BIOLOGIA PLANTARUM 47 (2): 313-316, 2003/4

BRIEF COMMUNICATION

Response of maize and sorghum to excess boron and salinity

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Abstract

The effects of 50 mM NaCl and 5, 10, 15 and 20 mM boron on the rate of germination, growth rate, contents of boron, sodium, potassium and chloride, and membrane permeability in maize (*Zea mays* L.) and sorghum (*Sorghum bicolor* L.) were studied. Germination rate, lengths of roots and shoots as well as dry matter production in the two tested plants, decreased with the increasing B concentration in nonsaline conditions, and markedly under salinity. Membrane permeability increased by increasing B concentration only under salinity. Increase in B concentration of sorghum was lower under salinity when compared to nonsaline conditions. Contrary to this, increase in B concentration of maize was higher under salinity. Under salinity Na and Cl concentrations increased and K concentration decreased in the both tested plants. Potassium concentration was decreased by B treatments under salinity.

Additional key words: germination, membrane permeability, potassium, sodium, *Sorghum bicolor*, *Zea mays*.

High concentrations of boron may often associate saline soils in semi-arid and/or arid climates Gupta *et al.* (1985). As B is removed more slowly than NaCl during leaching, it may still be present at excessive concentration in some reclaimed soils. Boron uptake is a passive process and it is greatly influenced by transpiration rate. On the other hand, Shu *et al.* (1991) and Pfeffer *et al.* (1999) observed that B is taken up both by passive (under high B concentration) and active (under low B concentration) mechanisms. Bingham *et al.* (1987) reported that wheat plants respond to B independently of soil salinity but according to Grieve and Poss (2000) excess external B and salinity interact to limit growth and yield components of wheat. Boron tolerance mechanism of plants has a similarity to salt tolerance mechanism (Alpaslan and Gunes 2001). Moreover, the highly B-tolerant *Prunus* rootstocks also showed high salt tolerance (El-Motaium *et al.* 1994).

This study aimed to examine whether salinity enhances or reduces the phytotoxicity of boron in sorghum and maize plants.

Maize (*Zea mays* L.) and sorghum (*Sorghum bicolor* L.) grains were obtained from Faculty of Agricultural, Assiut University. NaCl 0.0 (control) and 50 mM was applied in 1/10 Hoagland solution. Boron was applied at the rates of 0.0, 5, 10, 15 and 20 mM as H_3BO_3. Grains of the maize and sorghum were surface sterilized with 5 % (m/v) calcium hypochloride for 15 min and washed four times with sterile deonised water. These grains were then transferred to sterile Petri dishes (10 grains per Petri dish) and will be allowed to germinate in growth chamber at about 27 °C, germination percentages were recorded daily up to 4 d. For seedling development 10 grains were placed between folded paper towels, covered by plastic film, rolled up, and placed upright in 600 cm^3 beakers with 80 cm^3 of above mentioned solution of NaCl and/or B. Seedlings were grown in darkness in an incubator at temperature of 27 °C for two weeks. Distilled water was added as needed to compensate for evaporation loss. At the end of the experiment, the seedlings plumule and radicle lengths of the both tested plants were recorded. Also, membrane permeability of the excised leaves was measured as described by Yan *et al.* (1996). A portion of the leaves from the harvested plants was weighed and placed in a glass beaker with water for reverse osmosis. The leaves were incubated

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Received 26 November 2002, *accepted* 25 March 2003.
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at 30 °C for 3 h, and then the conductivity of the solution was measured with a conductivity meter. After the boiling the samples for 2 min, their conductivity was measured again when the solution was cooled to room temperature. The percentage of electrolyte leakage was calculated by using the following formula: EC [%] = $(C_1/C_2) \times 100$, where C_1 and C_2 are electrolyte conductivities measured before and after boiling, respectively.

Harvested plants were dried in oven at 75 °C for 24 h, until reaching a constant dry mass and subsequently ground. For the measurements of mineral elements, plant samples (20 mg) were digested in 5 cm^3 of 2 M HNO_3. The solution volume was brought to 20 cm^3, filtered and stored until analyzed. Na and K were measured by flame photometer (*Jenway PFP 7*, Essex, UK) and Cl was determined by potentiometric titration with $AgNO_3$ as described by Lambert and DuBois (1971). Boron was determined spectrophotometrically (*Spectronic Genesys ZPC*, Rochester, NY, USA) by the azomethine-H method (Wolf 1974).

The experiments were designed as completely randomized with three replications (10 plants each). The experimental data analyzed by the least significant difference test.

The germination percentage of maize and sorghum was no affected by low concentration of B (up to 10 and 5 mM respectively). Under NaCl stress the germination percentage of both plants decreased with the increasing concentrations of applied B. The decreased was more pronounced in maize than in sorghum (Fig. 1). In addition, the toxic effect of B on the germination percentage was more obvious in the presence of salinity. This is in accordance with the similar results of Yadav *et al.* (1989).

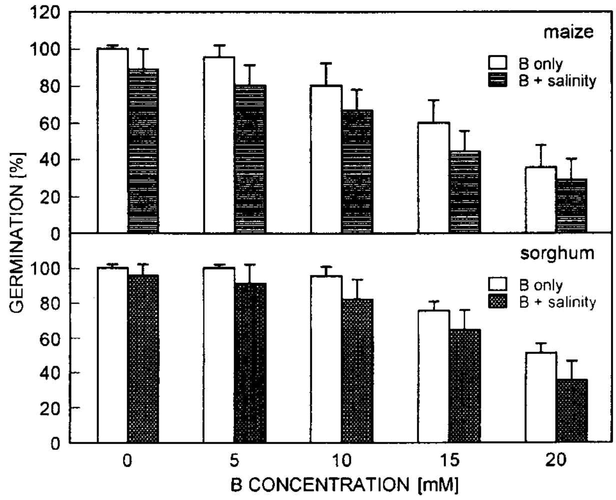

Fig. 1. Interactive effects of salinity and B concentrations on germination percentage of maize and sorghum grains. Data are the means (n = 3) with *vertical bars* representing standard errors.

The lengths of radicle and plumule and dry matter production of the two tested plants (Table 1) remained more or less unaffected up to the level of 5 mM B and then progressively decreased with increasing boron applied. Boron and salinity interaction markedly decreased these values as compared with the corresponding treatments with B only. This reducing was more obvious in maize plants than in sorghum especially under saline condition. Therefore, maize plants were more seriously affected by B toxicity (Marcar *et al.* 1999, Grieve and Poss 2000). Also, Alpaslan and Gunes (2001) deduced that the toxic effect of B would be more serious in salt sensitive crops (cucumber) than salt resistant crops (tomato). Membrane permeability (EC %) of excised

Table 1. Interactive effects of salinity and B on radicle (R), plumule (P) lengths [cm], the production of dry matter (D) [g $seedlings^{-1}$] and membrane permeability expressed as decrease in electric conductivity [EC %] of maize and sorghum plants. Significant differences from the control at * - P = 0.01 and ** - P = 0.05 .

NaCl [mM]	Boron [mM]	maize R	P	D	EC [%]	Sorghum R	P	D	EC [%]
0	0	7.5	4.7	1.155	13.95	8.6	5.6	2.677	9.11
	5	6.9	4.8	1.080	13.76	8.8	5.5	2.386	9.15
	10	5.5**	3.5**	0.785**	14.10	6.8**	4.2**	2.085**	8.77
	15	4.0**	2.2**	0.561**	14.26	4.9**	3.5**	0.917**	8.40
	20	2.3**	1.9**	0.353**	14.37	3.1**	2.3**	0.422**	8.72
50	0	6.8*	4.3	1.002*	15.80**	8.3	5.2	2.508	11.20**
	5	6.3**	3.9*	0.791**	16.30**	7.7*	4.5*	2.146**	12.80**
	10	4.6**	3.2**	0.574**	17.85**	5.9**	3.1**	2.031**	14.73**
	15	2.8**	2.1**	0.244**	18.91**	4.6**	2.7**	0.744**	14.85**
	20	1.7**	1.3**	0.147**	20.44**	2.3**	1.6**	0.335**	15.25**
$LSD_{0.05}$		0.77	0.70	0.14	0.91	0.80	0.83	0.312	0.75
$LSD_{0.01}$		1.10	0.91	0.19	1.25	1.10	1.14	0.430	1.03

Table 2. Interactive effects of salinity and B on the boron, sodium, chloride and potassium contents [mg g^{-1} dry matter] in the maize and sorghum plants. Significant differences from the control at * - $P = 0.01$ and ** - $P = 0.05$.

NaCl [mM]	Boron [mM]	Maize B	Na	Cl	K	Sorghum B	Na	Cl	K
0	0	34.7	9.8	4.9	14.1	21.5	5.7	2.8	11.5
	5	51.8**	10.5	5.8	14.7	33.7**	6.4	3.4	13.4*
	10	88.5**	12.2*	6.3	14.4	56.8**	6.2	3.9*	16.5**
	15	120.0**	13.3**	5.9	15.3	93.7**	7.3*	4.8**	15.7**
	20	148.0**	14.6**	6.5	16.4*	126.0**	8.0**	5.5**	14.3**
50	0	29.8	15.8**	7.4**	13.8	24.2	12.6**	4.6**	12.8
	5	45.7**	18.7**	8.5**	11.7*	24.8	12.9**	5.3**	12.1
	10	97.3**	21.7**	10.4**	9.5**	30.7**	13.6**	6.7**	11.2
	15	146.0**	27.5**	12.1**	8.7**	48.6**	14.4**	7.9**	9.4*
	20	164.0**	27.3**	14.7**	7.3**	88.2**	15.3**	8.8**	8.6**
$LSD_{0.05}$		6.77	2.04	1.53	2.01	5.80	1.31	1.53	1.70
$LSD_{0.01}$		9.27	2.80	2.10	2.75	7.95	1.80	2.10	2.30

leaves of maize and sorghum plants (Table 1) was not affected under applied B only. This result is in agreement with that of Inal and Tarakcioglu (2003). However, EC % increased in the both plants by applied B under saline conditions. It is worthy of note that a membrane permeability of maize was higher than that of sorghum. The EC % variation between the plants explained why B, Na and Cl contents of maize were higher than those of sorghum.

Boron content increased in the two tested plants by increasing concentration of applied B only (Table 2). On the other hand, the concentration of B decreased in salinized sorghum plants, whereas in salinized maize plants an opposite pattern was exhibited. This is in accordance with the results obtained by Hu and Brown (1997) and Grattan *et al.* (1997). Also, Nable and Paull (1991) observed that the high B accumulation by susceptible genotypes or the lower accumulation of B by tolerant genotypes may be related to differences in membrane permeability associated with the composition of membrane and cell wall. In our study, membrane permeability and membrane leakage of maize plants was higher than that of sorghum plants. Therefore, it can be said that the capacity of maize membrane in the presence of B under saline conditions to restrict excess B uptake is lower than that of sorghum. Under saline condition the contents of each Na, Cl and K in the two experimental plants showed progressively greater accumulation, above that of the control with increasing B concentration (Table 2). However, K content of salinized sorghum remained more or less unaffected up to 10 mM B, thereafter the values tended to decrease with increasing of B applied. In the case of salinized maize, K content was significantly decreased with the increasing B concentration as compared with the control. This is in agreement with the results obtained by (Alfocea *et al.* 1993, Carjaval *et al.* 2000) suggested that K content is not affected by salinity stress in salt-tolerant tomato plants, while K uptake is strongly reduced by the ionic competition of Na with K in salt-sensitive tomato plants. Finally it can be concluded that the interaction of B and salinity decline the rate of germination and limited growth, but salt sensitive maize is affected more than salt tolerant sorghum plants. The higher B accumulation in salt sensitive plants than in salt tolerant plants was a result of increased membrane damage.

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