THE JOURNAL OF AGRICULTURE
OF THE UNIVERSITY OF PUERTO RICO

Issued quarterly by the Agricultural Experiment Station of the University of Puerto Rico, for the publication of articles by members of its personnel, or others, dealing with any of the more technical aspects of scientific agriculture in Puerto Rico or the Caribbean Area.

Vol. XLII | October 1958 | No. 4

Effects of the Calcium-Boron Relationship on Growth and Production of the Pineapple Plant

E. Hernández-Medina and M. A. Lugo-López[1]

INTRODUCTION

Work dealing with calcium-boron relationships in plant nutrition has revealed an apparent association between the calcium in the soil and the availability of boron to the plants. Naftel (*10, 11, 12*)[2] demonstrated that excessive liming adversely affected plant growth by bringing about boron deficiency. Cook, *et al.* (*4*) have shown that boron-deficient plants were most seriously affected where active calcium was greatest. According to Midgley, *et al.* (*9*), excessive application of liming materials such as calcium carbonate and calcium oxide, promotes boron fixation as long as they maintain the growth medium sufficiently alkaline. Wolf (*15*) found that the boron content of the crop decreased and boron deficiency occurred with increasing rates of application of hydrated lime. According to Jones *et al.* (*8*), plants grown in soils with a very high calcium content, such as alkaline or overlimed soils, required more boron than in acid soils. They pointed out that the physiological balance of calcium and boron in such soils tends to be disturbed because of the excess intake of calcium by the plants. In fact, they made the suggestion that plants growing in such soils may require more boron than is generally available.

To judge from the investigations mentioned above, metabolic disturbances of plants are likely to result in abnormal growth because of an initiation or accentuation of boron deficiency in them as a result of overliming the soil.

In Puerto Rico pineapple growers used to make lime applications to their pineapple soils every year. It appeared possible that these annual applications might accumulate in the soil to such an extent as to limit boron intake by the pineapple plant. This, in turn, could cause boron deficiency, which may probably have been reflected in low pineapple yields.

[1] Associate Horticulturist and Associate Soil Scientist, respectively, Agricultural Experiment Station, University of P.R., Río Piedras, P.R.

[2] Italic Numbers in parentheses refer to Literature Cited p. 222–3.

Therefore, a greenhouse experiment was undertaken to obtain fundamental knowledge on the effects of different calcium and boron nutrient levels upon the physiology of the pineapple plant under controlled conditions. It was felt that the data from this work could serve as a basis for future research.

MATERIALS AND METHODS

CULTURAL METHOD

For this experiment pineapple slips of the Red Spanish variety were obtained from Palo Blanco, Arecibo, which is one of the typical pineapple areas in Puerto Rico. The slips were selected for uniformity in size and weight and were planted in purified quartz sand in 5-gallon coffee-urn liners. The average weight of the slips was 327 gm. The extreme weights among all slips fluctuated between 300 and 350 gm.

The slips received only distilled water for a period of about 3 weeks, when they were given a dilute complete nutrient solution for some 60 days, and then the differential nutrient treatments were started. The nutrient treatments were maintained until fruiting. The slop-culture technique was adopted for applying the nutrient solutions. A liter of nutrient solution was applied to each culture every other day. This was sufficient to keep the nutrient medium wet, as judged from the dripping which began a relatively short period following the application of the fresh solutions. Once a week the cultures were flushed with distilled water so as to remove any concentration of salts at the surface of the sand. This was immediately followed by application of fresh nutrient solutions.

In this experiment five calcium nutrient levels were employed, as follows: 5, 50, 100, 250, and 500 p.p.m. Five cultures were grown at each calcium level, each receiving a different boron concentration. The concentrations of boron used were as follows: 0, 0.001, 0.25, 1.0, and 5.0 p.p.m. Thus, there was a total of 25 treatments in the whole experiment and each treatment was replicated 3 times, making a total of 75 cultures. Although 5 p.p.m. boron is probably insufficient to cause much toxicity in the plants, it was assumed that it might to some extent upset the normal metabolism of the pineapple plant. The experiment was arranged following a triple-lattice design.

The nutrient solutions were prepared by using the following salts in the molar concentrations indicated:

KH_2PO_4	0.00097
K_2SO_4	.00095
$NaNO_3$	.0071
$MgSO_4$	.0016

The different calcium levels were maintained as shown in the following tabulation:

Ca level (p.p.m.)	*Molar concentration of salts*
5	0.000125 $CaCl_2$
50	.00125 $CaCl_2$
100	.0025 $CaCl_2$
250	.00625 $CaCl_2$
500	.00625 $CaCl_2$ + 0.00625 $CaSO_4$

Other essential nutrient elements were supplied to all cultures expressed in p.p.m. as follows: Fe, 2.0; Mn, 0.5; Zn, 1.0; Cu, 1.0; and Al, 1.0.

Observations were made on the effect of the various calcium-boron nutrient treatments on plant growth and development. Six months after starting treatments leaf samples were taken from each plant for total and soluble calcium and boron determinations. The active or largest leaf of each plant was selected for this purpose (*14*). The meristematic tissue of the leaves was used for the analytical work. Leaf samples for chemical work were prepared as previously reported (*6*).

All plants were treated with acetylene to induce flowering. The treatment consisted in applying to the crown of the plants about 25 ml. of a solution made by dissolving 2 ounces of calcium carbide in 5 gallons of water in a closed container. The pineapple crop was harvested some 5 months after the plants received the acetylene treatment. The growth criteria considered to evaluate the effects of treatments were fruit yields, green and dry weights of plants, fresh and dry weights of roots, and number and weight of slips.

CHEMICAL ANALYSES

The procedure followed in grinding and ashing, and extracting the cell sap from the leaf-tissue samples has been reported elsewhere (*6*). Calcium was determined according to the official micromethod of the Association of Official Agricultural Chemists (*1*). The Berger and Truog quinalizarin method was used for the boron analyses (*2*).

RESULTS AND DISCUSSION

PLANT DEVELOPMENT

Pineapple plants grown where boron was omitted from the culture at the lowest and three highest levels of calcium—5, 100, 250, and 500 p.p.m. in cultures 1, 3, 4, and 5, made much less vegetative growth than plants grown in cultures which received the same level of boron, but had a low level of calcium, 50 p.p.m., culture 2. The plants in this last group were rather stout and green as compared with the almost slender and light-

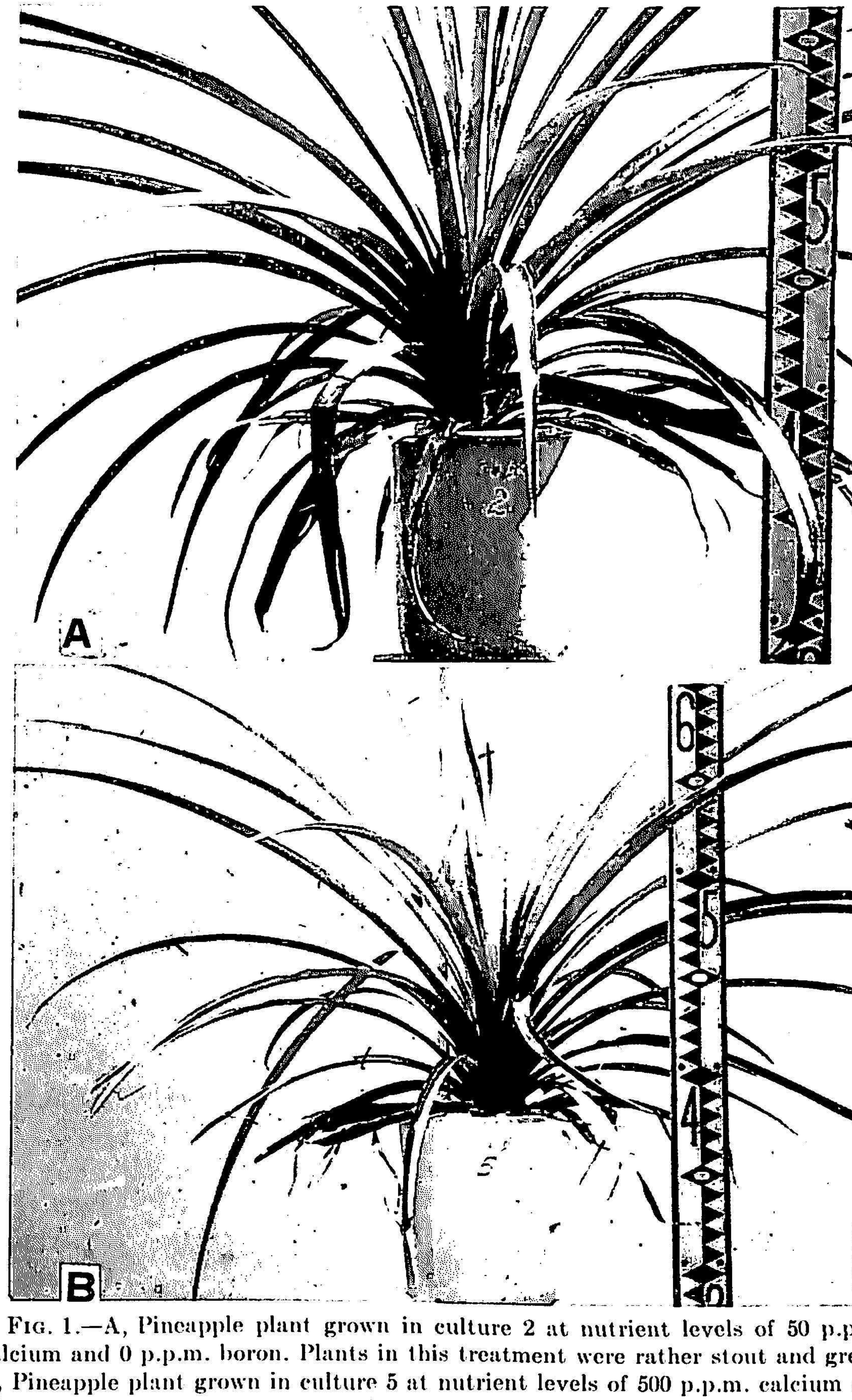

FIG. 1.—A, Pineapple plant grown in culture 2 at nutrient levels of 50 p.p.m. calcium and 0 p.p.m. boron. Plants in this treatment were rather stout and green. B, Pineapple plant grown in culture 5 at nutrient levels of 500 p.p.m. calcium and 0 boron. Plants in this treatment had a slender growth and were light green or yellow-green in color.

green or yellow-green plants of the former (fig. 1). No other differences in plant growth and development were observed which could be attributed to treatments.

EFFECT OF CALCIUM-BORON LEVELS ON FRUIT WEIGHT

The results on mean fruit weights from plants undergoing the various calcium-boron nutrient treatments are presented in table 1 and figure 2. Statistical analyses of the yield data indicate significant differences between treatment means. Pineapple plants at the highest level of calcium, 500 p.p.m., culture 5, but without boron, produced the lowest fruit yields. On the other hand, plants grown with low and intermediate amounts of calcium, without boron, 50, 100 p.p.m. calcium, cultures 2 and 3, were the heaviest yielders. The yield of plants from culture 2 was significantly higher at the 5-percent level than that of plants from culture 5, supplied with the highest nutrient concentration of calcium but without boron in the substrate. It is evident that fruit yield was adversely affected by the high calcium concentration when boron was omitted from the nutrient medium.

Further analyses of the yield data revealed rather interesting facts concerning the highest level of boron and the various levels of calcium. At the highest boron concentration, 5 p.p.m., yields of pineapples increased with increments of the calcium concentrations. Pineapple yields were largest in those plants which received 250 and 500 p.p.m. of calcium. respectively, at the highest boron level, cultures 24 and 25. The yields of plants grown at 250 p.p.m. of calcium were significantly higher at the 5-percent level than those of plants grown at 5 p.p.m. of calcium with the same boron level, culture 21. Thus it is apparent that a combination of high calcium and high boron seems to favor a more normal metabolism in the pineapple plant than a combination of very low calcium and high boron.

At a boron level of 0.25 p.p.m., plants which received calcium in amounts of 50 and 100 p.p.m. produced significantly higher fruit yields than plants at the same boron level but the lowest, 5 p.p.m., calcium level. However, at a boron level of 1 p.p.m., plants supplied with 250 p.p.m. of calcium yielded significantly better than those at the same boron level, but at either the lowest or highest calcium concentration.

EFFECT OF CALCIUM-BORON LEVEL ON GREEN AND DRY WEIGHT OF PLANTS

Table 1 further shows the mean green and dry weights of pineapple plants as affected by treatments. In the treatments from which boron was omitted it can be seen that the pineapple plants, culture 2, at the 50-p.p.m. calcium level produced significantly more green plant material at the 5- or 1-percent level than those which received the two highest nutrient concentrations of calcium, but no boron, cultures 4 and 5. Thus, high

TABLE 1.—*Mean fruit weight and green and dry weight of pineapple plants grown in sand cultures at different calcium and boron concentrations in the nutrient medium*

Culture No.	Treatment		Mean fruit weight	Mean green weight of plants	Mean dry weight of plants
	Ca	B			
	P.p.m.	*P.p.m.*	*Pounds*	*Pounds*	*Pounds*
1	5	0	2.11	6.02	0.91
2	50	0	2.59	9.59	1.52
3	100	0	2.39	7.74	1.15
4	250	0	2.10	5.64	.90
5	500	0	1.69	6.54	1.11
6	5	.001	2.58	7.83	1.18
7	50	.001	2.37	7.68	1.09
8	100	.001	2.58	8.27	1.25
9	250	.001	2.22	6.88	1.07
10	500	.001	2.38	8.31	1.22
11	5	.25	1.86	4.97	.66
12	50	.25	2.74	8.06	1.44
13	100	.25	2.63	8.99	1.19
14	250	.25	2.03	4.61	.73
15	500	.25	2.54	6.92	1.11
16	5	1.0	1.95	5.19	.79
17	50	1.0	2.74	7.28	1.07
18	100	1.0	2.75	9.92	1.53
19	250	1.0	3.12	8.55	1.22
20	500	1.0	2.31	8.07	1.28
21	5	5.0	2.12	6.71	1.00
22	50	5.0	2.35	6.31	.91
23	100	5.0	2.35	7.31	1.09
24	250	5.0	3.03	7.12	1.01
25	500	5.0	2.80	6.68	1.02
Least significant difference at:					
5-percent level			0.73	2.29	0.35
1-percent level			.98	3.08	.47

calcium levels adversely affected the green weight of plants when no boron was supplied. Furthermore, the plants of culture 2 produced significantly more green plant material at the 1-percent level than the plants grown in

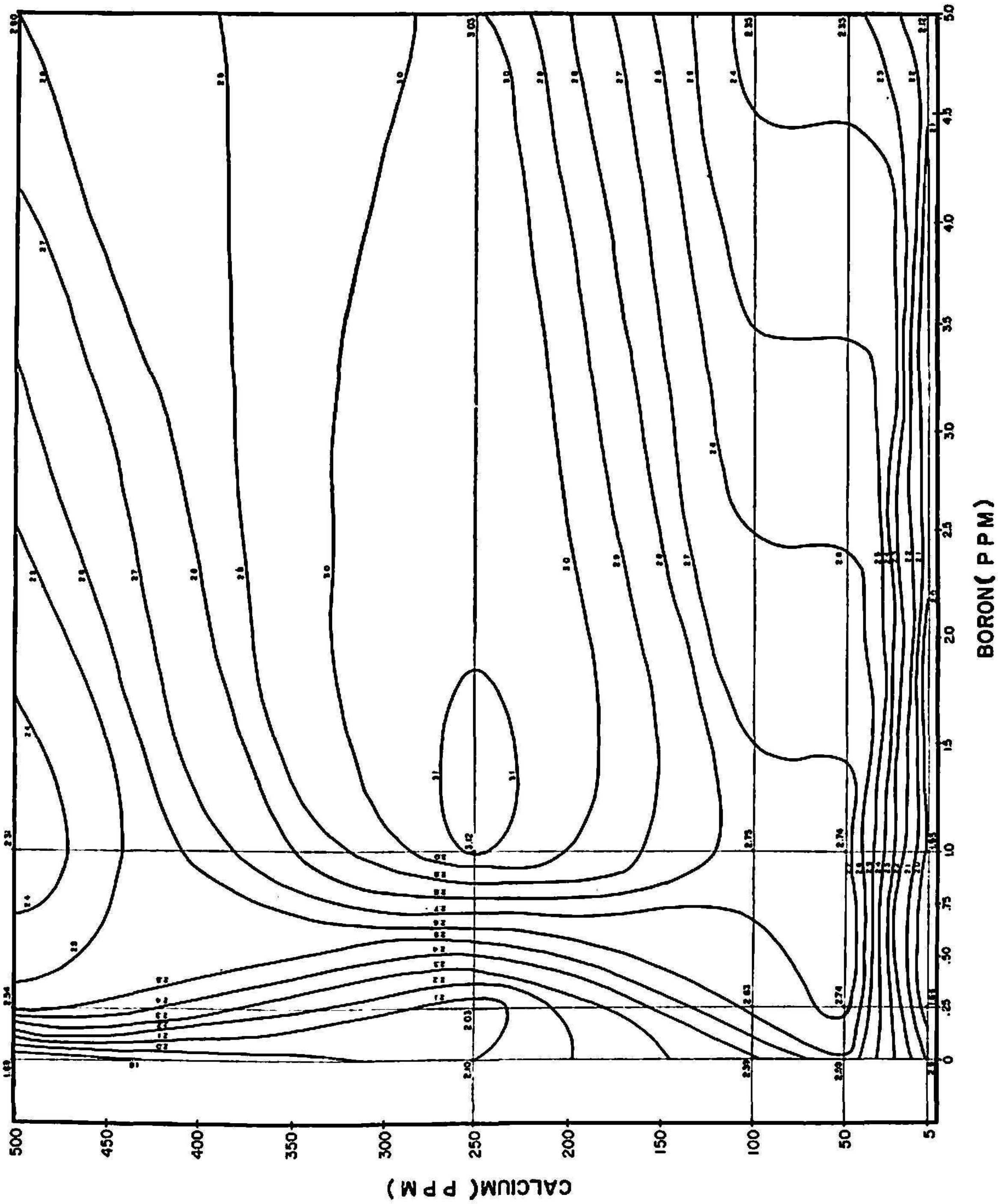

FIG. 2.—Mean fruit-weights of pineapple plants as affected by different calcium and boron concentrations in the nutrient medium.

culture 1 at the lowest calcium level, 5 p.p.m., and without boron. No significant differences were found between the green weight of plants grown at the highest boron level when the calcium was increased from 5 to 500 p.p.m. At the boron level of 0.25 p.p.m., increments in the calcium concentration induced significant differences in the green weight of plants, but the trend was not too definite. However, at the 1-p.p.m. boron level, increments in the calcium were apparently responsible for significant increases in the green weight of plants. Within any given calcium level, increases in the boron concentration did not exert any significant effect on the green weight of plants, except at 50 p.p.m. of calcium without boron, culture 2, at 5 p.p.m. of calcium and 0.001 p.p.m. of boron, culture 6, and at 250 p.p.m. of calcium and 1 p.p.m. of boron, culture 19.

The dry weight of plants in culture 2, 50 p.p.m. of calcium, from which boron was omitted, were highest of all within the group. This dry weight of the plants was significantly higher at the 1-percent level than that of plants grown at the lowest calcium level, culture 1. Increments of calcium above 50 p.p.m. with no boron reduced the dry weight of the plants as compared with those of culture 2, 50 p.p.m. calcium, and no boron. In fact, the dry weight of the latter plants was significantly higher at the 5- or 1-percent level than that of cultures 3, 4, and 5, at the highest calcium levels. Thus, at a deficient boron level, increments in calcium concentration above 50 p.p.m. reduced the dry weight of the plants. It should be recalled that the pineapple plants of culture 2 yielded best.

As in the green-weight data, no significant trend was observed in the dry weights of plants grown at the 5-p.p.m. boron level, when calcium concentrations were increased from the lowest to the highest levels. On the other hand, at the 1-p.p.m. boron level, increments in the calcium concentration caused irregular increases in the dry weight of plant material.

EFFECT OF CALCIUM-BORON LEVEL ON FRESH AND DRY WEIGHT OF ROOTS

After fruits were harvested, the fresh and dry weights of the roots were obtained (table 2) to determine whether the nutrients had any effect on root growth and development. Plants grown at low calcium, 50 p.p.m., but without boron, culture 2, significantly surpassed all other plants in root formation, even those grown at higher calcium concentrations. Presumably, the very low concentration of calcium in the absence of boron in culture 1 limited root growth and development. As shown in table 2, increments in the calcium concentration above 50 p.p.m. reduced root development, a phenomenon most pronounced at 250 p.p.m. of calcium.

Thus, it is apparent that calcium concentrations above 50 p.p.m. adversely affected root growth when no boron was added to the nutrient medium.

TABLE 2.—*Mean weight of fresh and dry roots and number and weight of slips of pineapple plants grown in sand culture at different calcium and boron concentrations in the nutrient medium*

Culture No.	Treatment		Mean fresh root weight	Mean dry root weight	Mean number of slips	Mean weight of slips
	Ca	B				
	P.p.m.	*P.p.m.*	*Grams*	*Grams*		*Grams*
1	5	0	209.3	66.2	0.33	6.67
2	50	0	382.9	96.8	5.33	214.00
3	100	0	226.8	63.1	1.67	24.00
4	250	0	214.9	52.4	.67	32.33
5	500	0	259.2	68.7	1.33	21.67
6	5	.001	246.0	77.8	1.00	85.33
7	50	.001	225.8	66.5	1.33	21.67
8	100	.001	256.8	82.7	1.33	32.33
9	250	.001	230.6	59.6	.67	21.33
10	500	.001	208.0	64.2	1.33	28.33
11	5	.25	176.0	51.9	0	0
12	50	.25	351.0	85.3	3.67	5.67
13	100	.25	220.7	90.1	1.33	43.00
14	250	.25	141.0	51.2	.33	4.00
15	500	.25	243.0	66.5	1.33	22.67
16	5	1.0	195.7	55.9	0	0
17	50	1.0	227.9	64.5	2.33	112.33
18	100	1.0	393.9	83.3	1.67	106.00
19	250	1.0	233.4	68.2	2.67	110.00
20	500	1.0	281.9	62.4	1.67	66.67
21	5	5.0	256.5	70.6	2.67	67.33
22	50	5.0	187.5	71.1	0	0
23	100	5.0	208.8	57.8	1.00	19.00
24	250	5.0	281.5	74.5	3.00	137.67
25	500	5.0	172.7	52.8	1.33	29.33
Least significant difference at:						
5-percent level			101.46	27.18	2.70	152.27
1-percent level			136.15	36.47	3.61	203.67

At the highest nutrient level of boron, 5 p.p.m., the fresh and dry weights of the roots did not show any definite trends with added calcium increments.

EFFECT OF CALCIUM-BORON LEVEL ON NUMBER AND WEIGHT OF SLIPS

The plants grown at the lowest calcium level, 5 p.p.m., but without boron, culture 1, produced the lowest mean number and weight of slips within the group (table 2). No slips were produced by plants of cultures 11, 16, and 22. The lack of slip production in cultures 11 and 16 might have been caused by lack of sufficient calcium for normal metabolic processes. We have as yet no satisfactory explanation for the lack of slip production in culture 22. The mean number and weight of slips decreased significantly at the three highest nutrient levels of calcium with no boron when compared with those at the 50-p.p.m. calcium level. Both insufficient and excessive calcium, and no boron, adversely affected the production of slips by the pineapple plant.

Variations in the boron level at a given calcium concentration were responsible for significant differences in number and weight of slips in some cases, as was previously observed for the green and dry weights of plants and roots.

CHEMICAL ANALYSES OF LEAF-TISSUE FRACTIONS

The results of the chemical determinations of total and soluble boron and calcium in the meristematic tissue of the active leaves of pineapple plants are presented in table 3. It appears that the total and soluble boron fractions, but particularly the soluble boron at a given boron level, were largely affected by the boron concentration of the substrate, and slightly influenced by the calcium concentration, with only a few marked exceptions. For instance, when boron was omitted from the nutrient solution, the soluble boron content of the meristematic tissue of active leaves of plants growing at the two highest calcium levels, 250 and 500 p.p.m., was relatively low as compared with plants growing at the three lower calcium levels (fig. 3). This suggests that soluble boron accumulating in the meristematic tissue of active leaves was affected in some way at the two highest calcium levels.

The greatest reduction of metabolically active boron occurred at the highest nutrient level of calcium, culture 5. Similar levels have been obtained by Brennan and Shive (*3*) and Hernández and Shive (*7*), working with tomato and corn plants, respectively. It should be recalled that the pineapple plants from this treatment, 500 p.p.m. of calcium and no boron, produced the lowest significant yield of pineapples when compared with the plants which received low calcium, 50 p.p.m. at the same boron level, and which yielded the most. The meristematic tissue of the active leaves of the plants from this treatment had the highest content of metabolically active boron. Thus it appears that the lowest yielding plants grown at the lowest boron and the highest calcium level, were associated with the lowest tissue content of soluble or active boron, while the highest yielding

TABLE 3.—*Total and soluble boron and calcium contents of meristematic tissue of active leaves of pineapple plants grown in sand culture at different calcium and boron concentrations in the nutrient medium*

Culture No.	Treatment		Total B	Soluble B	Soluble B, percentage of total	Total Ca	Soluble Ca
	Ca	B					
	P.p.m.	*P.p.m.*	*Mg./gm.*	*Mg./gm.*	*Percent*	*Mg./gm.*	*Mg./gm.*
1	5	0	0.018	0.009	50.0	2.03	1.33
2	50	0	.021	.013	61.9	3.71	.84
3	100	0	.020	.009	45.0	6.08	1.26
4	250	0	.018	.005	27.8	6.72	.74
5	500	0	.024	.002	8.3	9.97	4.12
6	5	.001	.023	.013	56.6	1.13	.34
7	50	.001	.024	.015	62.5	4.05	2.43
8	100	.001	.024	.015	62.5	5.45	2.51
9	250	.001	.019	.008	42.1	11.90	6.05
10	500	.001	.035	.014	40.0	8.79	1.46
11	5	.25	.020	.016	30.0	2.45	.60
12	50	.25	.034	.018	52.9	3.74	2.00
13	100	.25	.040	.028	70.0	6.38	2.27
14	250	.25	.047	.028	59.6	8.32	2.04
15	500	.25	.049	.026	53.1	9.79	4.35
16	5	1.0	.049	.024	49.0	4.80	3.47
17	50	1.0	.040	.028	70.0	7.07	4.80
18	100	1.0	.039	.031	79.5	5.59	1.45
19	250	1.0	.042	.014	33.3	9.98	4.80
20	500	1.0	.047	.027	57.4	11.90	6.54
21	5	5.0	.035	.025	57.1	1.85	1.24
22	50	5.0	.044	.024	54.5	3.77	1.71
23	100	5.0	.044	.031	70.5	5.05	1.17
24	250	5.0	.045	.015	33.3	10.00	8.37
25	500	5.0	.036	.009	25.5	8.57	2.92
Least significant differences at:							
5-percent level			0.0026	0.0032		0.333	0.141
1-percent level			.0034	.0043		.445	.188

plants were associated with the highest content of soluble active boron in the leaf-tissue fraction analyzed i.e., the plants grown at a 50-p.p.m. calcium level.

At the highest boron level increments in the calcium level did not have any marked influence on tissue content of total boron. However, soluble boron was reduced at the second highest calcium level, culture 24, and

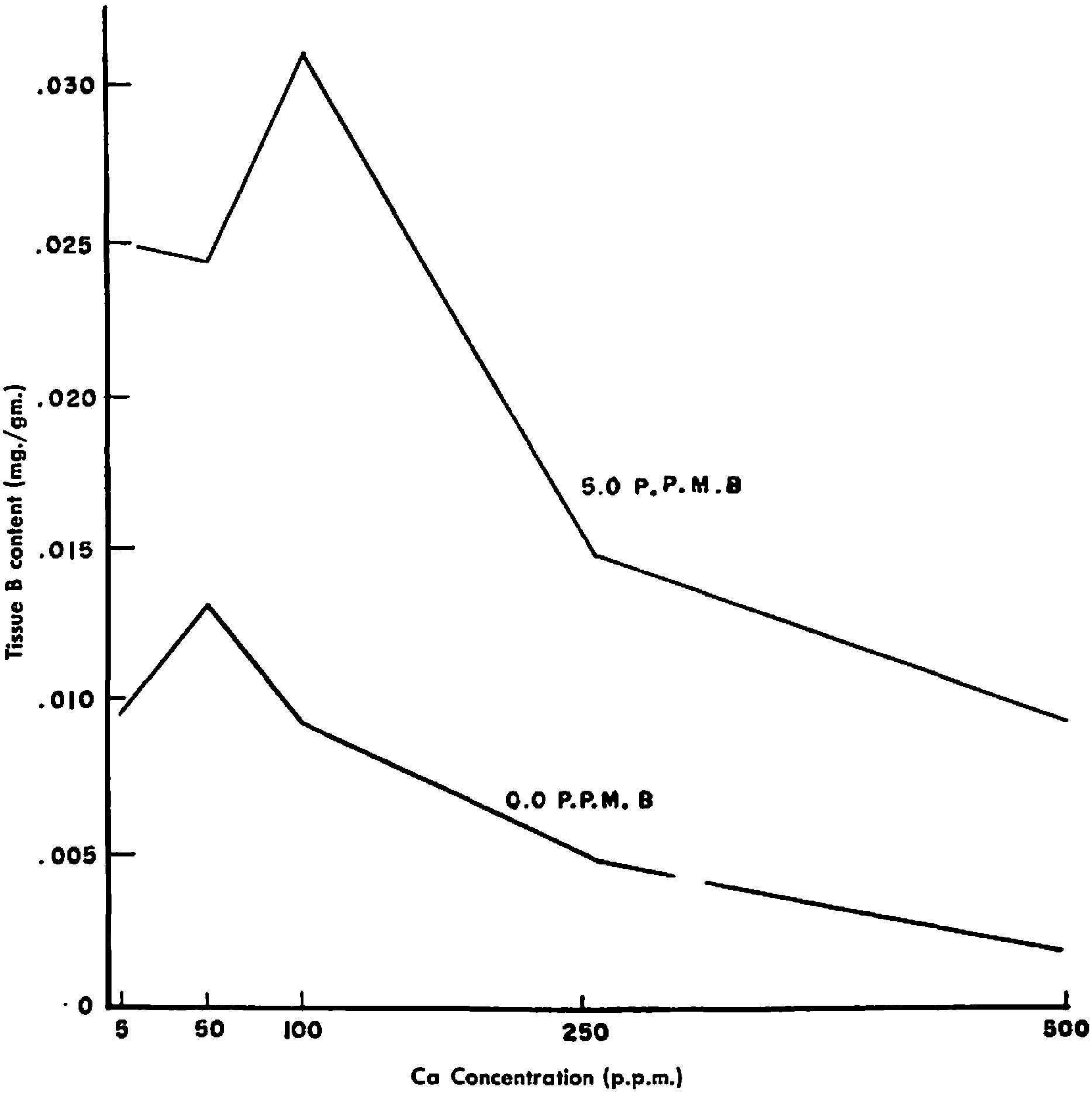

FIG. 3.—Soluble boron content of the meristematic tissue of active leaves of pineapple plants grown at 0 and 5.0 p.p.m. boron, plotted against calcium concentration in the substrate.

still more at the highest calcium level, culture 25, (fig. 3). This indicates the possibility that soluble boron might have been bound to some extent at the two highest calcium levels when boron was supplied at a high concentration in the nutrient medium. It should be recalled that the plants which received the two highest concentrations of calcium at the highest boron level produced higher yields than those which received the lowest calcium concentration at the same boron level.

In general, total calcium at any given boron level was largely determined by the calcium concentration and was not greatly influenced by the boron concentrations. With few exceptions, increments in the boron concentration did not greatly influence the total calcium content of the plant tissue at a given calcium level. On the other hand, and contrary to expectations, increments in the calcium concentration at a given boron level were not followed by a consistent increase of soluble calcium in the plant tissue, and there was no definite trend in soluble-calcium data at a given calcium level with increments of boron. As shown in table 3, soluble calcium does not seem to depend either on the total calcium or the total or soluble boron contents of the tissue.

CONCLUSIONS

The results presented in this paper show the interrelationship of calcium and boron, and their influence on the metabolism of the pineapple plant.

The fact that the pineapple plants which received only 5 p.p.m. of calcium without boron produced more than those which received the highest nutrient concentration of calcium, 500 p.p.m., at the same boron level, suggests that the combination of high calcium and deficient boron disturbs the normal metabolism of the pineapple plant more seriously than a combination of low calcium and deficient boron.

The detrimental effect of increments of calcium above 50 p.p.m., when boron was not supplied, suggests that abnormal plant metabolism may be expected in substrates deficient in boron, when calcium is present in relatively high concentrations. It is apparent that low levels of calcium are sufficient to promote a more normal plant metabolism than high levels used with a limited or deficient boron supply.

At a boron concentration of 5 p.p.m., increments of calcium produced significantly higher fruit yields in plants which received 250 and 500 p.p.m. of calcium than in those supplied with 5 p.p.m. of calcium only. This indicates that, at relatively high boron concentrations, a combination of high calcium and high boron tends to favor a more normal plant metabolism than does very low calcium and high boron. Similar results have been obtained by other investigators (*3*, *7*, *8*), insofar as plant growth is concerned. However, no significant trends were observed in some of the other growth criteria discussed, at least at the boron and calcium levels considered.

SUMMARY

1. The response of pineapple plants throughout their life cycle to different nutrient levels of boron in combination with different nutrient levels of calcium was studied in sand cultures.

2. Pineapple plants not receiving boron at the lowest and three highest

nutrient levels of calcium, 5, 100, 250, 500 p.p.m., made much less vegetative growth than those grown without boron, but at a low calcium level, 50 p.p.m. Plants in the last group were stout and green as compared with the rather slender and light-green or yellow-green plants of the former.

3. Pineapple plants grown without boron but at the highest calcium level produced the lowest fruit yields as compared with plants grown without boron but at low calcium, 50 p.p.m. These yielded most.

4. In pineapple plants supplied with the highest nutrient concentration of boron, 5 p.p.m., yields increased as the calcium concentration of the substrate increased from 5 to 500 p.p.m. However, yields were greatest from the plants that grew at the second highest calcium concentration, 250 p.p.m.

5. Either deficient or relatively high calcium concentrations, 5, 250, 500 p.p.m., adversely and significantly affected the green weight of plants when no boron was supplied. Low-calcium plants, 50 p.p.m., produced the highest significant green weights at the lowest nutrient level of boron.

6. Increments of calcium above 50 p.p.m. at the lowest nutrient level of boron induced significant reductions in the dry weights of plants, the weights of roots, and number and weight of slips. Deficient calcium induced a similar reduction.

7. At a given boron level, total boron in the plant tissue was largely a function of the boron concentration of the substrate and was not greatly influenced by its calcium concentration.

8. At the lowest level of boron, and at the two highest calcium levels, the content of soluble boron in the tissue was considerably less than at the three lowest calcium concentrations. The least soluble or metabolically active boron was found at the highest calcium level, while the highest content of the soluble fraction of this element was accumulated in the leaves of plants grown at low calcium, 50 p.p.m.

9. The lowest yielding plants grown without boron and at the highest level of calcium, 500 p.p.m., were associated with the lowest leaf-tissue content of soluble or active boron, while the highest yielding plants grown at the same boron level, but with low calcium, 50 p.p.m., were associated with the highest content of soluble or active boron in the meristematic tissue of the leaves.

10. Increments in the calcium level did not have any marked effect on the tissue content of total boron at the highest boron level. However, soluble boron was reduced to some extent in the tissue at the two highest calcium concentrations.

11. Plants grown at the highest level of boron and at the second highest level of calcium, 250 p.p.m., produced heavier yields than plants at the same boron level, but at either lower or higher calcium levels. However,

at the same boron level, increments in calcium did not definitely affect the green and dry weights of plants, the fresh and dry weights of roots, or the number and weights of slips.

12. Total calcium of the tissue was mainly determined by the calcium concentration of the substrate and was largely independent of the boron level. On the other hand, soluble calcium was unrelated to total calcium in the tissue, calcium in the substrate, or boron in the tissue.

RESUMEN

1. Se informan aquí los resultados de un estudio hecho con el fin de averiguar el comportamiento de la piña, durante todo su ciclo vegetativo, a la aplicación de los elementos boro y calcio, combinadamente. Para este estudio las plantas de piña se sembraron en tiestos con arena, a los cuales se les aplicaron elementos nutritivos.

2. Las plantas de piña que no recibieron boro y estaban sembradas en medios nutritivos con la menor concentración de calcio (5 p.p.m.) y en medios con las tres concentraciones más altas de este mismo elemento (100, 250, y 500 p.p.m.) tuvieron un crecimiento vegetativo mucho menor que las plantas a las cuales tampoco se les aplicó boro, pero que se sembraron en substratos con la concentración baja de calcio (50 p.p.m.). En comparación con las plantas robustas y verdes del último grupo, las del primero se veían menos vigorosas y su color era verde pálido o amarillo verdoso.

3. El rendimiento de las plantas sembradas en medios sin boro y con la máxima concentración de calcio fué menor que el de las plantas cultivadas en medios también sin boro, pero con calcio en su concentración baja (50 p.p.m.). La producción de estas plantas fué la más alta.

4. A medida que la concentración de calcio aumentaba de 5 p.p.m. a 500 p.p.m., aumentaba también el rendimiento de las plantas que recibieron la concentración máxima de boro (5 p.p.m.). No obstante, los rendimientos más altos fueron los de las plantas sembradas en los medios que tenían la segunda cantidad más alta de calcio, o sea, 250 p.p.m.

5. Cuando faltó el boro en medios deficientes en calcio (5 p.p.m.), así como también en aquéllos con cantidades relativanente altas de este último elemento (250 y 500 p.p.m.), el peso de la materia verde de las plantas se redujo. Este peso fué más alto en las plantas cultivadas en medios con poco calcio (50 p.p.m.) y con el mínimo de boro.

6. En los medios nutritivos con la concentración mínima de boro y en los cuales la cantidad de calcio era mayor de 50 p.p.m., se verificó una disminución en el peso de la materia seca, de las raíces, de los hijos y también en el número de éstos. Los resultados fueron análogos en medios nutritivos deficientes en calcio.

7. A un determinado nivel de boro, la cantidad total de este elemento en el tejido vegetal fué mayormente una función de su concentración en el medio nutritivo y no de la cantidad de calcio.

8. Al nivel más bajo de boro y a los dos niveles más altos de calcio, el contenido de boro soluble en el tejido vegetal fué considerablemente menos que el contenido de boro soluble en las plantas sembradas a los tres niveles más bajos de calcio. La menor cantidad de boro soluble o metabólicamente activo se halló en las plantas cultivadas en los medios que tenían la concentración más alta de calcio. La fracción soluble de este elemento se acumuló en mayor cantidad en las hojas de las plantas en cuyo substrato nutritivo era baja (50 p.p.m.) la concentración de calcio.

9. El rendimiento más bajo de las plantas sembradas en medios sin boro y con la concentración máxima de calcio estuvo acompañado de la cantidad más baja de boro soluble o activo presente en el tejido foliar. En cambio, el rendimiento más alto de las plantas cultivadas al mismo nivel de boro, pero con poco calcio (50 p.p.m.), estuvo asociado al contenido más alto de boro activo o soluble en el tejido meristemático de las hojas.

10. El aumentar la concentración de calcio en medios que tenían el más alto nivel de boro no produjo efectos notables en el contenido total de boro presente en el tejido. Sin embargo, la cantidad de boro soluble disminuyó un poco en el tejido de las plantas sembradas en los medios nutritivos con las dos concentraciones más altas de calcio.

11. Las plantas sembradas al nivel máximo de boro y al segundo nivel más alto de calcio (250 p.p.m.) tuvieron mayor rendimiento que las plantas sembradas en medios con las misma cantidad de boro, pero con cantidades de calcio que eran o más bajas o más altas. No obstante, a este mismo nivel de boro, el aumento en la concentración de calcio no tuvo influencia decisiva en ninguno de los siguientes valores: peso de la materia verde y de la materia seca de las raíces, número de hijos y peso de los hijos.

12. La cantidad total de calcio en los tejidos quedó determinada, mayormente, por la concentración de calcio en el substrato nutritivo y no dependió en gran manera del nivel del boro. Por otro lado, la cantidad de calcio soluble no demostró guardar relación alguna con la cantidad total de calcio en los tejidos con la cantidad de este mismo elemento en el substrato, o con la cantidad de boro en los tejidos.

LITERATURE CITED

1. Association of Official Agricultural Chemists, Official and Tentative Methods of Analysis, 6th ed., 1945.
2. Berger, K. C., and Truog, E., Boron determination in soils and plants using quinalizarin reaction, *Ind. of Eng. Chem. Anal. Ed.* **11** 540–5, 1939.
3. Brennan, E. G., and Shive, J. W., Effect of calcium and boron nutrition of the

tomato on the relation between these elements in the tissues, *Soil Sci.* **66** 65–75, 1948.

4. Cook, R. L., and Millar, C. E., Some soil factors affecting boron availability, *Soil Sci. Soc. Amer. Proc.* **4** 297–301, 1939.
5. Drake, M., Sielling, D. H., and Scarseth, G. D., Calcium-boron as an important factor in controlling boron starvation, *Amer. Soc. Agron.* **33** 454–62, 1941.
6. Hernández-Medina, E., The beneficial effect of filter-press-cake on pineapple growth development and production, I: Effect on the plant crop, *J. Agr. Univ. P.R.* **36** (3) 255–80, 1952.
7. Hernández-Medina, E., and Shive, J. W., Calcium-boron relationships in the nutrition of corn and the distribution of these elements in the plant, *J. Agr. Univ. P.R.* **30** (4) 251–91, 1946.
8. Jones, H. E., and Scarseth, G. D., The calcium-boron balance in plants as related to boron needs, *Soil Sci.* **57** (1) 15–24 1944.
9. Midgley, C. A. R., and Dunklee, D. E., The effect of lime on the fixation of borates in soils, *Soil Sci. Soc. Am. Proc.* **4** 302–7, 1939. .
10. Naftel, J. A., The influence of excessive liming on boron deficiency in soils, *Soil Sci. Amer. Proc.* **2** 383–4, 1937.
11. ——, Soil-liming investigations, V: The relation of boron deficiency to overliming injury, *J. Amer. Soc. Agron.* **29** 761–71, 1937.
12. ——, Recent studies on boron in soils, *Amer. Fertilizer* **89** (7) 5–8, 24, 26, 1938.
13. Reeve, E., and Shive, J. W., Potassium-boron and calcium-boron relationships in plant nutrition, *Soil Sci.* **57** 1–14, 1944.
14. Sideris, C. P., Krauss, B. H., and Young, H. Y., Assimilation of ammonium and nitrate by pineapple plants grown in nutrient solution and its effects on nitrogenous and carbohydrate constituents, *Plant Phys.* **13** 489–527, 1938.
15. Wolf, B., Factors influencing availability of boron in soil and its distribution in plants, *Soil Sci.* **50** 209–17, 1940.