

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