UDC: 631.416.3.27:633.11
original scientific paper

Acta Agriculturae Serbica, Vol. XIII, 25 (2008) 17-23

Boron Tolerance in Twelve NS Wheat Cultivars

Milka Brdar*
Institute of Field and Vegetable Crops, Novi Sad, Serbia

Ivana Maksimovic
Institute of Field and Vegetable Crops, Novi Sad, Serbia
Faculty of Agriculture, Novi Sad, Serbia

Marija Kraljevic-Balalic
Faculty of Agriculture, Novi Sad, Serbia

B. Kobiljski
Institute of Field and Vegetable Crops, Novi Sad, Serbia

Abstract: High concentrations of micronutrient boron may cause significant yield losses in wheat. One of the consequences of excess boron in wheat is root growth suppression. The objective of this study was to investigate the levels of root growth suppression during germination in the presence of different concentrations of boric acid (0-control, normal boron supply, 50 (B 50), 100 (B 100) and 150 (B 150) mg H_3BO_3/l). Twelve wheat cultivars, developed at the Institute of Field and Vegetable Crops in Novi Sad, were included in the analyses. The cultivars demonstrated significant differences with respect to root growth suppression at boron treatments. The genotypes were separated by hierarchical cluster analysis in two distinct phenotypic groups. The roots of cultivars Nevesinjka, Rapsodija, Milijana, Helena and Sonata are boron tolerant, whereas Košuta, Partizanka, Simonida, Kantata, Sofija, Balerina and Pesma are sensitive to excess boron.

Key words: boron tolerance, wheat.

*scholarship holder of the Ministry of Science of the Republic of Serbia

Introduction

High concentrations of soil boron may interrupt growth and development of wheat and other higher plants. The most frequent symptoms of boron toxicity in cereals include chlorosis and necrosis extending downward from leaf tips (Cartwright *et al.*, 1984), delay in development, reduced shoot growth and plant height (Paull *et al.*, 1988) and root growth suppression (Huang and Graham 1990). Consequently, significant yield losses due to excess boron have been observed in cereals (Cartwright *et al.*, 1984; Paull *et al.*, 1990; Avci and Akar 2005).

Furthermore, salinity aggravates boron toxicity symptoms, especially in arid and semi-arid regions. Moreover, salinity may induce yield reduction due to boron toxicity even in soils not exceedingly high in boron (Grieve and Poss 2000; Wimmer *et al.*, 2002; 2003). Saline soils, such as solonchaks and solonetz, occur frequently in Vojvodina (Miljković 1960).

As soil amelioration is difficult to achieve and an expensive short-term solution, the development of boron tolerant cultivars is the best approach in solving the problems related to boron toxicity (Nable *et al.*, 1997). Genetic variability among wheat genotypes in response to excess boron makes possible the development of high-yielding boron tolerant cultivars (Nable 1988; Huang and Graham 1990; Kraljević-Balalić *et al.*, 2004).

The objective of this study was to investigate the response to excess boron in 12 high-yielding wheat (*Triticum aestivum* L.) cultivars developed at the Institute of Field and Vegetable Crops in Novi Sad.

Materials and Methods

The experimental material included twelve high-yielding wheat cultivars developed at the Institute of Field and Vegetable Crops in Novi Sad (Pesma, Balerina, Sofija, Kantata, Simonida, Partizanka, Košuta, Sonata, Helena, Milijana, Rapsodija, Nevesinjka). The material was chosen with the aim to determine whether there was a variability regarding boron tolerance among domestic wheat genotypes.

The trial was conducted by the method proposed by Chantachume *et al.* (1995), including germination of 1200 wheat kernels per genotype, growth of seedlings on filter paper soaked with different (0-control, normal boron supply, 50 (B 50), 100 (B 100) and 150 (B 150) mg H_3BO_3/l) concentrations of boric acid solutions and the assessment of root growth suppression level at boron treatments. The length of the longest seedling root was measured and each sample included 50 seedlings, in 5 replications.

The kernels have been surface sterilized prior to germination, pregerminated at 4°C for 48 hours and at 18°C for 24 hours. Seedlings have grown in dark, at 18°C, for eleven days. Both control and treatment solutions included 0.5 mM $Ca(NO_3)_2x4H_2O$, 0.0025 mM $ZnSO_4x7H_2O$ and 0.015 mM H_3BO_3.

Selection criterion for boron tolerance was root growth suppression at treatments as compared to control (RGS-%, control=0%) and cultivars were separated by hierarchical cluster analysis into tolerant and sensitive groups. ANOVA method was performed and mean values and standard errors of the mean were calculated for the analyzed traits. All calculations, including grouping by hierarchical cluster analysis, were performed using STATISTICA 7.0 software package.

Results and Discussion

As root growth suppression (RGS) is a pronounced symptom of boron toxicity in wheat, twelve analyzed NS wheat cultivars were divided into boron sensitive and boron tolerant groups on the basis of average RGS at boron treatments (B 50, B100 and B150) as compared to the control.

The grouping was performed by hierarchical cluster analysis and two distinct groups were noticed. Cultivars Pesma, Balerina, Sofija, Kantata, Simonida, Partizanka and Košuta were classified as boron sensitive, while cultivars Sonata, Helena, Milijana, Rapsodija and Nevesinjka may be considered as boron tolerant. Both boron tolerant and sensitive groups were divided into several sub-groups, implying differences in the levels of boron toxicity tolerance or susceptibility within groups. For example, cultivar Pesma itself makes up one sub-cluster in the sensitive genotype group, which might be recognized as a sub-cluster of very sensitive genotypes (Diagram 1.). The variability detected within the group of 12 NS wheat cultivars confirms that boron toxicity tolerance in wheat has not been bred at the Institute of Field and Vegetable Crops in Novi Sad. It also confirms the very wide genetic variability, at least with respect to tolerance to excess boron, of the material that has been used in wheat breeding programs.

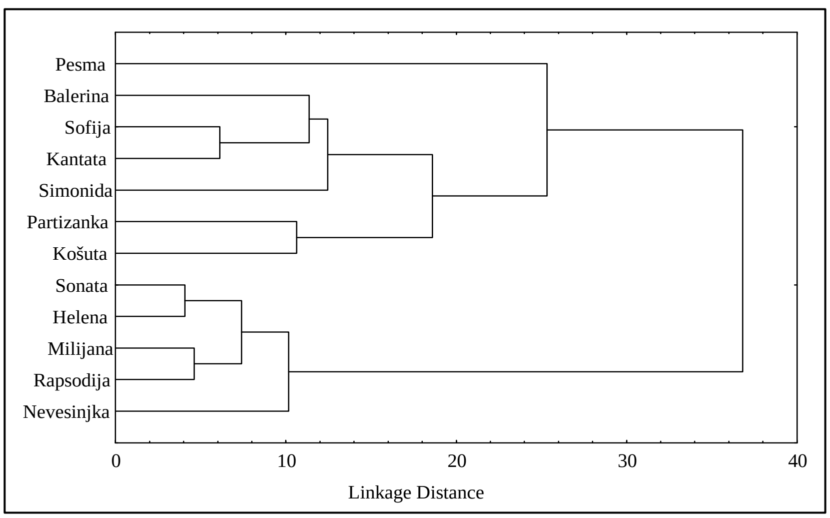

Diagram 1.Cluster analysis diagram for root growth suppression at boron treatments (average) in twelve NS wheat cultivars

ANOVA was performed in order to examine differences in wheat root length under normal (RL 0-control) and excessive (RL 50, RL 100, RL 150-treatments) boron supply. Average root growth suppression at boron treatments (RGS) was also included in ANOVA calculations.

ANOVA did not reveal significant differences between groups of tolerant and sensitive genotypes regarding RL 0, although the trait varied significantly within both groups. The interval of variation was 3.8 cm for boron sensitive and 4.9 cm for boron tolerant genotypes (Table 1.). This suggests that root length of wheat optimally supplied with boron per se does not indicate boron tolerance or susceptibility. This is in accordance with the results reported on wheat (Chantachume *et al.*, 1995) and barley (Rehman *et al.*, 2006).

Table 1. Root length in the control (RL 0), boron treatments (RL 50, RL 100, RL 150) and root growth suppression (RGS-average for treatments) in groups of boron sensitive (S) and boron tolerant (T) NS wheat genotypes

genotype	group	RL 0	RL 50	RL 100	RL 150	RGS
Pesma	S	12.5	10.8	9.6	5.7	30.7
Balerina	S	14.9	11.4	10.4	9.9	28.0
Sofija	S	13.4	11.6	9.8	7.8	27.2
Kantata	S	11.1	11.1	7.3	6.3	25.2
Simonida	S	12.4	12.1	8.4	7.4	24.5
Partizanka	S	14.6	13.5	11.6	8.4	23.3
Košuta	S	11.4	10.7	8.5	8.1	20.2
mean		12.9	11.6	9.4	7.7	25.6
SE of mean		0.3	0.3	0.3	0.3	1.4
F-values from ANOVA (within group of boron sensitive genotypes)						
		7.49**	2.02 ns	9.36**	10.17**	0.85 ns
Sonata	T	10.3	10.6	9.3	5.5	16.9
Helena	T	12.5	12.2	10.7	8.0	16.8
Milijana	T	11.6	10.9	10.9	7.6	15.6
Rapsodija	T	13.8	13.6	11.6	9.7	15.2
Nevesinjka	T	15.2	16.3	13.1	9.2	14.8
mean		12.7	12.7	11.1	8.0	15.8
SE of mean		0.4	0.5	0.3	0.3	1.6
F-values from ANOVA (within group of boron tolerant genotypes)						
		18.11**	18.75**	8.57**	23.34**	0.07 ns
F-values from ANOVA (between groups)						
		0.26 ns	4.59*	16.69**	0.66 ns	21.31**

ANOVA demonstrated significant differences in root length between groups at treatments B 50 and B 100. However, groups of tolerant and sensitive wheat cultivars did not differ significantly in root length in the B 150 treatment. Therefore, it may be unnecessary to treat wheat seedlings with boron concentrations that are as high as 150 mg H_3BO_3/l.

Root length in boron treatments varied significantly within both groups, being in conformity with expectations, considering the variation in root length within groups under normal boron supply. The only exception was RL 50 in the sensitive genotype group.

There were no significant differences in root growth suppression (RGS) within groups of sensitive and tolerant genotypes. ANOVA detected significant differences between groups, which was also the expected result, as the grouping was performed by hierarchical cluster analysis.

Boron tolerant wheat cultivars (Sonata, Helena, Milijana, Rapsodija and Nevesinjka) identified in this trial can be exploited for the purpose of creating new high-yielding cultivars that can grow and yield on boron-laden soils. However, the range between boron toxicity and deficiency is narrower than that for any other element (Eaton 1944). For wheat, soil boron concentrations below 0.5 ppm mean deficiency, however, only a few ppm may be excessive (Yau *et al.*, 1994). There is a question if, for the same genotype, tolerance to excess boron at the same time means inefficiency in boron utilization, or in other words, susceptibility to boron deficiency (Paull *et al*. 1993, Punchana 2003). Therefore, the genotypes characterized by longer roots at B 50 treatment with regard to control (Sonata, Nevesinjka) may be boron inefficient. Considering the 0 to 15.9 ppm B range that was reported for 1,600 soil samples symmetrically distributed in Vojvodina (Ubavić *et al.*, 1993), cultivars Helena, Milijana and Rapsodija may be recommended as a good starting material for breeding boron tolerant wheat genotypes. However, in order to examine the impact of various environmental factors, the cultivars have to be previously tested in field conditions.

Conclusions

Twelve NS wheat cultivars were divided by hierarchical cluster analysis into boron tolerant and sensitive groups on the basis of average root growth suppression at three boron treatments. Cultivars Pesma, Balerina, Sofija, Kantata, Simonida, Partizanka and Košuta were classified as boron sensitive. Sonata, Helena, Milijana, Rapsodija and Nevesinjka may be considered as boron tolerant.

Because longer roots at treatment B 50 as compared to control (normal boron supply) were measured for cultivars Sonata and Nevesinjka, they may be boron inefficient. Therefore, cultivars Helena, Milijana and Rapsodija may be recommended as a good starting material for breeding boron tolerance in wheat.

Prior to crossings, the results of this laboratory trial have to be confirmed in field conditions.

References

Avci M., Akar T. (2005) Severity and spatial distribution of boron toxicity in barley cultivated areas of Central Anatolia and Transitional zones. Turk J Agric For, 29, 377-382.

Cartwright B., Zarcinas B. A., Mayfield A. H. (1984) Toxic concentrations of boron in a red-brown earth at Gladstone, South Australia. Aust J Soil Res, 22, 261-272.

Chantachume Y., Smith D., Hollamby G. J., Paull J. G., Rathjen A. J. (1995) Screening for boron tolerance in wheat (*T. aestivum* L.) by solution culture in filter paper. Plant Soil, 177, 249-254.

Eaton F. M. (1944) Deficiency, toxicity and accumulation of boron in plants. J Agric Res, 69, 237-277.

Grieve C. M., Poss J. A. (2000) Wheat response to interactive effects of boron and salinity. J Plant Nutr, 23, 1217-1226.

Huang C., Graham R. D. (1990) Resistance of wheat genotypes to boron toxicity is expressed at the cellular level. Plant Soil, 126, 295-300.

Kraljević-Balalić M., Kastori R., Kobiljski B. (2004) Variability and gene effects for boron concentration in wheat leaves. Proceedings of the 17th EUCARPIA General Congress, 8-11 September, Tulln, Austria, Genetic Variation for Plant Breeding, 31-34.

Miljković N. (1960) Karakteristike vojvođanskih slatina i problem bora u njima. PhD thesis, University of Novi Sad, Faculty of Agriculture (in Serbian)

Nable R. O. (1988): Resistance to boron toxicity amongst several barley and wheat cultivars: A preliminary examination of the resistance mechanism. Plant Soil, 112, 45-52.

Nable R. O., Bañuelos G. S., Paull J. G. (1997) Boron toxicity. Plant Soil, 193, 181-198.

Paull J. G., Cartwright B., Rathjen A. J. (1988) Responses of wheat and barley genotypes to toxic concentrations of soil boron. Euphytica, 39, 137-144.

Paull J. G., Rathjen A. J., Cartwright B., Nable R. O. (1990) Selection parameters for assessing the tolerance of wheat to high concentrations of boron. Genetic aspects of plant mineral nutrition, N. El Bassam et al. (Eds.), 361-369.

Paull J. G., Rathjen A. J., Langridge P. (1993) Location of genes controlling boron tolerance of wheat. Proceedings of the 8th International Wheat Genetics Symposium, 20-25 July, Beijing, China, Vol. 2, 1065-1069.

Punchana S. (2003) Relating responses to boron deficiency and toxicity in wheat. M. Sc. Agronomy Thesis. Graduate School, Chiang Mai University, Thailand

Rehman S., Park T. I., Kim Y. J., Seo Z. W., Yun S. J. (2006) Inverse relationship between boron toxicity tolerance and boron contents of barley seed and root. J Plant Nutr, 29, 1779-1789.

STATISTICA 7.0, StatSoft, University Licence, University of Novi Sad, 2004

Ubavić M., Bogdanović D., Dozet D., Hadžić V., Ćirović M., Sekulić P. (1993) Sadržaj teških metala u zemljištima Vojvodine. Zbornik radova Instituta za ratarstvo i povrtarstvo, Vol. 21, 49-58.

Wimmer M. A., Mühling K. H., Läuchli A., Brown P. H., Goldbach H. E. (2002) Boron toxicity: the importance of soluble boron. Boron in plant and animal nutrition. Kluwer Academic / Plenum Publishers, New York, 241-253.

Wimmer M. A., Mühling K. H., Läuchli A., Brown P. H., Goldbach H. E. (2003) The interaction between salinity and boron toxicity affects the subcellular distribution of ions and proteins in wheat leaves. Plant Cell Environ, 26, 1267-1274.

Yau S. K., Hamblin J., Ryan J. (1994) Phenotypic variation in boron toxicity tolerance in barley, durum and bread wheat. Rachis, 13, 20-25.

TOLERANCIJA 12 NS SORTI PŠENICE NA SUVIŠAK BORA

- originalni naučni rad-

Milka Brdar[*]
Institut za ratarstvo i povrtarstvo, Novi Sad

Ivana Maksimović
Institut za ratarstvo i povrtarstvo, Novi Sad
Poljoprivredni fakultet, Novi Sad

Marija Kraljević-Balalić
Poljoprivredni fakultet, Novi Sad

B. Kobiljski
Institut za ratarstvo i povrtarstvo, Novi Sad

Rezime

U koncentraciji višoj od optimalne mikroelement bor može uzrokovati značajne gubitke prinosa pšenice. Jedan od nepovoljnih efekata bora na pšenicu je redukcija rasta korena. Naklijavanjem na filter papiru navlaženom rastvorima H_3BO_3 koncentracija 0, 50, 100 i 150 mg/l ispitan je stepen redukcije rasta korena kod 12 sorti pšenice poreklom iz Instituta za ratarstvo i povrtarstvo u Novom Sadu. Utvrđena je značajna varijabilnost ispitivanih sorti u pogledu redukcije rasta korena u prisustvu suviška bora. Hijerarhijskom klaster analizom je izvršeno grupisanje genotipova na osnovu fenotipske sličnosti za dato svojstvo i uočene su dve fenotipske grupe. Sorte Nevesinjka, Rapsodija, Milijana, Helena i Sonata su ispoljile tolerantnost na suvišak bora, dok je korenov sistem sorti Košuta, Partizanka, Simonida, Kantata, Sofija, Balerina i Pesma osetljiv na visoke koncentracije ovog elementa.

[*] *stipendista Ministarstva nauke Republike Srbije*