RELATION OF BORON LEVEL TO PRODUCTION AND FRUIT QUALITY OF GRAPEFRUIT AND ORANGES

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The use of boron (B) in Florida citrus fertilization has increased markedly in recent years, following the identification of a deficiency of this element in the field (*8*). This widespread use of B appears to be justified, as recent observations (*7*) showed large scale deficiency in orange groves that had not received B. Boron had previously been used extensively on grapefruit to offset gumming of the fruit of trees that were treated with lead arsenate. Some growers and field production men have the opinion that a relatively high boron concentration in the foliage, even to the point of mild toxicity, leads to increased production and improved fruit quality.

The present tests were started with the primary objective of determining the effect of supplying boron at rates greater than necessary to prevent boron deficiency. It was desired mainly to test the effect on fruit quality and yield and to observe any secondary effects on growth and mineral pattern of the foliage.

METHODS AND MATERIALS

An initial random block experiment was started in the spring of 1951 in a 6-year-old grove of Ruby red grapefruit on Rough lemon stock. No symptoms of B deficiency were present, and an initial sampling of mature leaves showed 80 ppm B. Two rates of B were applied to the soil as sodium borax, as indicated in table 4. Five replicates were given these treatments, or a total of 18 3-tree plots. Inadvertently, the entire area was later sprayed with borax by the owner, and severe toxicity and defoliation resulted in the high soil treatments. It was felt that this damage would unduly modify tree behavior. Consequently, in 1952 a second experiment was started in a 5-year-old Thompson pink grapefruit grove on Rough lemon stock. The layout was the same except that 2-tree plots were used instead of 3. This grove likewise showed no B deficiency and an initial leaf concentration of 75 ppm B. Data are presented from both of these grapefruit tests. Neither variety was treated with lead arsenate during the experimental periods.

Likewise in the spring of 1952, random block tests were started in a 25-year-old planting of 3 orange varieties on sour orange stock. Hamlin, Valencia, and Temple oranges were growing in adjacent strips and fertilized in the same manner. No B had been used for several years, but a low analysis fertilizer mixture and some organic materials had been used, both of which would supply some B. The trees were thrifty and high yielding with no symptoms of B deficiency. Irrigation was practiced in these groves during dry weather. Initial samples of mature leaves ranged from 25-35 ppm B in all 3 varieties. Similar random block tests were started in all three varieties with each treatment being in quadruplicate for each variety.

All test plantings were on Lakeland fine sand. The B treatments were applied by hand, mostly within the area circumscribed by the drip. The intermediate rate was applied only once yearly, in early spring. The high rate was divided into two applications, once in early spring and once in midsummer to avoid excess toxicity while attempting to maintain a fairly high leaf B content. The test areas were fertilized by the owners with mixtures containing no added boron.

Leaf samples of 4 to 6 month-old leaves were taken for analysis in July or August each year. Leaves from non-fruiting spring growth were chosen. All leaf samples were analyzed for B (*4*) and most samples for the major nutrient elements N, P, K, Ca, and Mg. Manganese was determined on certain samplings. Samples of 24 fruit, selected for size uniformity, were taken early in the maturity season for each variety. Fruit measurements taken were percent total soluble solids, per-

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cent citric acid, mgm. vitamin C per 100 ml. juice, rind thickness, and percent juice. Tree height measurements were made only on the pink grapefruit.

Results and Discussion

In the grapefruit, the high rate of borax resulted in almost continual B toxicity, although this was usually mild and consisted of yellow dots, yellow tipping of many leaves, or a pale mottling of the leaves. This latter condition was somewhat similar to a Mn deficiency pattern but was less distinct. Only once was the treatment severe enough to cause defoliation, and that was in 1951 when a spray application was accidentally superimposed on the entire experimental area. A very heavy leaf drop occurred in the early fall which appears to have reduced yield (see table 4).

Grapefruit appeared to be considerably more tolerant of B than orange. Grapefruit leaves containing 300 ppm B seldom showed any sign of toxicity, and those with 600 ppm were only moderately affected. Cooper (*1*) also reports that grapefruit leaves with 400 to 600 ppm B show only slight toxicity under conditions of low salinity. Orange leaves have previously been shown to show toxicity symptoms with boron less than 300 ppm (*9*). In the present tests with oranges, considerable leaf yellowing and some defoliation resulted in the summer of 1954 when the leaf concentration was about 385 ppm B.

Tree size of pink grapefruit was not affected by B treatment during 4 seasons of growth. The trees averaged 6.6 feet in height in March of 1952 and 10.6 feet in the fall of 1955, with no trend in relation to treatment. It was repeatedly observed that vegetative growth flushes, but not bloom, started a few days sooner on both varieties of grapefruit in the trees with B added. This was true with the intermediate B level as well as the high level and occurred with the summer flush as well as with the spring growth. Usually new leaves were evident about 7-10 days sooner than on the trees which received no B supplement. Furthermore, mean leaf size was greater where B was applied. This was a very consistent effect and is illustrated in table 1 where the mean dry leaf weight of random leaf samples is shown. Each figure in table 1 is a mean of 144 spring flush leaves taken from 12 trees on the sampling dates shown in table 4. The respective weight increases over the no B treatments amount to 8.5 and 13.5%, respectively, for the two B increments and these differences are highly significant statistically. The difference in leaf size was perceptible at sampling time and is therefore probably due to increased area rather than leaf thickness. While no known explanation seems entirely adequate to account for this response, it is possible that it may be partly attributable to the shift in the K and Ca contents of the leaves that B apparently induced. That this effect of B on the base elements was nearly as consistent as its effect on leaf size may be seen in table 2. Leaf size of citrus has been shown to be related to K content (*6, 10*), but over a much lower range of K than found here. The only available information on leaf size and K level at relatively high levels of K is for oranges, and they indicate (*5*) no relation

Table 1. Mean dry weight (mgm./leaf) of 4-5 month old spring flush grapefruit leaves in relation to boron treatment

Year	Variety	Boron rate None	Intermediate	High
1951	Red	301	329	363
1952	Red	442	486	493
1952	Pink	387	465	502
1953	Pink	399	421	433
1954	Pink	590	613	639
1955	Pink	400	420	433
Mean		420	456**	477**

**Difference from no B is significant at 1% level.

Table 2. Variations in the K, Ca and Mg concentrations of Thompson pink grapefruit leaves in relation to B content

Year	p.p.m. B	Percent in leaf dry matter K	Ca	Mg
1952	82	2.40	3.55	0.33
	213	2.45	3.41	0.32
	700	2.88*	3.21*	0.33
1953	86	2.37	2.67	0.24
	146	2.44	2.72	0.22
	240	2.54*	2.57	0.22
1954	63	1.69	3.57	0.35
	201	1.79	3.30	0.29*
	618	2.30*	2.79*	0.28*

*Difference is significant at 5% level

between the two. Cooper et al. (2) also noted the interrelation of B with the base elements in grapefruit leaves but no measurements were made as to leaf size. A similar effect on the base elements in orange leaves was noted in a sand culture study with different levels of B (9), however, no effect on leaf size was found. Furthermore, a range of B from low to toxicity level in the orange trees of the present experiment had no appreciable effect on either leaf size or base cations in the leaves. Thus it is not possible to generalize as to the effect of B level on either leaf size or base element content.

One additional effect noted in both orange and grapefruit trees was that high B tended to accentuate the expression of Mn deficiency symptoms. These symptoms were mild and of relatively short duration during the rapid early growth of young leaves. Visual observations suggested a relation to B level, so Mn determinations were made on the regular leaf samples of 1955 which were symptomless for Mn at the time of collection. Table 3 shows that there was actually a slight but consistently lower Mn content in the high B leaves.

Table 3. The Mn concentration found in 1955 grapefruit and orange leaf samples in relation to B rate

Boron rate	p.p.m. Mn in leaf dry matter		
	Pink grapefruit	Hamlin	Valencia
None	30	21	19
Intermediate	28	20	17
High	26*	16*	16*

*Difference is significant at 5% level.

Yield of red grapefruit was reduced by high B following severe defoliation (table 4). Pink grapefruit showed a significant yield increase in relation to B supply in 1953 but a reverse relation the following year. The orange varieties showed no definite yield trend in relation to treatment (table 5), except possibly some effect on alternate bearing in Hamlin oranges in 1953 and 1954.

Fruit quality measurements showed (tables 4 and 5) that total soluble solids were never favorably affected by supplementary B levels and a significant decrease was noted in two of the grapefruit samplings. Citric acid was rather consistently reduced in grapefruit juice by increased B. The orange varieties were less consistent in this regard, but when an effect was manifest it was also toward less acidity with high B. The Temple orange did not show any reduction in acidity in these tests. Ratios of solids to acids frequently showed a trend toward a higher value, except for Temple orange, but the differences were relatively small and attained statistical significance only in the case of the Valencia samples of the 1952-53 season.

Vitamin C content was the most consistent factor to be affected by B level. Every sampling with all varieties showed a small but highly reproducible depression of vitamin C in relation to high B. This effect is noteworthy since it is also caused by high N and P which are also absorbed as anions.

No effect was noted on any variety in regard to B level affecting percentage of juice in the fruit or on rind thickness.

The present results from field grown trees largely confirm the results from a previous sand culture study with oranges (9). B can be tolerated over a wide range of foliage concentrations with relatively small effects on growth or fruiting. As to the benefit of maintaining B at a high level, the present results indicate that a slight favorable effect on early maturity might be realized by the reduction in acidity. However, this response was of such small magnitude that its effect on solids-acids ratio was usually not statistically significant under the conditions of this study. A study with larger samples would probably show that a practical increase in ratio would occur at least some years with some varieties.

These results from soil applications of B differ markedly from those of Deszyck and Sites (3) in which it was found that B applied as a foliage spray increased the acidity of grapefruit juice. The difference in method of applying B apparently accounts for the difference in response. Further work needs to be done so that a more exact comparison of the two methods of applying B can be made, but the present results indicate that possibly a soil application of B and a foliage spray of As (lead arsenate) would accentuate early grapefruit maturity rather than the two elements tending to nullify each other, as found by Deszyck and Sites (3).

Table 4. Relation of boron supply to leaf boron, yield, and fruit quality of red and pink grapefruit

Year	Treatment1/	Leaf B p.p.m. (dry)2/	Yield boxes /tree	Juice solids %	Citric acid %	Ratio S/A	Vit. C mgm. /100 ml.
		Ruby Red / Rough Lemon					
	0	190	3.6	8.04	1.02	7.88	34.7
1951	1.5	600**	3.5	7.82	0.98*	7.98	33.4
	4	940**	2.9*	7.41**	0.92**	8.05	32.4**
LSD @ 5%	-	33	0.5	0.31	0.04	N.S.	1.3
	0	110	2.2	7.84	1.10	7.13	40.3
1952	1.5	212**	2.1	7.71	1.10	7.01	39.6
	3	279**	1.7*	7.63	1.09	7.00	38.9*
LSD @ 5%	-	19	N.S.	N.S.	N.S.	N.S.	1.4
		Thompson Pink / Rough Lemon					
	0	82	1.5	7.33	1.29	5.74	36.2
1952	0.75	213**	1.5	7.16	1.28	5.60	35.2
	3	700**	1.4	6.93**	1.26*	5.48	33.9*
LSD @ 5%	-	23	N.S.	0.25	0.03	N.S.	1.9
	0	86	2.3	6.62	1.23	5.38	34.2
1953	0.5	146**	3.0*	6.63	1.20*	5.52	34.0
	2	240**	3.4**	6.67	1.18**	5.65	33.0
LSD @ 5%	-	17	0.5	N.S.	0.02	N.S.	1.3
	0	63	3.7	7.75	1.28	6.06	33.8
1954	0.5	201**	3.1*	7.74	1.26	6.17	32.5*
	3	618**	3.1*	7.72	1.22**	6.31	30.9**
LSD @ 5%	-	22	0.6	N.S.	0.04	N.S.	1.2
	0	69	1.7	7.52	1.20	6.27	38.9
1955	0.5	146**	2.3*	7.46	1.16*	6.49	38.2
	3	327**	2.3*	7.42	1.15*	6.45	37.1*
LSD @ 5%	-	18	0.6	N.S.	0.03	N.S.	1.4

1/ Ounces of sodium borate (borax) containing 44% B_2O_3 applied annually per tree.
2/ 4 to 6 month-old spring flush leaves.
*Difference is significant at 5% level.
**Difference is significant at 1% level.
N.S. - Differences do not reach the levels required at 5% level.
LSD @ 5% - Least significant difference required at 5% level.

Table 5. Relation of boron supply to leaf boron, yield, and fruit quality of 3 orange varieties

Year	Treatment	Leaf B p.p.m. (dry)	Yield boxes /tree	Juice solids %	Citric acid %	Ratio S/A	Vit. C mgm./ 100 ml.
		Hamlin / Sour					
	0	28	-	11.60	1.34	8.70	64.5
1952	0.75	46**	-	11.64	1.31	8.89	64.2
	6	118**	-	11.55	1.28*	9.10	63.1*
LSD @ 5%	-	7	-	N.S.	0.04	N.S.	1.4
	0	28	9.8	9.70	0.89	10.90	54.5
1953	1	57**	8.5	9.75	0.90	10.84	54.2
	11	184**	8.7	9.78	0.88	11.24	53.2*
LSD @ 5%	-	8	N.S.	N.S.	N.S.	N.S.	1.2
	0	20	6.4	9.98	1.17	8.56	59.9
1954	1.5	60**	6.8	10.26	1.22	8.46	59.8
	11	380**	7.6	9.72	1.16	8.41	55.6**
LSD @ 5%	-	11	N.S.	N.S.	N.S.	N.S.	1.9
	0	22	-	8.87	1.15	7.71	56.3
1955	1	66**	-	8.84	1.16	7.59	53.8*
	11	310**	-	8.61	1.10*	7.83	52.4**
LSD @ 5%	-	9	-	N.S.	0.05	N.S.	1.3
		Valencia / Sour					
	0	30	-	13.28	1.84	7.22	63.7
1952-53	0.75	51**	-	13.32	1.80	7.42	63.8
	6	131**	-	13.22	1.70**	7.80**	63.0
LSD @ 5%	-	8	-	N.S.	0.05	0.27	N.S.
	0	21	5.8	12.01	1.38	8.71	56.8
1954-55	1.5	56**	5.1	12.30	1.43*	8.62	56.9
	11	384**	5.3	12.24	1.34*	9.13	55.2*
LSD @ 5%	-	11	N.S.	N.S.	0.04	N.S.	1.3
		Temple / Sour					
	0	35	7.4	11.60	1.08	10.73	55.4
1953-54	1.5	47**	7.2	11.75	1.08	10.88	54.7
	11	111**	7.6	11.70	1.11	10.63	53.6*
LSD @ 5%	-	7	N.S.	N.S.	N.S.	N.S.	1.4
	0	27	6.6	12.06	1.39	8.68	61.0
1954-55	1.5	51**	7.0	11.99	1.37	8.77	59.7
	11	392**	5.8	11.55	1.40	8.25	57.6**
LSD @ 5%	-	12	N.S.	N.S.	N.S.	N.S.	2.0

See table 4 for footnotes on symbols.

SUMMARY

Field tests on the effect of B level on the growth of grapefruit and oranges were made by applying sodium borax to the soil in such amounts that wide ranges of leaf B were maintained for several years. The lowest level of B consisted of impurities in other fertilizer materials only with no intentional borax application. The highest level gave slight to moderate toxicity symptoms in most grapefruit growth flushes and none to slight toxicity symptoms in most orange growth flushes.

No favorable effect was noted on growth or yield although alternate bearing was induced in certain years. Leaf size of grapefruit increased as the B concentration increased. Increased B caused some shifts in the concentrations of K, Ca, and Mg in grapefruit leaves. Neither of these factors was apparent to an appreciable extent in the orange leaf samples. High B application was associated with reduced Mn content in both orange and grapefruit leaves.

Citric acid and vitamin C in the juice were rather consistently lowered by high B treatment, although the Temple orange failed to show any loss in citric acid. Total soluble solids were mostly unaffected by treatment. The ratio of solids to acids frequently showed a slightly higher trend with increased B but the differences were usually small and of doubtful practical significance.

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LONGEVITY OF CHELATED IRON TREATMENTS APPLIED TO CITRUS TREES

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In 1952, the iron chelate of ethylenediamine tetraacetic acid (FeEDTA) was introduced as a corrective for iron chlorosis in citrus growing on acid soils (1, 3). Since that time, this material has been widely used on Florida citrus. Use of the chelate for the correction of iron deficiency is rather expensive. For that reason, it is highly desirable to obtain maximum benefits from each application. Studies have been made during the past three years to determine some of the factors that affect the length of time chelated iron treatments will keep the trees free of iron chlorosis.

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Iron chlorosis in citrus on acid soils can be corrected by application to the soil of only 10 to 20 grams per tree of actual iron (Fe) as FeEDTA, the trees usually becoming completely green within six to eight weeks. On calcareous soils, the iron chelate of hydroxyethylethylenediamine triacetic acid (FeEDTA-OH) is more effective than FeEDTA. It usually requires 50 to 75 grams of iron per tree as FeEDTA-OH to correct iron chlorosis in citrus on calcareous soils, and greening of the trees may require four to six months (2). Some soils require larger amounts, or a repetition of the treatments six or eight months after the first application.