Response of ten winter wheat cultivars to boron foliar application in a temperate climate (South-West Poland)

Jolanta Korzeniowska

Institute of Soil Science and Plant Cultivation - National Research Institute in Pulawy, Department of Weed Science and Tillage Systems in Wroclaw, Orzechowa 61, 50-540 Wroclaw, Poland, email: j.korzeniowska@iung.wroclaw.pl

Abstract. Three strict field trials were conducted in 2003, 2004 and 2006, involving foliar application of boron to ten cultivars of winter wheat commonly grown in Poland. Boron was applied as 175 $g \cdot ha^{-1}$ of boracic acid. Foliar fertilization treatments caused a significant grain yield increase of four (Zyta, Kobra, Mewa and Pegassos) out of ten winter wheat cultivars. The average yield increment ranged between 9 and 15%. The cultivars which responded positively to the fertilization were the ones which produced the lowest yields on the control plots without boron. The nutritional demands of the cultivars Korweta, Kris, Soraja, Jawa, Symfonia and Sakwa for boron were much lower than those of the other cultivars. Although the foliar fertilisation with boron increased the concentration of this element in the shoots of these 6 cultivars, they did not respond with higher yield to the application of this element.

Key words: wheat varieties, B-demands and sensitivity, genotypic variation

INTRODUCTION

The majority of the reports which documented wheat sensitivity to boron (B) deficiency come from South Asia (Rerkasem & Loneragan, 1994; Rerkasem & Jamjod, 1997; Subedi et al., 1997; Subedi et al., 1999; Rerkasem et al., 2004; Wongmo et al., 2004). Boron deficiency causes grain set failure in wheat which is associated with poorly developed pollen and anthers (Cheng & Rerkasem, 1993; Huang et al., 2000). According to literature data, lack of boron can be intensifying by high temperature and high humidity (Bodruzzaman et al., 2005). Rawson (1996) showed that restriction of transpiration can cause an occurrence of B deficiency symptoms. All of this suggests that B deficiency in wheat is connected with tropical or subtropical climate zone. Since the soils in Poland are largely poor in boron (Kucharzewski & Debowski, 2000), it seems necessary to investigate if wheat cultivars grown in temperate climate are sensitive to boron deficiency.

MATERIALS AND METHODS

In the years 2003, 2004 and 2006, three strict field experiments were conducted involving foliar application of boron to ten winter wheat cultivars. The trials were performed at the Experimental Station of the Institute of Soil Science and Plant Cultivation in South-West Poland. The soils used for the trials were Haplic Luvisols, acidic or slightly acidic, with the organic matter content reaching 1.0–1.4%, well supplied in phosphorus, potassium and magnesium but low or moderately rich in boron (Table 1).

Table 1. Characteristic of experimental soils.

Year	pH KCl	OM	SF I	SF II	P_2O_5	K_2O	Mg	B
		%			mg·kg^{-1}			
2003	5.9	1.2	15	21	166	175	37	0.6 l
2004	6.0	1.0	18	19	128	215	67	0.5 l
2006	5.3	1.4	19	24	118	196	53	0.6 m

OM-organic matter, SF I – soil fraction < 0.02 mm, SF II – soil fraction = 0.01-0.02 mm
Content: l-low, m-medium. Assessment of B concentration depends on pH and soil fractions Wrobel (2004).

All the trials were carried out as two-factorial experiments with 4 replications, in the split-plot design, according to the following pattern:

Factor I – boron application:
a_1 – control (without B),
a_2 – 175 B g·ha^{-1}.

Factor II – wheat cultivar:
b_1 – Zyta, b_2– Korweta, b_3 – Pegassos, b_4 – Mewa, b_5 – Soraja, b_6 – Sakwa, b_7 – Kobra, b_8 – Kris, b_9 – Symfonia, b_{10} – Jawa.
The cultivars belonged to three technological groups: A - quality (Korweta, Zyta, Pegassos), B - bread (Kobra, Sakwa, Mewa, Kris, Soraja) and C – fodder (Jawa, Symfonia).

Boron application was carried out in spring during the tillering stage. All the objects received identical basic fertilization N – 130, P_2O_5 – 80, K_2O – 120 kg·ha^{-1}. The surface of each plot was 30 m^2, with 24 m^2 to be harvested.

Soil samples were taken for chemical analyses before trials establishment. In addition, aerial parts of wheat plants at the early elongation stage and grain samples were collected from each trial. Organic carbon in soil was determined by Tiurin method (acc. to Polish standard No. PN-91/Z-15005), pH was established potentiometrically in 1 mol KCl·dm^{-3}, P and K were determined using Enger-Riehm method (Polish standards No. PN-R-04023:1996 and PN-R-04022:1996 adequately), and Mg by Schachtschabel method (Polish standard No. PN-R-04020:1994). Boron was first extracted in 1 mol HCl·dm^{-3} (Gembarzewski & Korzeniowska, 1990) and then determined using calorimetry with curcumin (PN-93/R-04018). Having wet digested (H_2SO_4+H_2O_2) the plant samples, N and P were determined using flow analysis (CFA) and spectrometric detection, K was assayed by flame emission spectrophotometry and Mg by AAS method. Boron was determined by the ICP method following dry digestion in shoots and wet digestion in grain.

Program AWAR (Filipiak & Wilkos, 1995), made by Department of Applied Informatics, Institute of Soil Science and Plant Cultivation in Pulawy, was used to perform the analysis of variance. First, the two-way ANOVA for split-plot was conducted for each year separately. Next, an across-years ANOVA was used. Means were compared using the Tukey test.

RESULTS

The grain yields were averaged over three years (Table 2) since the impact of B application on the cultivars productivity was similar in each tested year. The combined, across-years ANOVA (not shown) indicated significant interaction "B application x cultivars". Two groups of winter wheat cultivars could be distinguished according to their response to B application: group I – significant grain yield increment (Mewa, Zyta, Kobra, Pegassos) and group II – lack of significant response (Korweta, Kris, Soraja, Jawa, Symfonia, Sakwa). It is interesting to notice that the cultivars which responded significantly to B application were the ones which produced the lowest grain yields on the control objects.

Table 2. Grain yield of ten winter wheat cultivars – averaged over 3 years in t ha^{-1}.

Cultivar-factor II	B application – factor I						Increase %	Group of cultivars
	0			+B				
Mewa	4.08	*ab*	*A*	4.70	*bc*	*B*	**15.2***	
Zyta	4.08	*ab*	*A*	4.64	*abc*	*B*	**13.9***	
Kobra	3.73	*a*	*A*	4.18	*a*	*B*	**12.2***	Group I-low
Pegassos	4.03	*ab*	*A*	4.37	*ab*	*B*	**8.6***	B efficency
		ab	*A*		*ab*	*A*		
Korweta	4.10	*cd*	*A*	4.40	*c*	*A*	7.1	
Kris	4.77	*bc*	*A*	5.05	*ab*	*A*	5.8	Group II-
Soraja	4.31	*bc*	*A*	4.54	*ab*	*A*	5.1	high
Jawa	4.40	*d*	*A*	4.51	*bc*	*A*	2.4	B efficiency
Symfonia	4.83	*d*	*A*	4.73	*abc*	*A*	-2.2	
Sakwa	4.77	*cd*		4.60			-3.6	
Tukey LSD: II/I factor - 0.482, I/II factor - 0.307								

Yields marked with the same small letters within columns and with the same capital letters within the same line did not differ according to Tukey's test ($\alpha < 0.05$). *) Significant increase.

Table 3. Macronutrients concentration in wheat shoots from control treatments - average over 3 years (%).

Cultivar	N	P	K	Mg	Group of cultivars
Mewa	3.46	0.43	3.64	0.12	
Zyta	3.32	0.46	3.49	0.12	Group I- low
Kobra	3.26	0.41	3.46	0.12	B efficency
Pegasoss	3.61	0.45	3.68	0.12	
Korweta	3.51	0.45	3.64	0.13	
Kris	3.62	0.48	3.67	0.12	
Soraya	3.39	0.44	3.67	0.12	Group II –high
Jawa	3.52	0.47	3.78	0.12	B efficiency
Symfonia	3.47	0.45	3.60	0.12	
Sakwa	3.52	0.46	3.66	0.11	
Optimum*	3.00-5.00	0.30-0.60	3.50-5.50	0.12-0.25	

***)** Optimum concentration in shoots at early elongation stage (*Bergmann*, 1992)

The analysis of macroelements in the aerial parts of wheat plants showed that all the cultivars were well supplied in nitrogen, potassium, phosphorus and magnesium at the early elongation stage (Table 3). Creating optimum nutrition of plants with macroelements is essential in studies on microelements.

The concentration of B in shoots of winter wheat which was not amended with this element ranged between 1.9 and 2.6; the grain produced by this wheat contained 2.0 – 2.4 mg B $\cdot kg^{-1}$ (Table 4). Boron application raised the concentration of this element in shoots and grains of most of the wheat cultivars tested.

Table 4. Boron concentration in $mg \cdot kg^{-1}$.

Cultivar	Shoots (elongation stage)		Grain (maturity)		Group of cultivars
	0	+B	0	+B	
Mewa	2.3	2.4	2.0	2.3	Group I- low B efficency
Zyta	2.4	2.8	2.3	2.5	
Kobra	1.9	2.7	2.3	2.3	
Pegassos	2.4	2.4	2.2	2.6	
Korweta	2.5	2.7	2.6	2.2	Group II –high B efficiency
Kris	2.5	2.8	2.4	2.6	
Soraja	2.4	2.5	2.4	2.6	
Jawa	2.6	2.9	2.4	2.6	
Symfonia	2.4	3.1	2.4	2.4	
Sakwa	2.5	3.0	2.4	2.5	
Average	2.4 a	2.7 b	2.3 a	2.5 a	

Average concentrations marked with same letters within the part of plants did not differ according to Tukey's test (α <0.05).

DISCUSSION

In 1984, Graham (1984) defined 'nutrient efficiency' as an ability of a genotype to grow and yield well on soil which is insufficient in this component compared with the standard genotype. This simple definition enabled researchers to compare cultivars even though the mechanism responsible for differences between them had not yet been fully clarified. Extending Graham's definition, Rerkasem & Jamjod (1997) defined B efficiency as an ability of a genotype/cultivar to function properly in a soil too low in boron for other cultivars. Using this definition in our study, we classified 4 out of 10 winter wheat cultivars as B-low efficient and 6 others as B-high efficient. The natural concentration of boron in the experimental soils was too low in boron for the B-low efficient cultivars: Mewa, Zyta, Kobra and Pegassos. These cultivars yielded lower than the other cultivars on the control plots and responded with a significant increase in grain yields to the application of boron (Table 2). They were also characterised by a slightly lower B concentration in grain than group II cultivars (Table 4). This suggests that the former cultivars were less efficient in using boron contained in soil than the other cultivars. In contrast, for the cultivars classified as group II (B-high efficiency) the initial concentration of boron in soil was sufficient. They produced higher grain yields on plots not treated with boron and accumulated higher levels of this micronutrient in grain than group I cultivars.

The concentration of boron in shoots at the early elongation stage was not a completely reliable indicator of the plants' supply of this element. Cultivars from both groups revealed similar concentrations of boron, with just a slight tendency for lower B concentration among group I cultivars. Rerkasem & Jamjod (2004) underline that the B concentration in vegetative parts of wheat is not a good indicator of boron supply of plants. The most precise indicator is the B concentration in anthers, which for practical reasons is impossible to study during commercial plant production.

The critical value of boron concentration during the early elongation stage is 6.0 according to Bergmann (1992) or Jones et al. (1991) and 2.5 $mg \cdot kg^{-1}$ according to Shnug (2007). When analysing the concentrations of boron in wheat shoots set in Table 4, it seems that the critical value of 2.5 $mg \cdot kg^{-1}$ is the most reliable figure. However, in light of the differences between the cultivars, one should rather refer to a range of critical values for wheat as a plant species rather than to a single critical value. In the present research, higher grain yields were obtained when the concentration of boron in wheat shoots ranged between 1.9–2.4 $mg \cdot kg^{-1}$.

CONCLUSIONS

1. The ten winter wheat cultivars tested differed significantly in their nutritional demands for boron. At the same concentration of boron in soil, four out of ten wheat cultivars responded to foliar boron application with 8.6-15.2% grain yield increase while the other six cultivars did not respond to the treatments.
2. Boron concentration in shoots during the early elongation stage was not a good indicator of the plants' supply of this element. The concentration of boron in grain served this purpose slightly more effectively.
3. Because of the differences between wheat cultivars, a range of critical values rather than a single critical value of boron concentration should be used for wheat as a species.
4. Winter wheat demand for boron fertilization is connected not only with tropical but also with temperate climate zone.

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