EFFECT OF FERTILIZATION ON Al CONTENT OF DIFFERENT WHEAT GENOTYPES

UTICAJ ĐUBRENJA NA SADRŽAJ AL U BILJKAMA RAZLIČITIH GENOTIPOVA PŠENICE

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Abstract: *This study examines the effect of different fertilization treatments on Al content of winter wheat at the early stem elongation stage. The investigation was conducted on vertisol soil at an experimental field of the Small Grains Institute, Kragujevac. Physical and most of the chemical properties of the soil were very unfavourable, such as low pH ($pH_{(KCl)} < 4.5$) and low Ca and P_2O_5 levels. The experiment included a control and six fertilization treatments ($N_{80,120}$; $N_{80,120}P_{60}K_{60}$; $N_{80,120}P_{100}K_{60}$; $N_{80,120}P_{100}K_{60}$; $N_{80,120}P_{60}$; $N_{80,120}P_{100}$; $N_{80,120}K_{60}$). Seven winter wheat cultivars were examined, including Takovčanka, Studenica, Kg–100, Matica, Lazarica, Toplica and Kg–56. Al content of young wheat plants was considerably affected by different fertilization treatments. A high Al content was reported for NK and NP treatments. The higher nitrogen application rate induced an increase in Al content of the aerial portions of plants by about 36% as compared to the lower rate used. Al accumulation in the plants differed considerably across the wheat genotypes observed in this study. The highest Al accumulation in the plants was found in cv. Lazarica (1.63 mg Al g^{-1} dry matter). The genotypes showed a different response to Al content of the plants.*

Sažetak: *U radu je izučavan uticaj različitih načina mineralne ishrane na sadržaj Al u biljkama ozime pšenice u fazi ranog vlatanja. Ispitivanje je izvedeno na oglednom polju Instituta za strna žita u Kragujevcu na zemljištu tipa vertisol. Zemljište je manje povoljnih fizičkih i veoma nepovoljnih hemijskih osobina, posebno niske pH vrednosti ($pH_{(KCl) < 4.5)}$, niskog sadržaja Ca i P_2O_5. Ogled je pored kontrolne varijante obuhvatio i šest varijanti mineralne ishrane ($N_{80,120}$; $N_{80,120}P_{80}K_{60}$; $N_{80,120}P_{100}K_{60}$; $N_{80,120}P_{100}K_{60}$; $N_{80,120}P_{80}$; $N_{80,120}P_{100}$; $N_{80,120}K_{60}$). U ogledu je ispitivano sedam sorti ozime pšenice (Takovčanka, Studenica, Kg–100, Matica, Lazarica, Toplica i Kg–56). Primena različitih varijanti mineralne ishrane imala je znatan uticaj na sadržaj Al u mladim biljkama pšenice. Visok sadržaj Al u biljkama konstantovan je na NK i NP varijantama mineralne ishrane. Primenom veće doze azota u odnosu na nižu ostvareno je povećanje sadržaja Al u nadzemnom delu biljaka u proseku za 36%. Ispitivani genotipovi pšenice ostvarili su veoma različitu akumulaciju Al u biljkama, pri čemu je najveća akumulacija Al konstantovana kod sorte Lazarica (1.63 mg Al g^{-1} suve mase). Takođe i reakcija ispitivanih genotipova na sadržaj Al u biljkama je bila različita.*

Key words: *wheat, genotypes, fertilization, Al.*
Ključne reči: *pšenica, genotipovi, đubrenje, Al.*

INTRODUCTION

Aluminum toxicity in combination with soil acidity represents a major growth limiting factor for plants in many parts of the world. The effects of aluminum on plant growth, crop yield, uptake and nutrients distribution in vegetative and reproductive parts are still not fully understood (TANG et. al., 2003; KOCHIAN et. al. 2005; WANG et. al., 2006).

The aim of our investigations was to examine the reaction of different wheat genotypes to the aluminum presence in the soil under different fertilization systems.

MATERIAL AND METHODS

The study was conducted in a stationary field experiment involving fertilization set up in 1985 at an experimental field of the Small Grains Institute Kragujevac in 2004–2007. The soil was vertisol, having low pH and very poor physical properties. The trial was established as a randomized block design in five replications. The size of the elementary plot was 100 m^2. The plot was divided into two parts of 50 m^2 each, fertilized with two nitrogen rates (80 kg N – N_1 and 120 kg N – N_2). The trial involved a control and six treatments ($N_{80,120}$; $N_{80,120}P_{60}K_{60}$; $N_{80,120}P_{100}K_{60}$; $N_{80,120}P_{60}$; $N_{80,120}P_{100}$; $N_{80,120}K_{60}$) with individual mineral fertilizers, including CAN (calcium ammonium nitrate with 27% N) as a nitrogen fertilizer, super phosphate containing 17% P_2O_5 as a phosphorus fertilizer and 60% of potassium salt as a potassium fertilizer. The phosphorus and potassium fertilizers, combined with half of the nitrogen fertilizer, were used in seedbed preparation, whereas the remaining half of the nitrogen was used for top dressing at the full tillering stage. Other cultural practices used were conventional ones. The research involved seven winter wheat cultivars (Takovčanka, Studenica, Kg–100, Matica, Lazarica, Toplica and Kg–56) planted at an optimum planting date and cultivated in a crop rotation with millet. Plant samples (50 plants) were collected at the stem elongation stage, dried to constant weight and ground in an electric grinder. Prior to grinding, dry matter yield was weighed using a technical balance. Aluminium concentration of the plant material was determined colorimetrically by an aluminium–acetate buffer subsequent to the dry burning of the plant samples. The results of the analyses were presented as average values and subjected to the statistical mathematical method of the analysis of variance (MEAD et al., 1996).

RESULTS AND DISCUSSION

The content of aluminium in the aerial portions of the winter wheat plants examined at the stem elongation stage was extremely high, ranging from 0.17 to 1.62 mg/g^{-1} of dry matter on average (table 1). The lowest average content was found in the control (0.30 mg/g^{-1} dry matter), whereas the applied fertilization treatments induced a considerable increase, ranging from 0.06 to 0.20 mg/g^{-1} of dry matter at the lower nitrogen rate used (N=80 kg N/ha) and 0.05-0.34 mg/g^{-1} of dry matter at the higher N rate of 120 kg N/ha. The content of Al is below 0.20 mg Al g^{-1} dry matter in most cultivated plants, except in aluminium accumulators (Matsumoto, 2000). A high Al content of the aerial portions of wheat, which is, in some cases, over eight times the above values, is induced by high acidity and increased mobile Al content of soil (FOY, 1996; MOSSOR–PIETRASZAWSKA TERESA, 2001).

The lowest aluminium concentration of wheat plants was produced by the control as well as by the treatments with complete NPK fertilizer. The use of nitrogen and potassium fertilizers induced a considerable increase in Al concentration in the aerial portions of the plants as compared to the control and the other treatments. Furthermore, a significant increase was also found in NP treatments, particularly at the higher nitrogen rate used. The higher nitrogen rate (120 kg N/ha) resulted in a higher Al content of the plants as compared to the lower rate of 80 kg N/ha. The acidity of the examined soil was increased by KCl as well as by increased nitrogen rates due to the leaching of base cations, particularly of Ca^{2+}, which led to an increase in Al content (MOSSOR–PIETRASZAWSKA TERESA, 2001).

The content of aluminium of the wheat plants observed in this study varied significantly between the cultivars (tab. 1). The lowest Al concentration in the plants (0.24 and 0.29 mg/g^{-1} of dry matter, respectively) was found in cv. KG–100 at both nitrogen rates used. cv. Lazarica had the highest Al concentration in the aerial portions of plants (0.73 mg/g^{-1} dry matter) at the higher nitrogen rate applied, whereas the highest concentration of Al at the lower nitrogen application rate of 80 kg N/ha was found in cv. Takovčanka (0.40 mg/g^{-1} dry matter). Similar results were obtained by other authors (DELHAIZE and RYAN, 1995; BLAIR and

TAYLOR, 1997).

Table 1.

Fertilization (A_1 = control, A_2 = N, A_3 = NP_1K, A_4 = NP_2K, A_5 = NP_1, A_6 = NP_2, A_7 = NK) and cultivar effects on the aluminium status in wheat (B_1 = Takovčanka, B_2 = Studenica, B_3 = KG–100, B_4 = Matica, B_5 = Lazarica, B_6 = Toplica, B_7 = KG–56)

Aluminium (Al) concentrations (Al mg/g^{-1} dry matter)																
	B_1	B_2	B_3	B_4	B_5	B_6	B_7	xA	B_1	B_2	B_3	B_4	B_5	B_6	B_7	xA
	Nitrogen rate: 80 kg N/ha (N_1)								Nitrogen rate: 120 kg N/ha (N_2)							
A_1	0.36	0.32	0.28	0.32	0.20	0.26	0.35	0.30	0.36	0.32	0.28	0.32	0.20	0.26	0.35	0.30
A_2	0.58	0.22	0.26	0.22	0.35	0.32	0.59	0.36	0.31	0.56	0.25	0.35	0.34	0.25	0.43	0.35
A_3	0.58	0.43	0.17	0.22	0.41	0.20	0.20	0.31	0.35	0.47	0.33	0.18	1.62	0.44	0.84	0.60
A_4	0.27	0.20	0.17	0.38	0.31	0.38	0.40	0.30	0.30	0.40	0.34	0.35	0.45	0.28	0.32	0.35
A_5	0.34	0.40	0.18	0.54	0.18	0.28	0.30	0.32	0.24	0.31	0.32	0.40	0.35	0.61	0.59	0.40
A_6	0.40	0.50	0.18	0.44	0.73	0.27	0.28	0.40	0.33	0.40	0.27	0.67	1.30	0.31	0.32	0.51
A_7	0.29	0.20	0.41	1.48	0.38	0.31	0.42	0.50	0.52	0.34	0.23	0.84	0.85	1.23	0.50	0.64
xB	0.40	0.32	0.24	0.51	0.36	0.29	0.36	0.35	0.34	0.40	0.29	0.44	0.73	0.48	0.48	0.45
LSD–test (5% and 1%)									LSD–test (5% and 1%)							
5% 1%	A: 0.006 0.008		B: 0.006 0.008		AB: 0.016 0.021				A: 0.006 0.008		B: 0.006 0.008		AB: 0.016 0.021			

The aerial dry matter of the winter wheat plants observed in this study varied considerably, being treatment- and genotype-dependent (table 2).

Table 2.

Fertilization (A_1 = control, A_2 = N, A_3 = NP_1K, A_4 = NP_2K, A_5 = NP_1, A_6 = NP_2, A_7 = NK) and cultivar effects on dry matter status in wheat (B_1 = Takovčanka, B_2 = Studenica, B_3 = KG–100, B_4 = Matica, B_5 = Lazarica, B_6 = Toplica, B_7 = KG–56)

Dry matter (g^{-1} dry matter)																
	B_1	B_2	B_3	B_4	B_5	B_6	B_7	xA	B_1	B_2	B_3	B_4	B_5	B_6	B_7	xA
	Nitrogen rate: 80 kg N/ha (N_1)								Nitrogen rate: 120 kg N/ha (N_2)							
A_1	4.63	4.06	3.13	3.13	3.33	3.50	4.03	3.69	3.30	3.16	3.46	1.66	2.40	2.83	3.53	2.90
A_2	4.76	4.80	4.03	4.03	4.03	3.90	5.26	4.40	6.40	4.60	4.96	4.23	5.07	4.03	5.33	4.94
A_3	6.10	9.63	7.00	6.53	6.77	7.26	7.76	7.29	7.20	9.19	6.10	6.40	7.33	5.97	5.83	6.86
A_4	6.43	8.56	11.07	10.66	8.30	10.30	7.56	8.98	7.28	9.94	6.80	5.57	5.47	6.30	5.63	6.71
A_5	7.00	5.50	6.83	5.36	4.30	7.66	7.53	6.31	5.80	7.30	7.60	5.72	6.70	11.75	6.20	7.29
A_6	6.80	5.20	5.50	6.70	5.00	7.60	5.26	6.01	4.90	4.92	5.90	5.13	5.76	4.93	7.63	5.59
A_7	5.60	5.63	5.83	6.16	4.70	4.73	5.43	5.44	7.36	4.19	4.90	5.73	3.90	10.00	6.07	6.02
xB	5.90	6.20	6.20	6.08	5.20	6.42	6.12	6.02	5.96	6.19	5.93	5.50	5.21	6.48	5.93	5.88
LSD–test (5% and 1%)									LSD–test (5% and 1%)							
5% 1%	A: 0.823 1.091		B: 0.823 1.091		AB: 2.178 2.887				A: 1.021 1.354		B: 1.021 1.354		AB: 2.703 3.582			

The highest aerial dry matter yield of plants at both nitrogen application rates (N_1 and N_2) was obtained in NPK fertilization treatments (8.98 g^{-1} dry matter), particularly in the NP_2K treatment having a higher percentage of phosphorus of 100 kg P_2O_5/ha. The lowest dry matter yield of the winter wheat genotypes studied was produced by the control as well as by the NK fertilization treatment, being considerably decreased as compared to the other treatments. The aerial dry matter yield was lower at the higher N rate used (120 kg/ha) as compared to the yield obtained at the lower N rate of 80 kg N/ha. The yield decrease in the NK treatment was most likely due to an intensified accumulation of Al in small wheat plants. Moreover, higher amounts of mobile Al in the soil inhibit the uptake of P and reduce the uptake of other major nutrients (Ca, Mg, K, Cu and Zn), affecting negatively the metabolic processes, the growth and development of wheat plants and, hence, the achieved yield (MARSCHNER, 1991; FOY, 1992; DELHAIZE and RYAN, 1995).

The aerial dry matter yield of the winter wheat cultivars observed in this study differed considerably between the cultivars (tab. 2), the highest being produced in cv. Toplica (6.48 g^{-1} dry matter) at both nitrogen application rates, and the lowest in cv. Lazarica (5.20 g^{-1}

dry matter). Similar results were previously obtained by other authors, as well (GARVIN and CARVER, 2003).

CONCLUSION

The results of the study on the effect of fertilization and wheat genotype on Al content of plants cultivated on acid vertisols suggested the following:

- The content of Al in the aerial portions of winter wheat plants at the stem elongation stage was extremely high (0.17 to 1.62 mg/g^{-1} dry matter).
- Fertilization treatments, particularly those with nitrogen and potassium fertilizers, induced a considerable increase in Al content in the aerial portions of wheat plants, the highest being found in cv. Lazarica.
- NK fertilization, particularly at the higher N rate applied, resulted in a considerably lower aerial dry matter yield. The lowest yield was produced by cv. Lazarica, which gave the highest Al content of the aerial portions of plants.
- NPK fertilization with a lower N rate and an increased rate of phosphorus fertilizer, as well as an adequate choice of cultivar to be used on acid vertisol lead to higher productivity of plants and an increased nutritional value of healthy food.

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