A FURTHER INVESTIGATION OF THE REPLACEMENT OF BORON BY INDOLEACETIC ACID[1]

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It has been reported (**2**) that low concentrations of indoleacetic acid in the nutrient solutions supplied to cotton seedlings will partially replace boron for growth in cultures deficient in this element. This finding constitutes a fundamental advance in the elucidation of the role of boron in the metabolism of the plant. The further implication of auxins in respiration (**1**) and growth indicates that boron might function through some relationship with these enzyme systems. It was believed desirable, therefore, to attempt to confirm this work and extend it to other and more suitable experimental plants.

Experimental data

Plants were grown in washed silica sand in varnished clay pots. Seedlings of suitable size, germinated in either sand or soil, were transplanted into sand which had been thoroughly leached with distilled water. The following experimental plants were used: cotton, unknown variety; sunflower, var. Russian Mammoth; tomato, var. Early Baltimore; tobacco, var. Maryland Mammoth; and soybean, var. Manchu no. 3. Four replications of each treatment were made with the exception of the series harvested on June 21, 1941. In this case only three replications were employed.

The composition of the nutrient solutions was as follows:

KH_2PO_4	0.0018 M
K_2HPO_4	0.0012 M
$Ca(NO_3)_2$	0.0042 M
$CaCl_2$	0.0011 M
$Mg(NO_3)_2$	0.0021 M
$MgSO_4$	0.0011 M
NH_4NO_3	0.0042 M

During periods of low light intensity ammonia nitrate was omitted from the solution. Minor elements were included in the concentrations recommended by HOAGLAND (**3**). In series 1 the solution was supplied twice daily by a manually operated air pressure type subirrigation system. In series 2, approximately 500 ml. of nutrient solution was supplied manually each day. Unbalanced solution was removed by weekly leaching with distilled water. The indoleacetic acid was supplied in the nutrient solution at a level of 1 p.p.m. when the subirrigation culture was employed. In the latter series it was added separately and cumulatively each day in such amounts as to pro-

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duce a concentration of 0.2 p.p.m. in the solution, assuming saturation of the sand.

Normal greenhouse conditions prevailed. During periods of high light intensity, plants were kept in whitewashed houses having intensities of approximately 1000 foot candles. This was similar to the intensity employed by EATON (2). Summer temperatures varied between 65° to 90° F. during the day and 60° to 80° F. during the night. Winter temperatures were 65° to 70° F. and 60° to 65° F., respectively. Photoperiods were normal during the summer months and were lengthened to 16 hours by means of incandescent lamps during the winter.

TABLE I

SERIES 1. EFFECT OF INDOLEACETIC ACID ON GROWTH OF PLANTS IN THE PRESENCE AND ABSENCE OF BORON IN THE NUTRIENT MEDIUM

PLANT, TREATMENT, AND DATE OF SAMPLING	DAYS OF IAA TREATMENT[2]	WET WEIGHT OF TISSUE PER PLANT		DRY WEIGHT OF TISSUE PER PLANT		DRY MATTER		TOP / ROOT
		TOP	ROOT	TOP	ROOT	TOP	ROOT	
		gm.	*gm.*	*gm.*	*gm.*	%	%	
June 26, 1941								
Sunflower, CN[1]	......	41.7	15.9	3.73	0.80	8.9	5.0	4.6
" CN-B	......	15.3	6.2	1.61	0.40	9.5	6.5	4.0
" CN + IAA[1]	15	40.0	16.9	3.17	0.95	7.9	5.6	3.5
" CN + IAA-B	15	18.2	6.7	1.65	0.44	9.1	6.6	3.8
Cotton, CN	......	21.8	8.9	2.27	0.52	9.6	5.9	4.4
" CN-B	......	8.1	3.8	1.08	0.32	10.3	8.4	3.4
" CN + IAA	15	19.4	6.95	2.13	0.36	11.0	5.2	5.9
" CN + IAA-B	15	12.3	8.3	1.14	0.47	9.3	5.6	2.4
Soybean, CN	......	28.6	18.9	4.26	1.27	14.4	6.7	3.0
" CN-B	......	18.9	15.8	2.83	1.05	15.0	6.0	3.8
" CN + IAA	15	32.6	20.9	4.71	1.35	14.4	6.5	2.9
" CN + IAA-B	15	15.8	13.2	2.72	0.95	15.5	7.2	2.9
Dec. 13, 1941								
Tobacco, CN	......	253.6	32.8	20.80	2.68	9.2	8.2	7.8
" CN-B	......	101.0	15.4	9.99	1.52	10.9	9.9	6.6
" CN + IAA	65	252.7	41.7	21.98	3.61	10.4	8.7	8.3
" CN + IAA-B	65	167.7	21.6	14.42	1.86	7.5	8.6	7.8

[1] CN, complete nutrient; IAA, indoleacetic acid.
[2] Concentration 1.0 p.p.m. in nutrient solution.

Under the conditions used, boron deficiency symptoms appeared in those plants not receiving this element without regard to the presence or absence of indoleacetic acid. No compensatory action was noted either in the time of onset or degree of intensity of deficiency symptoms. This observation was substantiated by anatomical observations of the stems.[2] Examination of sections of stem taken at the fourth internode from the stem tip showed the necrotic areas typical of boron deficiency in the region of the first formed xylem and the surrounding xylem parenchyma cells regardless of the presence of indoleacetic acid in the culture.

Examination of the data showed that in only one instance was there any

[2] Appreciation is expressed to B. ESTHER STRUCKMEYER, Department of Horticulture, University of Wisconsin, who prepared and examined these sections.

TABLE II

SERIES 2. EFFECT OF INDOLEACETIC ACID ON GROWTH OF PLANTS IN THE PRESENCE AND ABSENCE OF BORON IN THE NUTRIENT MEDIUM

PLANT, TREATMENT AND DATE OF SAMPLING	DAYS OF IAA TREATMENT[2]	WET WEIGHT OF TISSUE PER PLANT			DRY WEIGHT OF TISSUE PER PLANT			DRY MATTER			TOP/ROOT RATIO
		LEAF	STEM	ROOT	LEAF	STEM	ROOT	LEAF	STEM	ROOT	
		gm.	*gm.*	*gm.*	*gm.*	*gm.*	*gm.*	%	%	%	
October 17, 1941											
Sunflower, CN	......	15.9	30.9	17.3	2.26	2.62	1.63	14.2	8.5	9.4	3.3
" CN–B	......	7.5	13.6	6.2	0.81	0.91	0.49	10.8	6.7	7.9	3.5
" CN + IAA[1]	40	14.5	29.9	14.0	2.04	2.82	1.32	14.1	9.5	9.4	2.8
" CN + IAA–B	40	7.5	18.6	9.7	1.26	1.22	0.75	16.8	6.6	7.7	3.2
January 16, 1942											
Tomato, CN	......	40.7	31.7	20.9	4.59	3.79	1.72	11.2	8.6	8.2	4.9
" CN–B	......	30.1	21.8	13.1	2.87	1.99	1.25	9.6	9.1	9.5	4.9
" CN + IAA	30	37.9	31.9	22.1	4.00	3.23	1.67	10.5	10.1	7.6	4.2
" CN + IAA–B	30	31.9	21.2	11.2	2.90	1.79	0.96	11.0	11.8	8.6	4.8
Sunflower, CN	......	14.2	38.9	9.6	1.63	2.69	0.68	11.5	6.9	7.1	6.4
" CN–B	......	8.9	12.3	5.4	0.85	0.73	0.24	10.5	5.9	4.5	6.6
" CN + IAA	30	16.0	37.1	13.2	1.88	3.94	0.95	8.5	9.1	7.2	6.1
" CN + IAA–B	30	7.5	13.1	5.3	0.79	0.81	0.23	10.5	5.8	4.4	6.5

[1] CN, complete nutrient; IAA, Indoleacetic acid.
[2] Concentration 1.0 p.p.m. in solution in October 17, 1941 sample; added daily and cumulatively at 0.2 p.p.m. in January 16, 1942 sample.

significant increase in the dry weight of boron deficient plants receiving indoleacetic acid (tables I and II). In this instance, the tobacco harvested on December 19, 1941, was significantly higher when indoleacetic acid was supplied. It had been noted, however, that the symptoms of boron deficiency appeared somewhat earlier in those plants receiving indoleacetic acid and more secondary tissue was produced from developing axillary buds. Renewed growth in such circumstances is frequently observed in tobacco that has become severely deficient (**5**). It is believed that the somewhat greater mass of tissue produced by plants receiving indoleacetic acid may have been principally due to the earlier appearance of initial symptoms. No significant correlations of moisture content or root-top ratios to the presence or absence of either boron or indoleactic acid were found.

Discussion

It is recognized that the technique employed in this study differed in several major respects from that of EATON (**2**). He used unaerated solution culture and produced symptoms of boron deficiency at a much earlier stage of growth than is possible under normal conditions in sand cultures. Whether any protective action of indoleacetic acid in conditions producing boron deficiency is more efficient in the seedling than in the more mature plant is, as yet, undetermined. The concentration of indoleacetic acid, moreover, was higher in the sand culture experiments.

It may be that other environmental factors are involved in the differences of results obtained. Eaton noted that the protective action of indoleacetic acid was largely nullified by high light intensities (**2**), and it may be that this effect is more pronounced in the older plants. It has also been observed that the severity of boron deficiency may be accentuated by high levels of calcium (**6**). The solution employed in this study contained higher levels of calcium ion than did that used by Eaton in his study. HOAGLAND and SNYDER (**4**) have suggested that the degree of aeration of nutrient solutions may be related to the severity of boron deficiency. Suitable conditions for repeating these experiments under more rigidly controlled conditions of light intensity and other environmental factors are not available to us. Elucidation of a possible relation between boron and the auxins, however, might well provide valuable insight into the metabolic function of both.

Examination of the data indicates, however, that under the conditions employed any appreciable replacement of boron by indoleacetic acid in growing plants was absent. Whether or not it occurs under more suitable and limited environmental conditions is still unknown.

Summary

No significant alleviation of boron deficiency by indoleacetic acid was noted in sand culture under normal greenhouse conditions with tomato, cotton, sunflower, soybean, and tobacco plants.

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