Asian Journal of Plant Sciences

ISSN 1682-3974

science alert

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Asian Journal of Plant Sciences 10 (5): 307-311, 2011
ISSN 1682-3974 / DOI: 10.3923/ajps.2011.307.311

Effect of Time and Concentration of Boron Foliar Application on Yield and Quality of Sugar Beet

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Abstract: A field experiment was carried out at the Research Center of Barkat-e-Jovein, Jovein agro-industries, Northeastern Iran, during 2008 to evaluate the effect of concentration and time of boron foliar application on root yield and quality of sugar beet (*Beta vulgaris*). Treatments consisted of 3 application times (30, 45 and 60 DAP) and 4 application rates (spraying with concentrations of 0, 4, 8 and 12% corresponding with 0, 0.35, 0.70 and 1.22 kg B ha^{-1} as water-soluble B (Boric acid)). Results revealed that application time had neither any considerable effect on sucrose concentration, root yield, k^+, Na^+, molasses sugar, nor on reducing nitrogen. Boron application increased root yield and sucrose concentration by 12.12 and 26.35%, respectively decreasing k^+, Na^+, α-amino-N and molasses sugar compared with those of the control. In this study, no significant differences were found to exist between boron application times. On the other hand, the highest root yield and sucrose concentration were obtained by spraying with 12% boric acid at 60 days after planting.

Key words: Boron, application time, concentration of spraying, fertilizer, *Beta vulgaris*

INTRODUCTION

Nowadays, manure is being extensively used as a robust tool to maximize crop productivity. Among the nutrients in the soil, deficiency in nitrogen, phosphorus, potassium, zinc and boron has been identified as one of the major constraints in beet crop production and based on plant needs, should be added to the soil accordingly. The availability of micronutrients in the soil can strongly affect the production and quality of sugar beet. Karamvandi (1997) evaluated appropriate rates of fertilizer application to maximize sugar beet productivity at 12 sites in Karaj and Saveh, central Iran and revealed that consumption of 20 kg ha^{-1} Borax can result in an increase in root yield from 45.29 to 48.82 Mg ha^{-1}, in sucrose concentration from 16.72 to 17.93% and in yield of white sugar from 6064 to 7338 kg ha^{-1}. Dordas *et al.* (2007) reported that spraying 0.5 kg boron ha^{-1} increased concentration of B in vegetative and reproductive organs of sugar beet; in their study, foliar application of boron lead to higher yield and better quality compared to the time using boric acid in soil; increasing root yield resulting from boron application ranged from 10 to 445 kg ha^{-1} in different years of study. Gezgin *et al.* (2001) showed that consumption of 0.3 kg B ha^{-1} will increase root yield by 12.5, 12.1 and 11.1% and sucrose yield by 8.7, 13.8 and 3.5% compared to the times of non-consumption in soil, of spraying foliar and of spraying foliar in soil, respectively. Consumption of boron in large quantities, however, showed a reduction in yield and sugar production in all methods of application.

The highest yield and quality of sugar beet were obtained when 0.3 kg ha^{-1} boron was added to the soil as borax. El-Gawad *et al.* (2004) showed that adding 0.5 kg B ha^{-1} to the soil as boric acid will reduce total soluble boron, while this parameter was not affected by different amounts of Zinc and Manganese. Application of these three micronutrients in 105 DAP, compared to the time of their application in 60 DAP, had greater effect on qualitative components of sugar beet. Despite the important role of micronutrient at higher yield or quality of sugar beet, there is still a lack of information regarding the role of micronutrient and more specifically the effect of boron application on sugar beet particularly in the context of Iran. The purpose of this study was to evaluate the effects of different concentrations and different application times of boric acid on quantitative and qualitative aspects of sugar beet in Jovein region as the major area of sugar beet cultivation in Iran.

MATERIALS AND METHODS

The experiment carried out at the Research Center of Barkat-e-Jovein, Jovein agro-industries, Northeastern

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Table 1: Physico-chemical properties of soil

Clay	Silt	Sand	pH	EC	Total N	Available P	K	B	Na	Ca	Mg	Organic matter
---------(%)----------				(ds.m^{-1})	------------------------------------(mg kg^{-1})------------------------------------							(%)
20	10	70	7.8	1.5	0.014	3.35	175	0.34	35	8.27	5.09	1.12

Table 2: Chemical properties of irrigation water

pH	EC (ds.m^{-1})	Sulfate	Chloride	Bicarbonate	Sodium	Calcium	Magnesium	Boron
		------------------------------------(mg L^{-1})------------------------------------						
6.5	1.2	0	3.3	13.4	2.2	9.2	6.0	0.12

Iran. The experiment was established in a loam sandy soil as shown in Table 1. The experimental design was a factorial andomized complete block design with four replicates. Factors were: Boric acid (containing 17% boron); application time in three levels (30, 45 and 60 DAP) and the concentrations of boric acid being sprayed in four levels (spraying with a solution containing 0, 4, 8 and 12‰ B, corresponding with 0, 0.35, 0.7 and 1.22 kg B ha^{-1}, respectively).

The treatments were laid out in 2.4×8 m plots. Seeds were sown at a spacing of 0.60 m between rows and 0.20 m within rows. Seeds were sown by sugar beet pneumatic system. Sowing date was the 4th week of March, 2008. Adjacent subplots were separated by a 0.6 m wide ridge and different factors were separated by a 1.2 m wide ridge (Table 2). All plots were weeded manually during the growth period. No serious incidence of insect or disease was observed and no pesticide or fungicide was applied to either plants.

During the growth of sugar beet, other fertilizers were applied based on soil analysis results. Irrigation during the growth season was done as Sprinkler and in 8-day intervals. Boric acid spraying was conducted using dorsal sprayer in the last hours of each day. In all three stages, spraying was done three days after irrigation. At harvesting time, one meter from the beginning and a half meter around each plot was removed as a marginal effect. The remaining area was harvested manually. Twenty root samples were randomly separated and sent to the laboratory to determine the percentage of sugar. Root samples required for qualitative analysis after freezing were also sent to Sugar-beet Research Organization. Sucrose percentage (%) was determined in fresh roots polarmetrically using the Pol method and Nitrate and Nitrite were determined in roots according to the method described by Singh (1988). Data collected were subjected to the analysis of variance (ANOVA). Test of significance of the treatment difference was carried out on a basis of Duncan multiple-range test. The significant differences between treatments were compared with the critical difference at 5 and 1% levels of probability.

RESULTS AND DISCUSSION

Root yield: Root yield was not different in boric acid application times (Table 3). The greatest root yield was observed at 60 DAP. The reason for such a lack of differences between different boric acid application times can be due to short time-intervals between boron applications in different treatments. A number of studies have shown that with one-month intervals between boron spraying times there will be no significant impact on root yield, which, by itself, indicates that root yield affected by various factors as well as the role of boric acid in this regard seems almost negligible. Wassif *et al*. (2002) suggested that the best time for foliar application of boron is from late May to early June, prescribing that spraying should be repeated in 10 to 14 more days.

Boric acid concentrations significantly ($p<0.05$) affected root yield (Table 3). Spraying with concentrations of 8 and 12‰ significantly increased yield over the control. At the same time, differences between control and spraying with concentration of 4‰ were not significant (Fig.1). Stevens and Mesbah (2004) found that application of zinc, boron, iron and manganese increased root yield of sugar beet by 14% compared with the case of non-application of these micronutrients. It did not, however, significantly increase when using boron alone. Kristek *et al*. (2006) reported that root yield was 75.41, 79.03, 84.23 and 81.80 mg ha^{-1}, respectively when 0.5, 1, 2 and 4 kg B ha^{-1} were applied in spray. Yield reduction at high levels of boron is attributed to the toxicity of this element.

Sucrose concentration: Sucrose concentration was not affected by boric acid application time (Table 3). El-Gawad *et al*. (2004) indicated that boron application at 105 DAP had greater effect on qualitative yield of sugar beet than that of the boron application at 90 DAP, though there was no significant difference among the treatments.

The effect of different concentrations of boric acid on sucrose concentration was significant ($p<0.01$) (Table 3). The least sucrose concentration was observed at the

Table 3: Analysis of variance table for the yield, concentrations of sucrose, potassium, sodium, reducing nitrogen in root and molasses sugar

SOV	df	Yield	Sucrose concentration	Potassium	Sodium	Reducing nitrogen	Molasses Sugar
Replication	2	14.21ns	1.4ns	1.05ns	0.06ns	0.27ns	0.14ns
Application time	2	28.18ns	1.23ns	0.74ns	0.14ns	0.71ns	0.22ns
Boron concentration	3	52.92*	27.37**	5.38**	1.97**	1.26**	1.89**
Interaction	6	30.49 ns	1.48 ns	0.40 ns	0.17 ns	0.19 ns	0.058 ns
Error	22	13.8	4.92	1.04	0.21	0.105	0.18
CV		7.52	7.52	22.57	16.08	13.51	20.54

ns: not significant; * and ** represent significant difference over control at $p<0.05$ and $p<0.01$, respectively

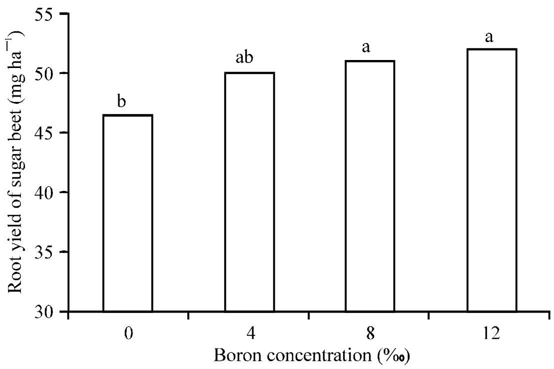

Fig. 1: Effect of boric acid on root yield of sugar beet. Values followed by the same letter do not differ significantly at p = 1% according to DMRT

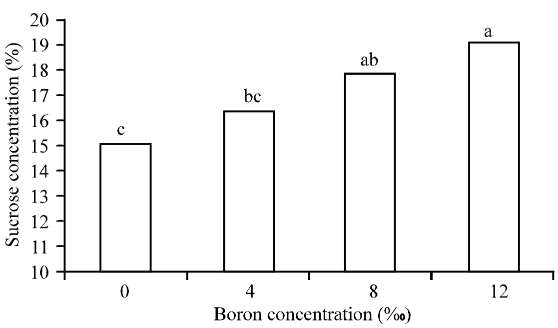

Fig. 2: Effect of boric acid application time on the sucrose concentration. Values followed by the same letter do not differ significantly at p = 1% according to DMRT

control, increasing significantly along with the increase in boron concentration. Although there was no significant differences between concentrations of 12 and 8‰ (Fig. 2), increased concentration of boric acid increased the percentage of sucrose through the balance in the sodium uptake and nitrogen consumption. Al-Mohmmad and Al-Geddawi (2001) showed that boron consumption in sugar beet significantly reduced root rot, increasing the sugar yield due to increased glucose levels in roots and phloem sap. In their study, compared to the control, boron application increased sucrose concentration by 6.5 and 16% at the first and second years of study, respectively.

Root impurities

Potassium content: Analysis of variance revealed that potassium content was not affected by boric acid application time (Table 3). Spraying at 30 DAP (4.88 meq K 100 g^{-1} of root) exhibited the greatest potassium content, while spraying at 60 DAP (4.07 meq K 100 g^{-1} of root) had the least potassium content (Table 4).

Effect of different concentrations of boric acid on the potassium content was significant (Table 3). At different concentrations of boric acid, the only significant differences were between concentrations of 4% and those of the control (Table 4). Javaheripour *et al.* (2005) reported that application of 20 kg boric acid ha^{-1} increased potassium content in roots of sugar beet from 5.34 to 5.42 meq 100 g^{-1} of root. The results found in this study are inconsistent with those of Kristek *et al.* (2006) who reported that boron application had no impact on potassium content in sugar beet root.

Trend of changes in potassium with regard to different concentration of boron was not clear in the present study. There was a negative relationship between potassium content and concentration of boron application. The greatest potassium content was observed in the control, which decreased by 30.6% at spraying with concentration of 12‰ (Table 4).

Sodium content: Sodium content was not significantly changed between different times of boron application (Table 3). Spraying at 45 DAP exhibited the greatest sodium content, while spraying at 60 DAP had the least sodium content (Table 4). The least accumulation of sodium at boron application at 60 DAP can be due to the fact that increased leaf area in this date will facilitate the increase in boron absorption.

There was a significant difference between different concentrations of boric acid in sodium content ($p<0.01$). Among the qualitative characteristics of sugar beet, boron had the most effective impact on the sodium content. Increasing boron application decreased sodium content to different extents: sodium content was 1.75 Meq 100 g^{-1} root for concentration of 4‰, 1.58 Meq 100 g^{-1} root for concentration of 8‰ and 1.26 Meq 100 g^{-1} root for concentration of 12‰ which compared with the control, decreased by 26, 34 and 47%, respectively, (Table 4).

Table 4: Effect of boric acid application time and different doses of boric acid on potassium, sodium, reducing nitrogen and molasses sugar

Source of variation	Potassium (meq 100 g^{-1} of root)	Sodium (meq 100 g^{-1} of root)	Reducing nitrogen (meq 100 g^{-1} of root)	Molasses Sugar (meq 100 g^{-1} of root)
Application time (DAP)				
30	4.88a	1.90a	3.00a	2.26a
45	4.66a	1.85a	2.30a	1.82a
60	4.07a	1.48a	2.16a	2.07
Application amounts (‰)				
0	5.58a	2.38a	2.91a	2.49a
4	4.62ab	1.75b	2.58b	2.04b
8	4.14b	1.58b	2.44c	1.91bc
12	3.81b	1.26b	2.01c	1.78c

*Values followed by the same letter within the same columns do not differ significantly at p = 5% based on DMRT

Tariq *et al*. (1993) showed that application of boron decreased sodium content in sugar beet root. Similar results have also been reported by Javaheripour *et al*. (2005) in their study, however, application of 10 and 20 kg boric acid ha^{-1} prior to sowing did not increase the sodium content over the control.

Reducing nitrogen content: No statistically significant differences have been found to exist among different times of boron application on reducing nitrogen (Table 3). Despite the lack of significant differences in different times of boron application, the least amount of nitrogen reduction was observed at boric acid application in 60 DAP (Table 4).

Faster nitrogen absorption at boron application in 60 DAP, compared to other application times, could have resulted in reduction of nitrogen accumulation in this treatment. Highly significant differences appear in connection with effect of different concentrations of boric acid on reducing nitrogen (Table 3). The least reduction of nitrogen content occurred when boron applied at concentration of 12‰ and increased along with a decrease of boron concentration (Table 4). Boric acid application at concentration of 12‰ compared to a time of non-consumption decreased the reduction of nitrogen by an amount of 31%. There was no significant difference between spraying with concentrations of 4 and 8‰ (Table 4). Increase in soil boron decreased the reduction of nitrogen through reducing the absorbed nitrogen. Kristek *et al*. (2006) found that application of 0.5, 1, 2 and 4 kg B ha^{-1} decreased the reduction of nitrogen compared to control by 41, 48, 56 and 74%, respectively.

Molasses sugar: No significant differences have been found to exist between the various times of boron application on molasses sugar (Table 3). Lowest quantities of molasses sugar were observed at boric acid application in 60 DAP, while the maximum molasses sugar were obtained at boric acid application in 45 DAP which did not show any significant differences with boric acid application in 60 DAP (Table 4). Molasses sugar can be affected by different amounts of boric acid. There was significant difference between consumption and non-consumption of boric acid in molasses sugar. The lowest molasses sugar was observed at spraying with concentration of 12‰ (Table 4). It is reported that in fields with boron deficiency, sugar extraction operation is confronted with more problems so that lower percentage of sugar will be extracted. Therefore, the remaining sugar in the form of molasses (sugar molasses) in these fields is higher in amount than that which has received enough boron. Javaheripour *et al*. (2005) stated that increasing the amount of boric acid can reduce molasses sugar so much so that the consumption of 30 kg boric acid reduced sugar molasses by 4.86% in comparison to a time of non-consumption.

CONCLUSIONS

The overall results indicate, under semi-arid conditions of Jovein area, no statistically significant differences were found to exist between boron application times, though the beet crop can be sprayed with a concentration of 12‰ boric acid to achieve significantly higher yield or quality.

ACKNOWLEDGMENTS

This work has been supported by grant from Islamic Azad University, Sabzevar branch. The authors gratefully appreciate Mr. Khalili for his technical assistance and providing essential facilities during the studies.

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