CONTEMPORARY AGRICULTURE / *SAVREMENA POLJOPRIVREDA* 63 (1-2) 36-43, 2014.
UDC: 63(497.1)(051)-"540.2" ISSN 0350-1205

UDC: 631.559:582.542

YIELD RESPONSE TO ELEVATED SOIL BORON IN WHEAT CULTIVARS OF LOCAL AND FOREIGN ORIGIN

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SUMMARY: The two-year field study was aimed to investigate the effect of increasing soil boron treatments (3.3, 6.7 and 13.3 g H_3BO_3/m^2) on eight wheat cultivars, as well as to estimate the rate in which yield decreases followed the increase in soil boron. A strong positive linear relationship was found between the treatments and soil hot water extractable boron. On average, wheat yield response to elevated soil boron was decrease of 7.7%. Cultivars of local origin over-yielded foreign cultivars at all levels of boron supply. The estimated yield loss was 1.8% per increase in soil boron of 0.1 ppm.

Key words: *wheat cultivars, yield, boron tolerance.*

INTRODUCTION

Macro- and micronutrients are elements essential for healthy growth and development of vascular plants. Both nutrient deficiency and toxicity are disorders that may significantly decrease yield of agricultural plants. Nutrient deficiencies can be ameliorated by fertilizer application; however, toxicity-related problems are more difficult to manage. For the past few decades, elevated amounts of micronutrient boron (B) have received broad attention as possible yield-limiting factor in cereals. This is especially true for arid and semiarid environments, as well as for saline soils, which occupy approximately 200,000 ha in Vojvodina.

Soil boron concentration affecting plants strongly enough to cause significant

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Original scientific paper / *Originalni naučni rad*

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*This article results from the project TR31066 (2011-2014), supported by Ministry of Education, Science and Technological Development of Republic of Serbia

yield decrease is not easy to determine. It depends on plant species (e.g. monocotyledonous plants are generally more sensitive when compared to dicotyledonous), soil type, texture, moisture, temperature, pH etc. Since great variability in boron tolerance has been reported within plant species, breeding tolerant cultivars has been proposed as the most promising approach for solving the problem (Miljković, 1960; Matoh, 1997; Nable et al., 1997; Yau and Ryan, 2008; Reid, 2010; Mertens et al., 2011; Wimmer and Goldbach, 2012; Brdar-Jokanović et al., 2013).

This study was undertaken to assess the effect of elevated soil boron on high-yielding wheat (*Triticum aestivum* L.) cultivars of different origin. The second aim of this research was to estimate the rate in which wheat yield decreases following the increase in soil boron.

MATERIAL AND METHODS

Four high-yielding wheat (*Triticum aestivum* L.) cultivars of local origin (Arija, Astra, Kantata, Oda – NS cultivars, Novi Sad, Serbia) and four high-yielding cultivars originating from breeding institutions in the region (Fundulea 4 – Romania, Magdalena – Hungary, Trakija – Bulgaria, Žitarka – Croatia) have been included in two-year (2005-06, 2006-07) field study comprising control and three boron treatments, replicated three times. The trial was set at the Rimski Šančevi experimental field (Institute of Field and Vegetable Crops, Novi Sad, Serbia, 45°20' N, 19°51' E, 84 m altitude). Soil was fertile chernozem.

Official reports of Republic Hydrometeorological Service of Serbia have been used for weather data analysis (Table 1.).

Table 1. Meteorological data for the two wheat growing seasons and 30-year average, Rimski Šančevi, Novi Sad, Serbia

Tabela 1. Meteorološki podaci za dve sezone u kojima je izvođen ogled i tridesetogodišnji prosek, Rimski Šančevi, Novi Sad, Srbija

Parameter / *Parametar*	2005-06	2006-07	1981-2010
Average daily temperature (°C) / *Srednja dnevna temperatura (°C)*	9.2	10.6	8.6
Minimum temperature (°C) / *Minimalna temperatura (°C)*	−14.0	−6.0	−3.1
Maximum temperature (°C) / *Maksimalna temperatura (°C)*	34.0	36.0	28.1
Sum of temperatures (°C) / *Suma temperatura (°C)*	2465.0	2599.5	2317.1
Sum of precipitation (mm) / *Suma padavina (mm)*	498.4	390.9	465.3

Main plot (1.2 m^2) consisted of six rows, with intra and inter spacing of 2 and 20 cm, respectively. Sowing was performed at optimum time (mid-October), and harvesting when plants reached maturity (mid-July and third decade of June for the first and second growing season, respectively).

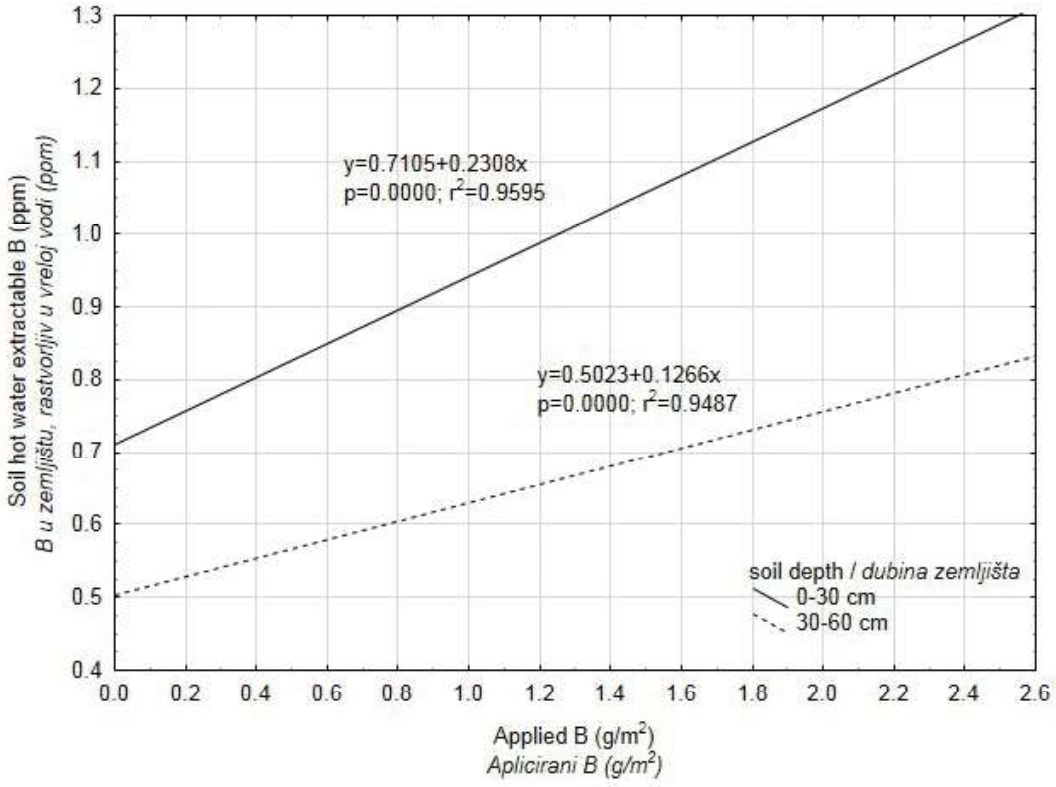
Plots were treated immediately after sowing with boric acid (H_3BO_3) dissolved in distilled water at the rates of 3.3 (B1), 6.7 (B2) and 13.3 (B3) g per m^2. Besides for boron treatments, standard agronomic procedures have been applied. Soil sampling (depth 0-30 and 30-60 cm) was performed at wheat heading and hot water extractable boron concentration was determined by atomic absorption spectrophotometer.

Data was processed by analysis of variance. Polynomial regression analysis was

performed in order to estimate the rate in which wheat yield decreases as a function of increasing soil boron concentrations. STATISTICA 12 software package (StatSoft, Tulsa, OK, USA, University license, Novi Sad) was used for data analysis.

RESULTS AND DISCUSSION

In order to confirm that the increasing boron treatments applied at wheat sowing gradually increase boron concentration in the soil and that those effects last throughout the plant life cycle, soil sampling was performed at heading and hot water extractable boron was determined. Strong positive linear relationship was found between the applied treatments and soil boron concentration (Graph 1.), which was true for soil depth of both 0-30 and 30-60 cm. The increase in soil boron was more pronounced in 0-30 than in the 30-60 cm soil layer (32.5 and 25.2% of the initial concentration, for every g of added B/m^2 of soil, respectively). This pattern was expected, since the plots were treated by watering soil surface with boric acid dissolved in distilled water. Opposite, the increase in boron concentration with soil depth was noted for soils naturally laden with the element, with the point of maximum concentration depending on soil type, texture, humidity etc. (Jelenić et al., 1973; Brennan and Adcock, 2004).



Graph 1. The effect of increasing boron treatments on hot water extractable soil boron

Grafik 1. Uticaj tretmana borom na koncentraciju bora u zemljištu, rastvorljivog u vreloj vodi

Analysis of variance detected significant ($p<0.01$) yield variation among the analyzed wheat cultivars, seasons and boron treatments (Table 2). In addition, all the interactions were significant (cultivar/season, cultivar/treatment, season/treatment and cultivar/season/treatment). Therefore; the applied treatments affected wheat yield and these effects were not the same for all cultivars and for the two seasons of the experi-

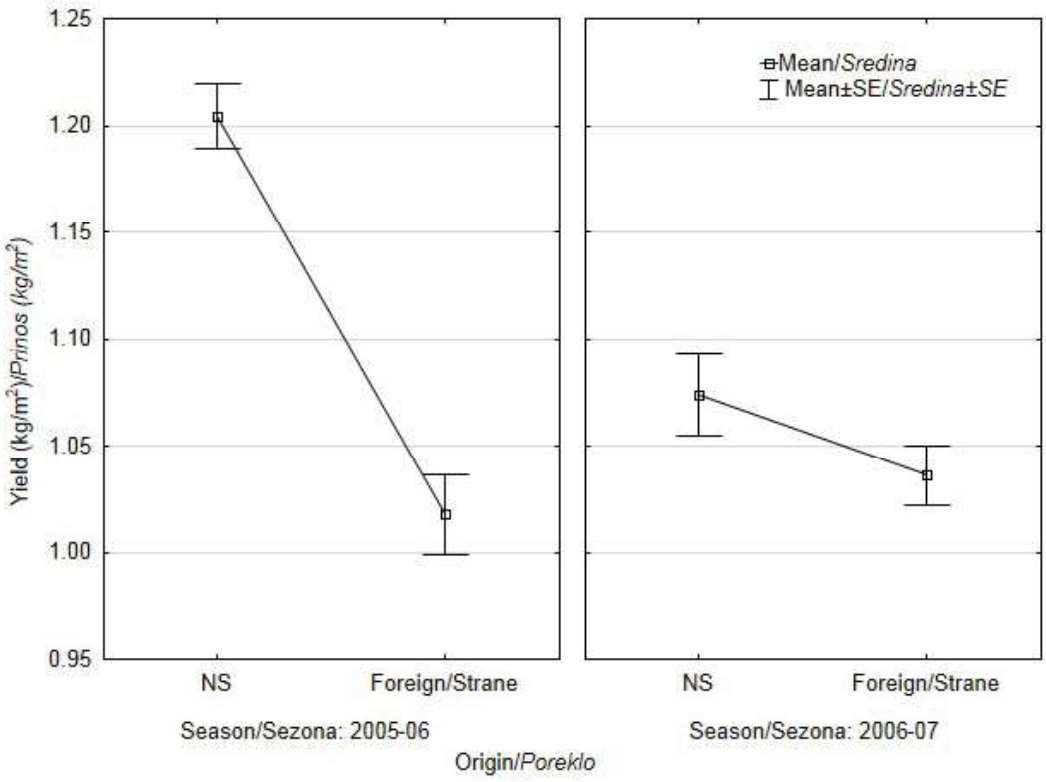
ment. Differences among wheat cultivars in yield response to elevated soil boron have been also documented by other authors (Nable et al., 1997; Kalayci et al., 1998; Yau and Ryan, 2008; Prabhakar et al., 2013). In our trial, yield response to boron treatments ranged from the reduction of 19.1% (Žitarka, 2005-06) to the increase of 5.0% (Kantata, 2006-07). On two-year average, the highest level of boron tolerance exhibited cultivar Kantata (increase of 1.4%) and the lowest Žitarka (decrease of 13.2%). Average yield decrease due to boron treatments of 7.7% was somewhat lower than expected according to literature data, which might be due to both soil chemical properties and choice of wheat cultivars included in the analyses.

Table 2. Mean squares from analysis of variance for wheat yield
Tabela 2. Sredine kvadrata iz analize varijanse za prinos pšenice

Effect / *Efekat*	df	Mean squares / Sredine kvadrata	p
Cultivar / *Sorta* (C)	7	0.1744	0.0000
Season / *Sezona* (S)	1	0.1506	0.0000
Treatment / *Tretman* (T)	3	0.2800	0.0000
(C) / (S)	7	0.1288	0.0000
(C) / (T)	21	0.0108	0.0000
(S) / (T)	3	0.0085	0.0000
(C) / (S) / (T)	21	0.0076	0.0000
Error / *Pogreška*	128	0.0006	

df – degrees of freedom / *stepeni slobode*

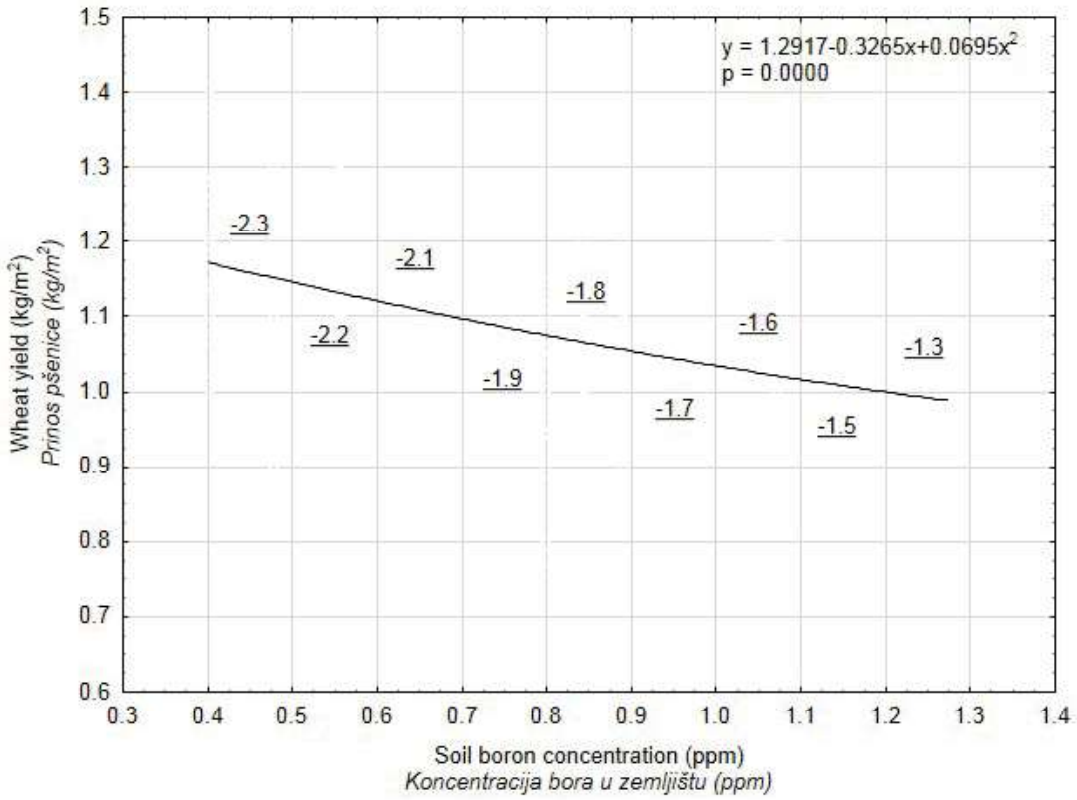
Although both local and foreign cultivars included in the experiment are high-yielding, cultivars of local origin (NS) over-yielded foreign cultivars at all levels of boron supply (Graph 1). This was somewhat expected, since they have been constructed with the aim to achieve high yields in local environmental conditions. Lower average yields that have been noted for all cultivars in 2006-07 in comparison to 2005-06 may be attributed to higher temperatures and lower sum of precipitation characterizing the season (Table 1).



Graph 2. Yield of local (NS) and foreign wheat cultivars (average of all levels of boron supply)

Grafik 2. Prinos lokalnih (NS) i stranih sorti pšenice (sredina kontrole i svih tretmana)

In order to investigate the rate in which wheat yield decreases in response to increasing soil boron concentration, data was subjected to polynomial regression analysis and Graph 3 was constructed. The constructed polynomial curve covers the observed range from 0.4 to 1.3 ppm hot water extractable soil boron and the corresponding wheat yields. The estimates of yield losses due to soil boron increase (underlined) are given along the curve in steps of 0.1 ppm. As seen in the graph, the average wheat yield decrease was about 1.8% per 0.1 ppm increase in soil boron concentration. The estimated percentage of yield response to boron gradually decreases along the curve, which would primarily be attributed to the mathematical model applied for its construction.



Graph 3. Wheat yield decrease following the increase in soil boron concentration

Grafik 3. Redukcija prinosa pšenice kod rastuće koncentracije bora u zemljištu

The estimated yield losses are high and confirm the conclusions of other authors that even a slight increase in soil boron concentration may exhibit detrimental effects on crops. According to Miljković (1964), Yau et al. (1994) and Shorrocks (1997) soil hot water extractable boron in the range of only 0.7 to few ppm may be toxic to susceptible plant species and varieties. The fact that Ubavić et al. (1993) examined in detail 1609 samples of Vojvodina agricultural soils (0-30 cm depth) and reported boron range of 0.0 to 15.9 ppm, with average value of 3.49 ppm, highlights the importance of research on boron tolerance in major agricultural crops, primarily the sensitive ones such as cereals. In addition, our trial was performed on fertile chernozem using appropriate agronomic procedures, which minimized other soil constraints that could lead to yield reduction. Therefore, higher yield decreases are expected on less fertile soils and those containing high levels of other elements or compounds, such as saline soils.

CONCLUSION

Between the applied boron treatments and soil hot water extractable boron was found a strong positive linear relationship. The increase in soil boron following the increasing treatments was 32.5 and 25.2% of the initial concentration for every g of added B/m^2 of soil (for soil depth of 0-30 and 30-60 cm, respectively). Wheat yield in response to elevated soil boron decreased 7.7% in average, ranging from 13.2% decrease in Žitarka to 1.4% increase in Kantata. Cultivars of local origin over-yielded foreign cultivars at all levels of boron supply. The estimated yield loss was 1.8% per increase in soil boron of 0.1 ppm.

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PRINOS LOKALNIH I STRANIH SORTI PŠENICE GAJENIH NA ZEMLJIŠTU KOJE SADRŽI POVIŠENE KONCENTRACIJE BORA

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Izvod

Dvogodišnji poljski ogled je postavljen sa ciljem ispitivanja uticaja tretmana borom (3.3, 6.7 and 13.3 g H_3BO_3/m^2) na osam sorti pšenice, kao i procene intenziteta kojim se prinos smanjuje usled rastuće koncentracije ovog elementa u zemljištu. Utvrđena je jaka pozitivna linearna veza između primenjenih tretmana i zemljišnog bora rastvorljivog u vreloj vodi. Prosečna redukcija prinosa pšenice na tretmanima iznosila je 7,7%. Kod lokalnih sorti je zabeležen viši prinos u odnosu na strane, bez obzira na tretman. Procenjeno je da porast koncentracije zemljišnog bora od 0,1 ppm za posledicu ima redukciju prinosa od 1,8%.

Ključne reči: sorte pšenice, prinos, tolerancija na bor.

Received / Primljen: 21.11.2013.
Accepted / Prihvaćen: 07.0 2.2014.