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TOLERANCE OF WHEAT SEEDLINGS TO EXCESS BORON

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Present in excessive amounts, micronutrient boron may become toxic for plants. The aim of this study was to investigate boron tolerance in seedlings of 12 wheat (*Triticum aestivum* L.) genotypes treated with boric acid. Selection criterion was root growth suppression in the presence of boron, which varied between 15.2 (Apache) and 46.3% (Renan). Root lengths on control and root growth suppression on treatments were not correlated. Boron content and dry weight of seedlings varied in vast intervals in all groups on control, as well as on treatments, which is probably caused by different boron tolerance mechanisms. Root growth suppression in genotypes Apache, Trakija and Bezostaja 1 was less than 20% and they may be considered as boron tolerant. Renan, Fundulea 4, Magdalena, Pergamino Gaboto and Donjecka 48 are marked as boron

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sensitive owing to more than 30% shorter roots on boron treatments. Norin 10/Brevor 14, Radika, Žitarka and Mironovska 808 were medium tolerant to excess boron.

Key word: wheat, boron tolerance

INTRODUCTION

Boron is an essential micronutrient for higher plants. Present in excessive amounts, boron can limit plant growth and yield, especially in arid and semi-arid environments. In wheat, reduced height and shoot growth, delay in development (PAUL et al., 1988) and reduction in root growth (HUANG and GRAHAM, 1990) may occur as the consequences of excess boron.

High concentrations of boron are often found in association with saline soils, such as solonchaks and solonetz, which are common in Vojvodina (MILJKOVIĆ, 1960). Ameliorating boron laden soils is difficult, expensive and short-time solution, thus, the development of boron tolerant cultivars is better approach to overcome problems associated with excess boron (NABLE et al., 1997).

Considerable genetic variation in response to high concentrations of boron exists at both inter- and intra-specific levels. Many authors reported large variation in boron tolerance amongst wheat genotypes (NABLE, 1988; HUANG and GRAHAM 1990; KRALJEVIĆ BALALIĆ et al., 2004).

The purposes of the study were to investigate the response of 12 wheat (*Triticum aestivum* L.) genotypes to excess boron and to get information about relationships among traits related to boron tolerance in wheat.

MATERIAL AND METHODS

Twelve genetically divergent high-yielding wheat (*Triticum aestivum* L.) cultivars have been included in the trial in order to estimate their tolerance to excess boron. The chosen cultivars were Renan, Apache (France), Fundulea 4 (Rumania), Magdalena (Hungaria), Pergamino Gaboto (Argentina), Donjecka 48, Mironovska 808 (Ukraine), Norin 10/Brevor 14 (USA), Radika (Macedonia), Žitarka (Croatia), Bezostaja 1 (Russia) and Trakija (Bulgaria).

The method proposed by CHANTACHUME et al. (1995) was used. 1200 kernels of each cultivar were surface sterilized and pre-germinated at $4^{o}C$ for 48h and $18^{o}C$ for 24h. The kernels were germinated and the seedlings have grown on filter paper soaked with different (0, 50, 100 and 150 mg/l) concentrations of boric acid solution (B0-control, B50, B100, B150-treatments), in dark, at $18^{o}C$, for eleven days. All solutions included 0.5 mM $Ca(NO_3)_2x4H_2O$, 0.0025 mM $ZnSO_4x7H_2O$ and 0.015 mM H_3BO_3.

Root length (RL-cm), dry weight of seedlings (W-mg) and boron content in seedlings (BC-mg/kg dry matter) were measured. The samples included 50 seedlings in 5 replications. To determine boron concentrations, samples were prepared by method 4, suggested by LAING et al. (2003). Boron concentration was measured by ICP-spectrophotometry.

Root growth suppression on treatments with regard to control (RGS-%) was used as selection criterion for boron tolerance and genotypes were separated into three groups: tolerant (T-RGS less than 20%), medium tolerant (MT-RGS between 20 and 30%) and sensitive (S-RGS above 30%). Reduction of seedlings' dry weight on treatments (WR-%) was also analyzed. Numerical values corresponding to boron concentration on treatments (BCT) are transformed and they represent the ratio of boron content on treatments and on control.

The results were processed by ANOVA method and LSD-test was performed. Mean values, standard errors of means and correlation coefficients among studied traits were calculated. STATISTICA 7.0 software package was used.

RESULTS AND DISCUSSION

A selection criterion for boron tolerance in wheat was root growth suppression (RGS) on boron treatments with respect to control at seedling stage, proposed by CHANTACHUME et al. (1995). Twelve wheat cultivars were classified as sensitive, medium tolerant or tolerant. Renan, Fundulea 4, Magdalena, Pergamino Gaboto and Donjecka 48 had RGS above 30% and they are marked as boron sensitive. Norin 10/Brevor 14, Radika, Žitarka and Mironovska 808 were medium tolerant to excess boron. Bezostaja 1, Trakija and Apache had RGS less than 20% and they may be considered as boron tolerant.

Analysis of variance demonstrated significant differences among groups regarding almost all analyzed traits. The only exception was dry weight of seedlings on control (W). Analysis of variance failed to detect significant differences among cultivars within groups regarding RGS, since the groups are formed on the basis of that trait. All other traits varied significantly among cultivars within each group.

Root length on control (RL) varied in the scale of 25.3 cm for sensitive cultivars, 23.5 cm for medium tolerant and 26.8 cm for tolerant genotypes. RGS varied between 46.3 (sensitive Renan) and 15.2% (tolerant Apache). The intervals of variation for seedlings' dry weight on control (W) were 3.5 mg/seedling for sensitive genotypes, 1.5 mg for medium tolerant and 9 mg for boron tolerant. The highest seedlings' dry weight reduction on treatments (WR) was noted for sensitive genotype Renan (33.5%). On the contrary, tolerant cultivar Bezostaja 1 had 2.1% heavier seedlings on treatments with regard to control (Table 1.).

RL and RGS were not significantly correlated, as well as W and WR (Table 2.), which might imply that RGS and WR demonstrate the differences among genotypes regarding response to excess boron. JEFFERIES et al. (2000) also confirmed RGS as a valuable selection criterion for boron tolerance in wheat; however, they found no correlation between RGS and WR. In our trial RGS and

WR were positively correlated, nevertheless, vast interval of variation for WR in the group of sensitive genotypes (Table 1.) diminishes the emphasis of WR as selection criterion for tolerance to excess boron in wheat. In addition, WR was negatively correlated with RL, therefore cultivars with longer roots in the absence of boron tend to have less WR on boron treatments.

Table 1. Root length on control (RL-cm), root growth suppression on boron treatments (RGS-%), dry weight on control (W-mg), dry weight reduction on treatments (WR-%), boron content on control (BC-mg/kg dry matter) and on treatments (BCT-transformed data) in seedlings of 12 wheat cultivars

cultivar	group	RL	RGS	W	WR	BC	BCT
Renan	S	16.2 a	46.3 a	8.9 a	33.5 a	14.1 a	14.7 a
Fundulea 4	S	22.0 a	36.2 a	7.8 b	4.8 b	2.8 b	69.5 b
Magdalena	S	39.0 b	35.6 a	11.3 c	16.2 c	13.2 c	12.8 a
Pergamino Gaboto	S	35.4 b	34.8 a	9.6 d	8.9 d	13.8 a	12.1 a
Donjecka 48	S	41.5 b	30.8 a	10.7 e	2.3 e	14.6 d	10.3 a
mean		30.8	36.7	9.7	13.1	11.7	23.9
Norin10/Brevor14	MT	29.7 a	29.8 a	9.9 a	20.6 a	17.8 a	13.2 a
Radika	MT	53.2 b	23.7 a	11.4 b	2.7 b	12.7 b	10.8 b
Žitarka	MT	34.7 a	22.2 a	10.0 a	9.0 c	27.3 c	7.0 c
Mironovska 808	MT	37.5 a	21.9 a	10.5 c	16.3 d	15.6 d	11.2 b
mean		38.8	24.4	10.5	12.2	18.4	10.6
Bezostaja 1	T	33.0 a	18.6 a	10.5 a	+2.1 a	26.6 a	6.2 a
Trakija	T	39.8 b	15.9 a	15.0 b	3.0 b	16.1 b	9.3 b
Apache	T	13.0 c	15.2 a	6.0 c	0.0 ab	25.3 c	5.7 a
mean		28.6	16.6	10.5	0.5	22.7	7.1
F-values from				*among groups*			
ANOVA		4.30*	11.05**	0.87ns	10.73**	23.67**	6.45**

a-e values within columns followed by the same letter do not differ significantly at the 0.05 level of probability according to LSD test

S, MT, T-boron sensitive, medium tolerant and tolerant cultivars

Boron content on control (BC) varied in vast interval in all three groups of genotypes. In average, seedlings of sensitive cultivars had the lowest BC. The highest BC had tolerant genotypes (Table 1.), and significant negative correlation between BC and RGS was found (Table 2.), which is in contrast with results of NABLE (1988), PAULL et al. (1988) and KALAYCI et al. (1998). They found that boron tolerant genotypes accumulate less boron both on control and on boron treatments. NABLE et al (1990) and OERTLI (1994) implied that BC should not be accepted as selection criterion for wheat tolerance to excess boron. Nevertheless, the smallest boron concentration on treatments with regard to control (BCT) had tolerant genotypes, and therefore BC and BCT are negatively correlated (Table 2).

Table 2. Correlation coefficients among root length (RL), dry weight (W) and boron content (BC) on control, root growth suppression (RGS), dry weight reduction (WR) and boron content on treatments (BCT) in seedlings of 12 wheat cultivars

	W	BC	RGS	WR	BCT
RL	0.69**	ns	ns	-0.26*	-0.28*
W		ns	ns	ns	-0.31*
BC			-0.37**	ns	-0.71**
RGS				0.45**	ns
WR					ns

ns, *, ** - insignificant and significant at the 0,05 and 0,01 levels of probability, respectively

Correlation coefficients between BC and RL, and between BC and W were insignificant. Similarly, BCT was not correlated with RGS and WR. Moreover, the intervals of variation regarding both BC and BCT were rather vast in all groups, which implies the conclusion that boron toxicity tolerance in wheat might be the result of different mechanisms. It disallows boron content as selection criterion for boron tolerance. Different tolerance mechanisms are proposed by PAULL et al. (1992), KALAYCI et al. (1998) and REID et al. (2004).

The response to excess boron was previously studied in three out of twelve cultivars included in our experiment, using SSR molecular marker technique (MARJANOVIĆ 2005). Pergamino Gaboto and Norin 10/Brevor 14 were marked as sensitive and medium tolerant in both trials, respectively. However, in research performed by MARJANOVIĆ (2005) cultivar Trakija was found to be boron sensitive, yet the level of root growth suppression on boron treatments in our study assorted it in the group of tolerant genotypes. It might be explained by the fact that boron tolerance assessment in molecular marker trial was limited on 7B chromosome. JEFFERIES et al. (2000) proposed that the regions on chromosomes 7B and 7D are associated with boron tolerance in wheat. Molecular marker trial which includes regions on both 7B and 7D chromosomes, together with field experiment, may highlight the inconsistency concerning response to excess boron in cultivar Trakija.

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TOLERANCIJA KLIJANACA PŠENICE NA VISOKE KONCENTRACIJE BORA

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I z v o d

Mikroelement bor može imati toksično dejstvo na više biljke ukoliko se u spoljašnjoj sredini nađe u visokoj koncentraciji. Cilj rada je bilo ispitivanje tolerancije na bor kod klijanaca 12 genotipova pšenice (Triticum aestivum L.) tretiranih bornom kiselinom. Selekcioni kriterijum je bila redukcija rasta korena u prisustvu bora, koja je varirala između 15,2 (Apache) i 46,3% (Renan). Nije zabeležena korelacija između dužine korenovog sistema na kontroli i redukcije rasta korena na tretmanima. Sadržaj bora i masa suvih klijanaca su varirali u širokim intervalima u svim grupama, i na kontroli i na tretmanima, čemu su verovatno uzrok različiti mehanizmi tolerancije na bor. Kod genotipova Apache, Trakija i Bezostaja 1 je redukcija rasta korena bila manja od 20% i oni bi se mogli smatrati tolerantnim na bor. Renan, Fundulea 4, Magdalena, Pergamino Gaboto i Donjecka 48 su svrstani u grupu osetljivih genotipova. Redukcija rasta korena je u ovoj grupi iznosila preko 30%. Sorte Norin 10/Brevor 14, Radika, Žitarka i Mironovska 808 su bile srednje tolerantne na visoke koncentracije bora.

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