THE EFFECT OF FERTILIZATION AND LIMING ON SOME GRAIN QUALITY PROPERTIES OF WHEAT

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ABSTRACT

The present research was carried out to investigate fertilizer and lime effect on some grain quality properties of wheat cultivars (thousand grain weight and hectoliter weight). The experiment was set up at the experimental field of the Small Grains Research Centre Kragujevac over 2003/2004-2004/2005 seasons. The soil was smonitza (vertisol) with very high natural acidity. The trial consisted of a completely randomized block experimental design with three replications, the size of each plot being 14 m^{-2}. The research included six winter wheat varieties (Takovčanka, Studenica, KG-100, Matica, Ana Morava and Toplica) created in Small Grains Research Centre of Kragujevac. The following variants of fertilization were applied: Control -T_1 (no fertilization), mineral fertilizer-T_2 (500 kg ha^{-1} NPK – 15:15:15), nitrogen fertilizer + lime fertilizer-T_3 (75 kg N ha^{-1} in form of KAN + 2.0 t ha^{-1} $CaCO_3$ in form of "Njival Ca" - 98.5% $CaCO_3$), mineral fertilizer + lime fertilizer–T_4 (500 kg ha^{-1} NPK + 2.0 t ha^{-1} $CaCO_3$), and mineral fertilizer + lime fertilizer + organic fertilizer –T_5 (500 kg ha^{-1} NPK + 2.0 t ha^{-1} $CaCO_3$ + 35.0 t ha^{-1} manure). The results showed significant influence of all kinds of fertilizers on the physical grain quality properties of wheat (thousand grain weight and hectoliter weight). The best results for both these components have been achieved with the combination of fertilizers (500 kg ha^{-1} NPK + 2.0 t ha^{-1} $CaCO_3$ + 35.0 t ha^{-1} of manure). High values for thousand grain weight and hectoliter weight were also recorded in the application of NPK fertilizers only. The lowest value for this properties are achieved in the control treatment (no fertilizer), and then on the combined fertilizers (N + $CaCO_3$).

Key words: wheat, 1000-grain weight, hectoliter weight, fertilization, acid soil

INTRODUCTION

Acid soils reduce crop production in 30-40% of the total world's arable land and 70% of potentially arable land. Acid soils in the Republic of Serbia account for more than 60% of total arable land, and most acid soils are located in the central parts of Serbia (STEVANOVIC et al., 1995). The acidity of these soils, their high contents of H^+ ions and low contents of essential plant nutrients, primarily P and Ca, are limiting factors for high yield of cultivated cereal crops. Acid soils have increased iron content, aluminum and other toxic elements and heavy metals, and have low productive capacity and poor chemical, biological, physical and water-air properties. These soils can be improved by different ameliorative interventions, like calcification and fertilization.

Soil acidity and associated infertility and mineral toxicities are major constraints to agricultural production in several parts of the world. The natural process of soil acidification is often intensified by agricultural practices, particularly nitrogen fertilization, and acid precipitation (RAO et al., 1993). Aluminium toxicity is a major yield-limiting factor in winter wheat production in many parts of the world (KARIUKI et al., 2007). Low-acidity soils causes a very complex problem (cultural, management, and lime application) are required. One possible solution is to choose and grow tolerant genotypes (JELIC et al., 2000). Plant species and genotypes within species differ widely in their soil-acidity tolerance (Al resistance).

Aluminium can react with other nutrients in the soil such as P to form less available compounds. In addition aluminium can interfere with the uptake and transport of substances in plant such as Ca, Mg, P, K, and water (RAYBURN et al., 2002; ZHANG et al., 2004). The major limiting factor for plant growth on acid mineral soils is Al toxicity, which is the most important yield-limiting factor (MARSCHNER, 1991).

Liming represents an effective management strategy in overcoming or minimizing soil acidity and related Al toxicity. A continuous acidification without liming may result in deterioration of soils that can make even the acid-tolerant genotypes useless. By raising pH up to above 5.5 through lime (i.e., $CaCO_3$) applications soluble and exchangeable Al are precipitated as hydroxy-Al species (DE PAUW, 1994; CAKMAK, 2002).

This research has been determining the individual and combined effects of chemical and animal manure, and lime on some physical grain quality properties of winter wheat.

MATERIAL AND METHOD

Experimental design

Experiment was set up at the experimental field of Small Grains Research Centre Kragujevac Serbia (20°55'12''E, 44°01'12''N, 185m asl) during 2003/2004-2004/2005 growing seasons. The soil was smonitza (vertisol) with very high natural acidity (pH H_2O=5.6 and in KCl = 4.2). The trial consisted of a completely randomized block experimental design with three replications, the size of each plot being 14 m^{-2} (7 m x 2 m). The research included six winter wheat varieties (Takovčanka, Studenica, KG-100, Matica, Ana Morava and Toplica) created in the Small Grains Research Centre of Kragujevac.

The following variants of fertilization were applied: Control -T_1 (no fertilization), mineral fertilizer-T_2 (500 kg ha^{-1} NPK – 15:15:15), nitrogen fertilizer + lime fertilizer-T_3 (75 kg N ha^{-1} in form of KAN + 2.0 t ha^{-1} $CaCO_3$ in form of "Njival Ca" - 98.5% $CaCO_3$), mineral fertilizer + lime fertilizer–T_4 (500 kg ha^{-1} NPK + 2.0 t ha^{-1} $CaCO_3$), and mineral fertilizer + lime fertilizer + organic fertilizer –T_5 (500 kg ha^{-1} NPK + 2.0 t ha^{-1} $CaCO_3$ + 35.0 t ha^{-1} manure).

Hectoliter weight (HW) determined using standard method. Thousand grain weight (TGW) was determined by counting and weighing samples of two times 500-kernels and then found values were averaged and multiplied by two. Both properties are determined on an average of samples from three replicates.

The analysis of variance was calculated according to randomize complete block design with three factors: genotype (G), treatment (T) and year (Y) using ANOVA (MSTAT-C program, 1989). The significant differences among the means were grouped according to least significant difference (LSD).

Climatic conditions during the experiment

For the better understanding of the efficiency of the applied doses of different fertilizers, the climatic conditions prevailing during the trial should be described (*Table 1*). Average temperatures were similar during first (8.7°C) and second (8.5°C) investigated years, which also were similar according to the long-term period (8.5°C). Mainly differences were in the winter period when plants were in hibernation that did not significant influenced on plant growing.

Sums of precipitation were higher in 2004/05 (490.8 mm) than in 2003/04 (480.2 mm) investigated year. According to long-term period, precipitations in both 2003/04 and 2004/05 vegetative period were higher for (62.4 mm and 73.0 mm, respectively). In May of 2004/05 year was higher precipitation for about 20 mm in relation with 2003/04 investigated year and long-term period (17.6 mm). In April 2003/04 was higher precipitation for 22.3 mm in relation with the same period of 2004/05.

Table 1: Average of monthly temperatures (^{o}C) and monthly sums of precipitation (mm)

Month	Temperature (^{o}C)			Precipitation (mm)		
	2003/04	2004/05	1990-2000	2003/04	2004/05	1990-2000
Oct	10.6	14.7	11.83	83.2	50.1	61.02
Nov	8.9	6.8	6.4	28.6	121.3	44.29
Dec	2.2	3.0	1.71	37.2	19.7	44.65
Jan	- 0.9	1.5	- 0.1	86.4	36.6	30.04
Feb	3.0	-1.5	2.62	59.5	66.9	29.87
Mar	7.1	4.5	5.99	21.3	43.6	33.21
Apr	12.8	11.6	11.6	52.3	43.3	52.88
May	14.5	16.4	16.37	50.3	70.2	52.57
Jun	19.8	19.2	20.37	61.4	39.1	69.28
$\bar{x} / \sum$	8.7	8.5	8.5	480.2	490.8	417.8

RESULTS AND DISCUSSION

The results showed that all fertilizer treatments gave higher TGW and HW than the control, and that NPK applications positively influenced these grain quality properties (*Table 2*). Differences between two seasons 2003/04 and 2004/05 were visible significant. In this investigation, the TGW and HW varied in accordance with genotype, applied treatments and years. The use of ameliorative fertilization significantly increased TGW and HW. Average values for TGW were ranged from 35.0g (T_1) to 42.0g (T_5). Matica cultivar had the highest average value for TGW (41.7g), and then Toplica, KG-100 and Studenica. Average values for 1000-grains weight varied by investigated year. In the second year of research 1000-kernels weight was higher by about 3 g compared with the first year.

The results of hectoliter weight showed that in average the best results achieved in T_5 variant when was applied NPK + manure + CaCO3 (78.1 kg hl^{-1}) and then in T_4 variant when was applied NPK and $CaCO_3$ (77.1 kg hl^{-1}). In average for all treatments, cultivar Toplica had the highest value of HW (77.2 kg hl^{-1}) and then Takovčanka and Studenica (76.5 kg hl^{-1} and 76.4 kg hl^{-1}, respectively).

The least improvement of investigated traits was observed by nitrogen and lime fertilizers application, while the best results were obtained by together NPK, manure and lime fertilizer application, which is in accordance to previous research (ZEIDAN et al., 2001; KISIC et al., 2004; KIANI et al., 2005; ZIVANOVIC-KATIC et al., 2005).

A wide range of long term trials has proved the positive effect of adequate fertilization on grain quality, like hectoliter weight and thousand kernel weight, protein content, wet gluten content and falling number. High values for thousand grain weight and hectoliter weight were also recorded in the application of NPK fertilizers only, which is consistent with previous research (VARGA et al., 2003; STIPESEVIC et al., 2009). The yield and quality of wheat will be increased by using animal manure combined with chemical fertilizer (LOTFOLLAHI, 2004).

Table 2: Mean values for thousand grain weight (g) and hectoliter weight (kg hl^{-1})

Cultivar	Treatments (Variants)											
	0 (T_1)		NPK (T_2)		N+$CaCO_3$ (T_3)		NPK+$CaCO_3$ (T_4)		NPK+manure + $CaCO_3$ (T_5)		Average	
	TGW	HW	TGW	HW	TGW	HW	TGW	HW	TGW	HW	TGW	HW
Takovčanka	32.0	70.6	39.1	77.4	36.8	74.3	36.7	78.3	40.5	81.1	37.0	76.5
Studenica	34.9	73.3	40.4	78.4	39.4	75.0	40.1	77.1	42.8	78.4	39.5	76.4
KG-100	37.0	71.4	40.4	74.5	38.0	73.2	39.2	75.0	43.0	75.9	39.5	74.00
Matica	34.8	71.1	43.1	74.2	40.2	75.0	44.0	77.2	46.4	75.5	41.7	74.6
Ana Morava	34.0	72.3	35.0	76.3	33.1	74.2	35.1	76.5	36.4	78.5	34.7	75.6
Toplica	37.0	74.3	40.2	78.4	39.1	76.1	39.4	78.1	43.1	79.2	39.8	77.2
Average	35.0	72.2	39.7	76.5	37.8	74.6	39.1	77.1	42.0	78.1	38.7	75.7
Season means for TGW: 2003/04= 37.26; 2004/05 = 40.15 Season means for HW: 2003/04= 74.25; 2004/05 = 77.18												

Analysis of variance showed highly significant differences among investigated genotypes (G), treatments (T), years (Y) and among interaction genotype x treatments (G x T) for thousand grain weight. Similar results were obtained for hectoliter weight by analysis of variance. Differences were highly significant for genotypes, treatments, years and interactions (G x T, G x Y) and differences were significant for interactions T x Y. The strongest individual influence for both TGW and HW had treatments and years, and than genotypes (*Table 3*).

Table 3: Analysis of variance for thousand grain weight (TGW) and hectoliter weight (HW)

Source	DF	MS		F		LSD			
						0.05		0.01	
		TGW	HW	TGW	HW	TGW	HW	TGW	HW
Genotype (G)	5	179.332	45.264	1479.955**	744.940**	0.231	0.164	0.362	0.257
Treatment (T)	4	242.288	197.662	1999.497**	3253.061**	0.228	0.162	0.378	0.268
G x T	20	11.608	7.583	95.794**	124.803**	0.419	0.297	0.571	0.406
Year (Y)	1	377.581	386.614	3116.013**	6362.760**	0.204	0.147	0.357	0.258
G x Y	5	0.060	0.254	0.494	4.180**	-	0.234	-	0364
T x Y	4	0.056	0.156	0.460	2.564*	-	0.229	-	0.379
G x T x Y	20	0.111	0.129	0.918	2.115	-	-	-	-

Acidity is a critical yield-limiting problem in many soils. About 40% of cultivated soils globally have acidity problem leading to significant decreases in crop production despite adequate supply of mineral nutrients such as N, P and K (CAKMAK, 2002). In acid soils major constraints to plant growth are toxicities of hydrogen (H+), aluminum (Al) and manganese (Mn) and deficiencies of P, calcium (Ca) and magnesium (Mg). Among these constraints Al toxicity is the most important yield-limiting factor (MARSCHNER, 1991; ZHANG et al., 2004). The liming caused improvement of some chemical soil traits i. e. decreasing of active and substitution acidity increasing of humus, total nitrogen, easy available phosphorus and potassium content. In previous investigation was established that use of nitrogenous fertilizer alone aggravated the problem of soil acidity by lowering the pH from 5.8 to 4.7 after 25 years (SHARMA and SUBEHIA, 2003). In their investigations in almost all the treatments, the organic carbon content increased: a marginal decrease occurred in the 100% N and control plots. Even under optimum application rates, the available N and K status decreased with time (SHARMA and SUBEHIA, 2003).

CONCLUSIONS

Ameliorative application of fertilizers positively influenced the 1000 kernel weight and hectoliter weight. The best results were achieved in the implementation of NPK fertilizers combined with lime and manure. These results indicate that the application of ameliorative fertilization can improve acidic soils and thus create favorable conditions for growth of plant species. The acid soils need manure in combination with NPK fertilizers and lime to improve their physicochemical and biological properties and consequently their productivity.

The results suggest that integrated application of N, P, and K fertilizers and manure is an important strategy to maintain or improve soil fertility, and nutrients balance, and minimize potential for pollution to the environment, while also sustaining high crop yield and quality.

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