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EFFECT OF SUBSTRATE HYDROGEN PEROXIDE ON GROWTH OF BORON DEFICIENT PLANTS

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Boron nutrition of plants has been extensively investigated and numerous functions for this element have been suggested (Gauch and Dugger, 1954). Shkolnik *et al.* (1951, 1952, 1954) have indicated one function as that of bringing about increased oxygen supply to the tissues, particularly to those of the roots. Experimenting with flax grown in the absence of boron (Shkolnik and Steklova, 1951, 1954), they noted that the addition of hydrogen peroxide to the nutrient solution resulted in the development of normal appearing plants. Inasmuch as an oxygen supplying agent seemed to replace boron effectively, they postulated that this element was somehow concerned with provision of an adequate oxygen supply to the tissues.

The present investigation was undertaken to determine whether substrate applications of hydrogen peroxide could alleviate boron deficiency in tomato, *Lycopersicon esculentum;* cotton, *Gossypium hirsutum;* and turnip, *Brassica Rapa.*

Material and Methods

Bonny Best tomato, Stoneville 2B cotton, and Purple Top White Globe turnip were the varieties utilized in this study. The plants were grown in the greenhouses at the University of Chicago during the period of April 12 to June 14, 1954. The first few weeks of this period were marked by relatively cool temperatures and overcast skies. During the final weeks, sunny and very warm days prevailed. Seeds were sown in quartz sand in quart, glazed jars. When the first true leaves of the seedlings began to expand, the plants were thinned to a uniform stand of two per jar.

With each species, three treatments were instituted, namely: adequate boron (B), inadequate boron (B—), and inadequate boron plus hydrogen peroxide (B—H_2O_2). Eight jars were included in each treatment, and the jars were randomly distributed within each plant group. Hoagland and Arnon's (1950) macronutrient solution 1 was utilized for all series. The micronutrient elements—manganese, zinc, copper, and molybdenum—were added to this solution in concentrations of 0.5, 0.05, 0.02, and 0.01 p.p.m., respectively. The solution of the B series received, in addition, 5 p.p.m. of boron. Uniform amounts of nutrient solution were applied 3 times per week, and distilled water containing 5 p.p.m. iron tartrate was added on other days. In the B—H_2O_2 series, daily applications

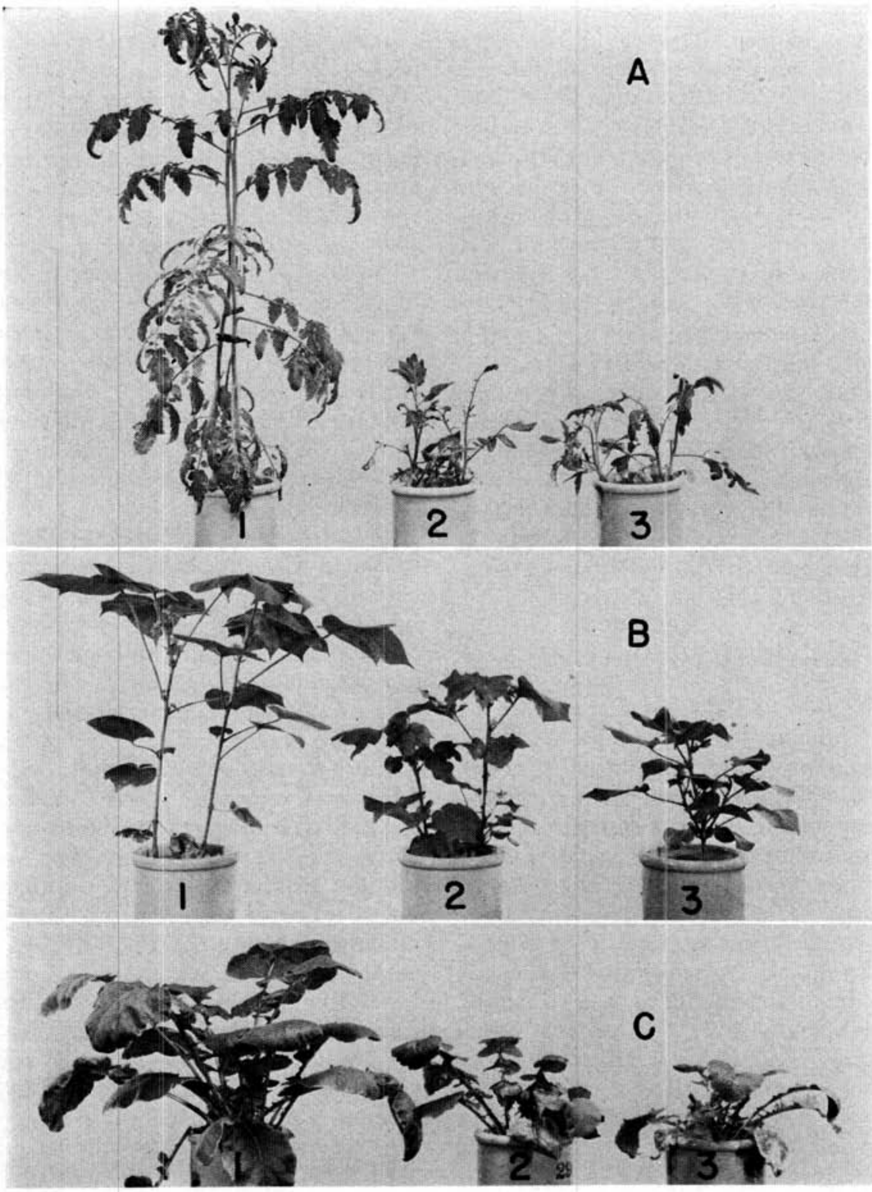

FIG. 1.—Tomato (*A*), cotton (*B*) and turnip (*C*), plants grown under conditions of adequate boron (1); inadequate boron plus hydrogen peroxide (2); and inadequate boron (3).

of hydrogen peroxide at a concentration of approximately 5 p.p.m. were made. The peroxide was combined with boron-deficient, nutrient solution or distilled water immediately prior to use. The various nutrient treatments were initiated approximately a week after the seeds were sown. Previous to this time all cultures received applications of distilled water or nutrient solution lacking boron.

At the time of harvest, the plants were fractionated and fresh weights obtained. Dry-weight determinations were made after drying in a forced-draft oven at 80°C. The dry material was ground in a Wiley mill (80 mesh), ashed at 450°C. in a muffle furnace, and analyzed for boron content by the curcumin method of Dible *et al.* (1954).

Results and Discussion

Growth Responses

Tomato.—Lack of boron in the nutrient substrate resulted in necrosis of the apical meristem with consequent reduction in stem height and number of main stem leaves and increase in the number of laterals (Fig. 1). The boron deficient plants also produced malformed, thickened leaves, which exhibited brownish purple discoloration. Visually, plants of both inadequate boron series were very similar, although those in the B—H_2O_2 group tended to be slightly shorter in height and have fewer leaves and laterals. The smaller size of the B—H_2O_2 plants, as compared to the B— group, was reflected in lower tissue fresh and dry weights (Table 1). The fresh and dry weights of the tissues of plants grown under conditions of inadequate boron were significantly less than those of the B series.

Although the percentage dry weights of the roots of plants on the inadequate boron treatments were higher than those on adequate boron, such was not true for leaves and stems. It is interesting to note that the boron concentration of the tissues followed a similar pattern (Table 2). The top-to-root ratios of plants on inadequate boron were very similar and slightly lower than that for the B series. Thus, under the conditions of this experiment, the growth data indicated that hydrogen peroxide did not adequately replace boron in the nutrition of tomato.

Cotton.—Similarly, lack of boron in the nutrient solution applied to cotton plants resulted in a reduction in main-stem growth and number of main-stem leaves and increased development of vegetative laterals (Fig. 1). Leaf malformations—including thickening, distortion in shape, repression of lobing, and downward cupping — were evident on plants receiving an inadequate boron supply. A comparison of plants in the B— and B—H_2O_2 series, however, revealed that plants in the latter group were taller, had more main-stem leaves and fewer vegetative laterals than those in the former (Fig. 1). This improved growth in the B—H_2O_2 series was also reflected in higher fresh and dry weights (Table 1). The top-to-root ratio of peroxide-treated plants exceeded that of boron-inadequate untreated and even more that of boron-adequate plants. Although some improvement in growth was noted with hydrogen peroxide applications, plants in this group were

TABLE 1.—Effect of Nutrient Treatment on Fresh and Dry Weight, Percentage Dry Weight, and Top-to-root Ratio of Tomato, Cotton and Turnip Plants.

Series	Roots			Leaves			Stems			Top to root ratio[2]
	Fresh[1] wt.	Dry[1] wt.	% dry wt.	Fresh wt.	Dry wt.	% dry wt.	Fresh wt.	Dry wt.	% dry wt.	
TOMATO										
Adequate boron	9.49	0.94	9.91	23.35	3.39	14.52	22.26	2.85	12.80	6.6
Inadequate boron	1.81	0.24	13.26	6.52	0.81	12.42	3.83	0.49	12.79	5.4
Inadequate boron plus H_2O_2	1.40	0.18	12.86	4.83	0.55	11.39	2.86	0.35	12.24	5.0
COTTON										
Adequate boron	10.29	1.37	13.31	13.61	2.67	19.62	5.08	1.55	30.51	3.0
Inadequate boron	1.61	0.26	16.15	3.38	0.65	19.23	1.30	0.39	30.00	4.0
Inadequate boron plus H_2O_2	1.74	0.47	15.85	4.40	0.86	19.55	1.77	0.53	29.94	4.9

TURNIP

Series	Roots			Shoots			Top to root ratio[2]
	Fresh wt.[1]	Dry wt.[1]	% dry wt.	Fresh wt.	Dry wt.	% dry wt.	
Adequate boron	26.92	3.01	11.18	42.48	4.63	10.90	1.5
Inadequate boron	1.89	0.36	19.05	10.63	1.74	16.37	4.8
Inadequate boron plus H_2O_2	2.48	0.29	11.69	9.97	1.46	14.64	5.0

[1] Fresh and dry weights in grams.
[2] Based on dry weights.

still significantly smaller than those supplied with adequate boron, indicating that peroxide did not effectively replace boron.

Turnip.—Boron deficiency in turnip was manifested by a stunting of the plants, a decrease in size and number of leaves, and a tendency for the leaves to curl and become highly tinted with yellow, orange, red, and purple areas (Fig. 1). The fleshy roots failed to grow and, at the time of harvest, measured only one-third the diameter of those from plants on adequate boron. The roots of deficient plants also exhibited necrotic lesions. The addition of hydrogen peroxide to the substrate did not appear to alleviate these symptoms in any way. The fresh and dry weights of the roots and shoots of plants on deficient boron were significantly less than those on an adequate supply (Table 1). The top-to-root ratios were much higher in boron deficient plants. This apparently indicated a greater influence of boron deficiency on root growth of turnip than on the other species studied.

TABLE 2.—Effect of Nutrient Treatment on Distribution of Boron in Tissues of Tomato, Cotton and Turnip Plants.

Series	Roots		Leaves		Stems		Total
	mg.:kilo	μg.:plant	mg.:kilo	μg.:plant	mg.:kilo	μg.:plant	μg.:plant
TOMATO							
Adequate boron	51.7	48.6	347.4	1177.7	18.0	51.4	1277.7
Inadequate boron	54.5	13.1	12.7	10.3	11.9	5.8	29.2
Inadequate boron plus H_2O_2	66.2	11.9	15.7	8.7	12.0	4.2	24.8
COTTON							
Adequate boron	57.6	78.8	120.8	322.6	12.4	19.3	420.7
Inadequate boron	76.7	19.9	27.2	17.7	7.4	2.9	40.5
Inadequate boron plus H_2O_2	71.8	20.1	24.2	20.8	6.2	3.3	44.2

TURNIP

Series	Roots		Shoots		Total
	mg.:kilo	μg.:plant	mg.:kilo	μg.:plant	μg.:plant
Adequate boron	54.2	163.1	344.3	1594.3	1757.4
Inadequate boron	21.1	7.6	20.3	35.2	42.8
Inadequate boron plus H_2O_2	33.4	9.7	22.4	32.7	42.4

CHEMICAL ANALYSES

Analyses of the tissues of plants for relative distribution of boron revealed a difference in plants grown under conditions of inadequate supply and those receiving an adequate amount. Plants receiving sufficient boron had the highest concentration, as well as the greatest total amount in the leaves or shoots (Table 2). With an inadequate supply, however, the greatest concentration was always observed to be in the roots. In the B— series the largest total quantity was found in the roots of tomato and cotton, while in turnip the largest quantity was in the shoots. The roots of tomato contained the greatest total amount in the B—H_2O_2 group, whereas in coton the quantities in the roots and leaves were comparable. With turnip of the B—H_2O_2 series, more boron was observed in the shoots. Although, on the basis of concentration, boron in the roots of tomato and cotton plants exhibiting deficiency symptoms exceeded that found in those not showing such signs, such was not true for turnip.

Tomato and turnip plants on an adequate boron supply accumulated over three times as much of this element as did cotton (Table 2). In the deficient series, however, cotton and turnip contained more boron than tomato. In all instances the total boron content of whole plants or tissues was significantly higher in the B group.

In a comparison of the B— and B—H_2O_2 series, the only instance of a significant difference in concentration or total quantity of boron was in the roots of turnip. It is of interest to note in this instance that, although the B—H_2O_2 roots contained more boron than those of the B— series, neither the total quantity in the plant nor the amount of dry matter produced was greater. It is obvious, therefore, that the addition of hydrogen peroxide to the substrate did not result in a substantial change in the pattern of boron distribution or in the total boron content of the plants.

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SUMMARY

To determine if hydrogen peroxide could replace the requirement for boron in tomato, cotton, and turnip, plants were grown in sand culture under three regimes of boron nutrition, namely: adequate boron, inadequate boron, and inadequate boron plus hydrogen peroxide. Hydrogen peroxide was added to the substrate daily, either in nutrient solution or distilled water in a concentration of approximately 5 p.p.m.

Growth measurements indicated plants of the inadequate boron plus hydrogen peroxide series were more comparable to the inadequate-boron group than to those of the adequate-boron treatment. Only with cotton was any improvement in growth noted as a result of hydrogen peroxide treatment. Deficient plants normally exhibited the greatest concentration of boron in the roots, whereas in plants with adequate boron the concentration was highest in the leaves. The addition of hydrogen

peroxide to the substrate did not result in a substantial change in the pattern of boron distribution or in the total boron content of the plants.

Under the conditions of this experiment, the results obtained did not support the hypothesis that boron is effectively replaced by hydrogen peroxide in tomato, cotton, or turnip.

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