SIGNIFICANCE OF BORON IN THE METABOLISM OF COTTON PLANT

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ABSTRACT

Cotton plants were sprayed with 0·125% and 0·250% boric acid solutions at intervals of nine, eleven, fourteen and eighteen weeks after sowing. Sprays of 0·125% boric acid were found to be optimum for significantly increasing the number of leaves and flowers, the RNA content of leaves at full blooming stage and the total nitrogen content of kernels, as compared to the control plants (untreated). The authors have discussed various biochemical possibilities for this promotive effect of boron on these morphological parameters.

INTRODUCTION

BORON occurs in most soils in extremely small quantities ranging generally from 20 ppm to 200 ppm. It does not normally occur in toxic quantities in most aerable soils unless it has been applied in excessive amounts either to the soil or through sprays. A critical survey of literature reveals that even when soils show no distinct deficiency symptoms of any essential element, plants do respond to some of them. Research work, conducted at the Indian Agricultural Research Institute, New Delhi, from 1954-1961, has shown that out of all the micronutrients only boron promotes the growth and increases the yield of crops (Dani).[1]

It has been pointed out by Holly and Duline[2] that the dose of boron sufficient for vegetative growth of cotton plant may fall deficient at the flowering stage, as it is necessary for flower-bud development. A number of investigators[3,4] have suggested that boron might play some important role in the protein metabolism of the cotton, plant, while certain other authors[5-7] have hypothesized its possible role in the metabolism of plant nucleic acids.

The present studies were, therefore, undertaken to explain the observed morphological changes on the basis of explicit biochemical reasoning and to find out a possible explanation for the higher needs of boron by the cotton plant at the flowering stage.

MATERIALS AND METHODS

Cotton (*Gossypium hirsutum* L.), variety 320 F, was grown on a uniformly fertile soil. Seeds were sown in straight lines, with an appropriate distance of 1½′ between the rows and 6″ to 8″ from seed to seed. Proper irrigation of the field was done at an interval of one month in the first instance and at adequate intervals thereafter, depending upon rainfall.

Eighteen healthy plants of almost equal height were selected from the field and randomly divided into three groups, each consisting of six plants. Two groups were put under 0·125 and 0·250% boric acid treatments and the third group was left untreated (control). Boric acid solutions were sprayed at intervals of nine, eleven, fourteen and eighteen weeks after sowing.

Number of leaves and flowers on each plant was recorded separately, just before each spray was to be applied. Samples of stems and leaves for RNA estimation were collected after one week of the final spray at the full blooming stage. Ripened seeds were collected for total nitrogen determination.

RNA contents of stems and leaves were determined by modified method of Schmidt-Thannhauser as detailed by Glick.[8] Total nitrogen in cotton-seeds was estimated by microkjeldahl method as described in A.O.A.C.[9] About thirty seeds were randomly picked from each plant their seedcoats removed and kernels crushed to fine powder for total nitrogen estimation.

RESULTS AND DISCUSSION

Effect on RNA Content.—A critical evaluation of the data pertaining to number of leaves (Fig. 1) shows that 0·125% boric acid sprays produced a highly significant effect, while 0·250% boric acid sprays suppressed the number of leaves without any significant inhibitory effect.

Table I represents the mean RNA contents of leaves and stems of cotton plants at full blooming stage. Both in the case of the leaves and the stems there was a significant decrease in the RNA content of 0·250% boric acid-treated plants, whereas 0·125% boric acid spray showed highly significant increase in the content of the leaf RNA only. The lower concentration of boric acid did not increase the

RNA content of stems, probably due to the higher utilization of the absorbed boron by the leaf tissues themselves. 0·250% boric acid seemed to be toxic to the cotton plant and therefore suppressed RNA biosynthesis. A highly significant increase in the RNA content of 0·125% boric acid-sprayed plants very clearly showed that the element was unequivocally participating in the biosynthesis of ribonucleic acids. Further investigations in progress in our laboratories are expected to decipher this aspect of the problem.

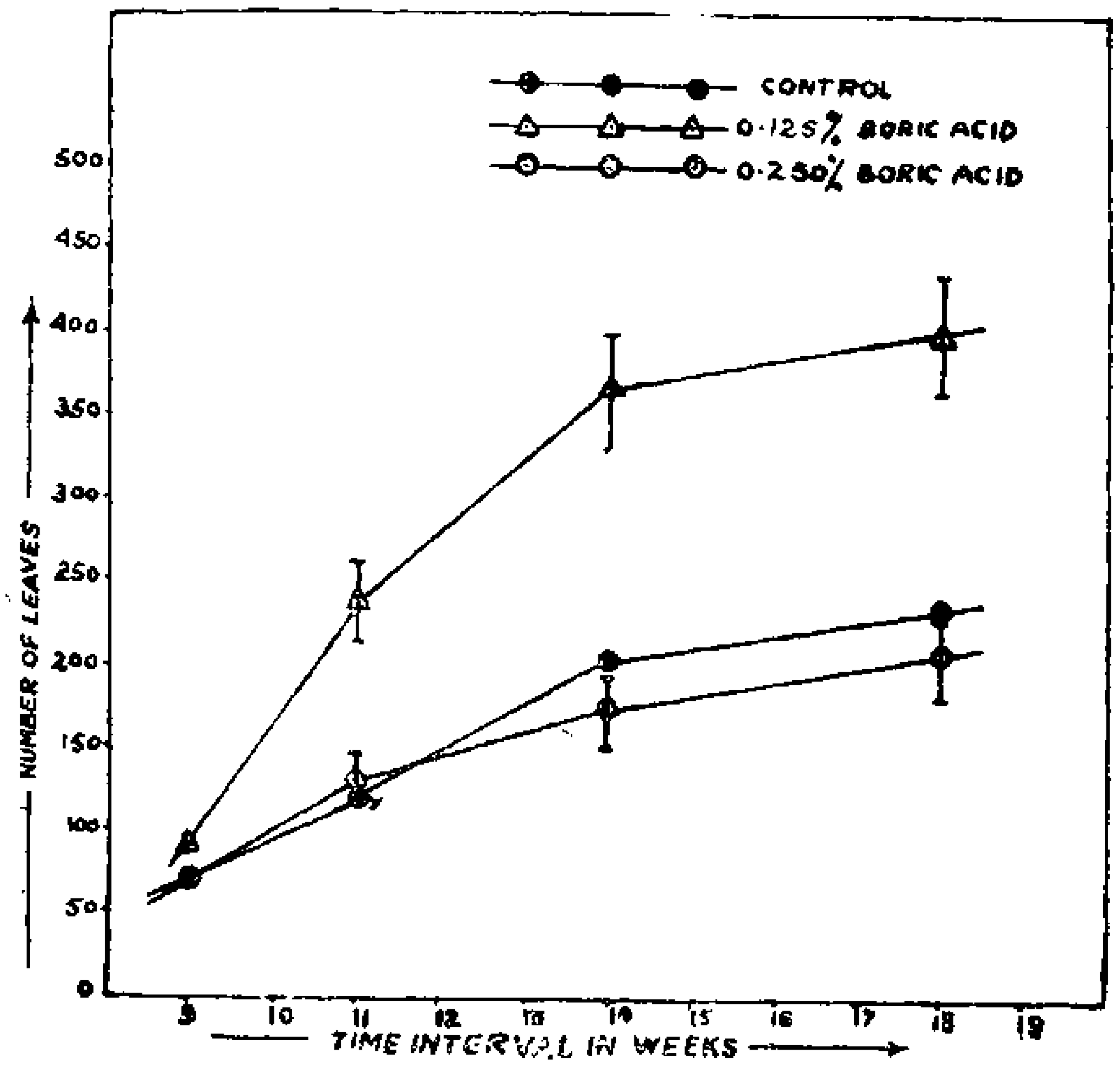

FIG. 1. Effect of boric acid sprays on the number of leaves of cotton plant. Each value represents a mean of six replications. Standard errors of the means are indicated by vertical lines.

TABLE I

*Statistical evaluation of the effects of boric acid treatment on the RNA content of leaves and stems, and the total nitrogen content of the kernels (seeds) in cotton plant**

Treatment	RNA (μg./gm. in dried tissue)		Nitrogen percentage
	Leaves	Stems	Kernels
1. Control	12·96	11·33	6·46
2. Boric acid (0·125%)	21·58	12·31	8·12
S.D. ±	2·072	1·380	0·176
t value†	7·20	1·22	16·30
3. Boric acid (0·250%)	10·47	10·16	7·04
S.D. ±	0·318	0·199	0·167
t value†	13·50	10·10	6·00

* Each reading represents a mean of six replications.

† Significant at 5% level when t_{10} as compared to control $\geqslant$ 2·23 highly significant at 1% level when t_{10} as compared to control $\geqslant$ 3·17.

Effect on Floral Initiation.—Our results show a highly significant increase in the number of flowers in the case of 0·125% boric acid-treated plants after two sprays (Fig. 2). The results became statistically still more significant after third spray. Boric acid sprays of 0·250% concentration did not show any significant increase in the number of flowers, probably due to some toxic effect on the conversion of leaf-buds to flower-buds.

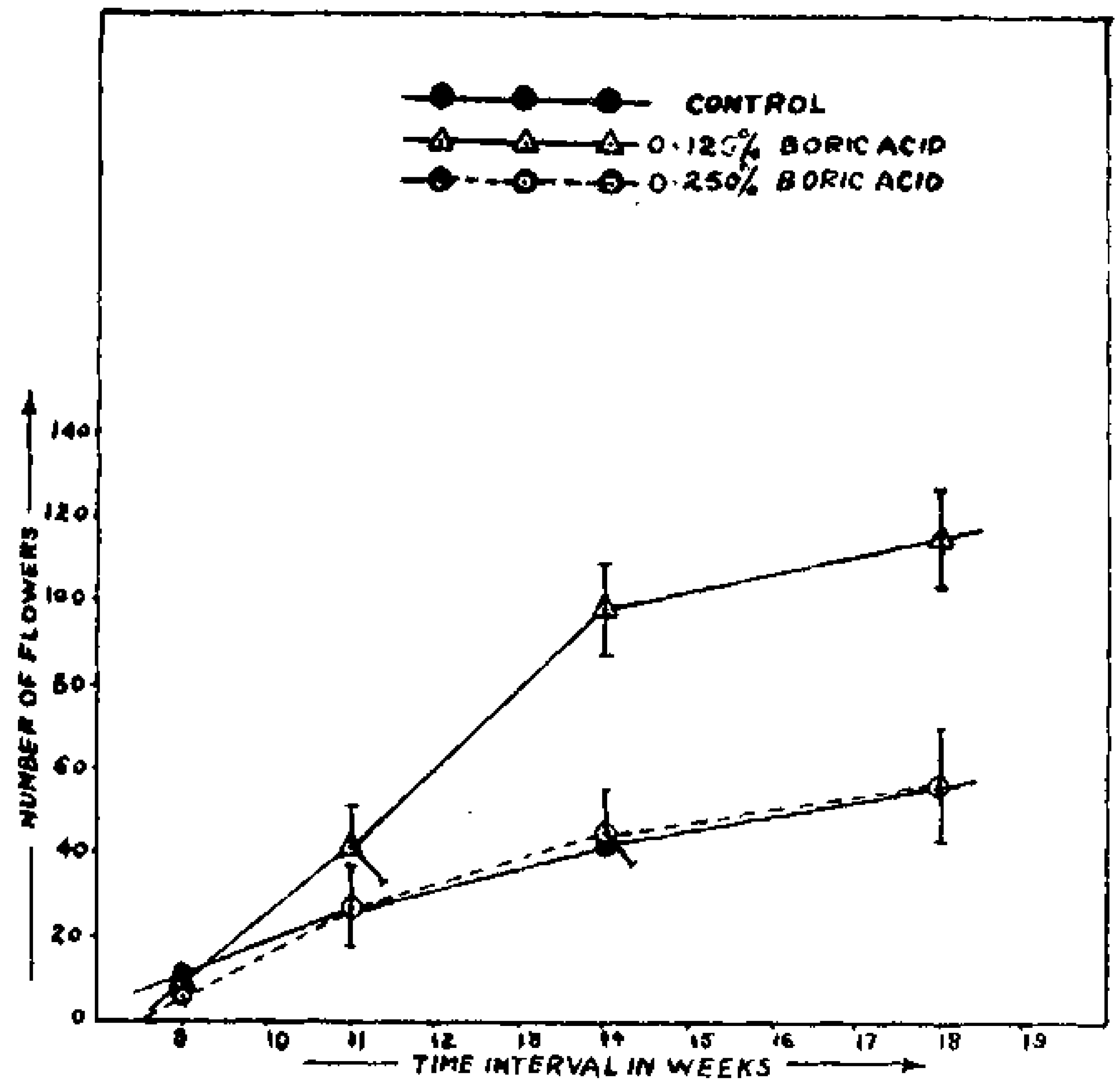

FIG. 2. Effect of boric acid sprays on the number of flowers of cotton plant. Each value represents a mean of six replications. Standard errors of the means are indicated by vertical lines.

The present authors suggest that the following two mechanisms might possibly explain the above effect of boron in increasing the number of flowers in cotton plant :—

1. Pineapple plant is the only known example in which ethylene (or acetylene) functions as a flowering hormone or a stimulant for the formation of the hormone. Boron might be playing a role in the cotton plant analogous to that of ethylene (or acetylene) in the pineapple plant, thus justifying its higher requirement at the flowering stage. Our observation regarding the inhibitory effect of the higher concentration of boric acid (0·250%) on floral initiation in cotton plant resembles the similar effect of high concentration of ethylene on the pineapple plant. It thus seems that ethylene and boron might be analogous growth regulators in pineapple and cotton plants respectively.

2. The effect of boron in significantly increasing the number of flowers in cotton plant might also be explained on the basis of

its action on auxin concentration. It is known that in the majority of plant species the application of indole acetic acid or other active auxins to the leaves delays the appearance of flower-buds, and in some cases its repeated and daily application inhibits flowering for a long time.

Shkol'nik and Maevskaya[5] have pointed out that the effect of boron on the synthesis of growth substances need exhaustive studies. It has been recently suggested by Coke and Whittington[10] that boron-deficient tissues suffer from an excessive auxin concentration either because the element is necessary for some growth processes, such as cell-wall formation or nucleic acid synthesis, which, when impaired, result in the accumulation of auxins, or because the indole acetic acid-oxidation system is affected by phenolic inhibitors which boron normally activates by complex formation.

In view of the above facts, it is possible that high boron levels needed at the flowering stage in cotton plant may be interfering either with the biosynthesis of indole acetic acid or by activating indole acetic acid-oxidation system. The outcome of any of these possibilities will lead to accelerated flowering due to suppressive effect of boron on indole acetic acid activation. The elucidation of the precise mechanism involved in this process at the molecular level is in progress in our laboratories.

Effect on Nitrogen (Protein) Content.—It is well known that, commencing from the flowering and fertilization processes (Doby and Füleky),[11] the leaves continually transport protein to the seed. The samples of leaf and stem tissues for the estimation of RNA were therefore taken at the full blooming stage of the cotton plant. Our main objective in doing so was to investigate whether the effect of boron on RNA concentration of leaves was in any way related to the increase in the total nitrogen content of the seeds, which, in turn, is derived to a large extent from the leaves in the form of soluble peptides and proteins.

It is interesting to note from our observations (Table I) that the total nitrogen percentage is significantly increased in the case of seeds obtained from plants treated with 0·125 and 0·250% boric acid, which means that the overall nitrogen content of the cotton-seeds is markedly increased by the application of boron. The element seems to play a multifold role in nitrogen turnover of the cotton plant either by affecting RNA or protein biosynthesis. Its action on increasing the mobility of labile nitrogen compounds is clear from a highly significant accumulation of nitrogen in the seeds of 0·250% boric acid-treated plants, even when this high concentration has proved to be toxic and suppressive for all other parameters studied.

CONCLUSION

Our observations emphatically suggest that intermittent sprays (3-4 weeks) of 0·125% boric acid solution on cotton plants, about five to six weeks old, will produce remarkably beneficial effects in promoting the number of leaves and flowers, which, in turn, might go a long way to enhance the yield of cotton. It should be applicable to all types of soils which do not contain toxic concentrations of boron. It is hypothesized that boron helps floral initiation of cotton plants, probably by suppressing indole acetic acid activity, or by stimulating the formation of flowering hormone. It also increases the percentage of total nitrogen of kernels, improving thereby the nutritive value of cotton-seed. This effect, in our view, is considered to be controlled through a direct or indirect effect of boron on protein biosynthesis.

ACKNOWLEDGEMENT

The authors are highly indebted to the University Grants Commission for providing the financial assistance to the Plant Biochemistry Section of the Department of Biochemistry, Panjab University, Chandigarh, for carrying out this research work.

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