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## WINTER WHEAT YIELD AND QUALITY DEPENDING ON THE LEVEL OF NITROGEN, PHOSPHORUS AND POTASSIUM FERTILIZATION

### SUMMARY

Tests were carried out on stationary field trial, soil type vertisol in the process of degradation. The land on which the view is derived is characterized by low pH (pH<5.0). The Dose of nitrogen was 120 kg N/ha, which was administered in combination with phosphorous and potassium fertilizer. The tests showed a significant grain yield. Nitrogen had a most significant impact on the yield of wheat. The average grain yield of all treatments in the 2008/09 growing season was significantly greater than in the following years, mostly as the result of highly favourable weather conditions at major stages of plant development. The average highest yield was achieved in the variant N120P100K60 (5.528 t/ha), although the high yield of more than 5 t/ha was obtained and the triple treatments NPK where nitrogen is applied in the maximum amount of 120 kg/ha, 60 kg/ha P<sub>2</sub>O<sub>5</sub> and 60 kg/ha K<sub>2</sub>O as well as variants NP in a quantity of 100 kg/ha P<sub>2</sub>O<sub>5</sub> and 60 kg/ha K<sub>2</sub>O. Also, the 1000-grain weight was highest in balanced fertilization with all nutrients NPK (40 g), in a quantity of 120 kg N/ha, 100 kg/ha P<sub>2</sub>O<sub>5</sub> and 60 kg/ha K<sub>2</sub>O. Averaged across years, significantly higher values for test weight were found in the control (76.91 kg/hl). Variance analysis showed statistically significant differences for grain yield and test weight between the vegetation seasons. Significant differences for 1000 grain weight between the variants of fertilization.

**Keywords:** fertilization, mineral nutrition, yield, wheat

### INTRODUCTION

Wheat productivity and grain quality in Central Serbia are governed by a range of factors, notably climate, soil, genetics and crop nutrition. Soil acidity in wheat fields in Central Serbia has become a severe problem that leads to a significant decline in grain yield and quality of wheat (Đekić et al., 2017a, 2019;

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Jelic *et al.*, 2015). The yield per unit area is the result of the action of factors of variety in interaction with environmental factors. The yield is largely dependent on the genetic potential and considerably vary primarily as a result of agro-ecological conditions during the growing season (Dodig *et al.*, 2008; Hristov *et al.*, 2011; Đekić *et al.*, 2017b; Jelić *et al.*, 2014; Djuric *et al.*, 2018; Jordanovska *et al.*, 2018; Popović *et al.*, 2016, 2018; Terzić *et al.*, 2018b).

Mineral fertilizers play a vital role towards improving crop yields but one of the main constraints in achieving proven crop potential is imbalanced use of nutrients, particularly low use of P as compared to N. The optimum rate of P application is important in improving yields of most crops (Jelic *et al.*, 2013). Plant nitrogen nutrition has a great impact on the technological quality of wheat cultivars. Nitrogen, in interaction with other elements of mineral nutrition, plays a significant role in the grain yield and quality (Jelic *et al.*, 2014; Đekić *et al.*, 2014, 2017a; Popović *et al.*, 2017; Terzic *et al.*, 2018a). For high yield and grain quality, it is necessary to adopt nitrogen by plants during the whole vegetation period (Jelić *et al.*, 2015). Understanding the fertilization, liming and rainfall effects have been a continuous endeavor toward improving farming technology and management strategy to reduce the negative impacts of these factors and to increase crop yield (Đekić *et al.*, 2019; Jelić *et al.*, 2016; Popović *et al.*, 2017; Terzic *et al.*, 2018a,b).

The objective of this study was to evaluate the effect of different fertilization systems on the grain yield and quality of wheat grown on a vertisol soil. The study was also aimed at optimizing fertilization for maximum profitability in the future wheat production of Central Serbia.

## MATERIAL AND METHODS

### Experimental design

The study was carried out in a stationary field trial involving fertilization over a three years period from 2008/09, 2009/10 to 2010/11. Trials were first set up in the experimental fields of the Small Grains Research Centre in Kragujevac in 1970. Plot size was 50 m<sup>2</sup>. The trial was set up in a randomized block design with five replications. Fertilization was regular and followed a long-time scheme.

The rates of nitrogen application were 120 kg/ha N, and they were applied either individually or in combination with two phosphorus rates and a potassium fertilizer. A non-fertilized variant served as a control. The winter wheat cultivar used in the experiment was "Vizija", the dominant cultivar in the production region of Serbia. Eight variants of mineral nutrition N (120 kg/ha N), P<sub>1</sub> (60 kg/ha P<sub>2</sub>O<sub>5</sub>), P<sub>2</sub> (100 kg/ha P<sub>2</sub>O<sub>5</sub>), NP<sub>1</sub> (120 kg/ha N and 60 kg/ha P<sub>2</sub>O<sub>5</sub>), NP<sub>2</sub> (120 kg/ha N and 100 kg/ha P<sub>2</sub>O<sub>5</sub>), NP<sub>1</sub>K (120 kg/ha N, 60 kg/ha P<sub>2</sub>O<sub>5</sub> and 60 kg/ha K<sub>2</sub>O), NP<sub>2</sub>K (120 kg/ha N, 100 kg/ha P<sub>2</sub>O<sub>5</sub> and 60 kg/ha K<sub>2</sub>O) and untreated control were tested in the experiment. Total amounts of phosphorus and potassium fertilizers and half the nitrogen rate are regularly applied during pre-sowing cultivation of soil.

The crop was harvested at full maturity. Grain yield (t/ha) was harvested and reported at 14% moisture. Three parameters, namely grain yield, 1000-grain

weight (g) and test weight (kg/hl) were analyzed. Thousand grain weight was determined using an automatic seed counter. Test weight is the weight of a measured volume of grain expressed in kilograms per hectoliter.

### Soil analysis

The trial was set up on a vertisol soil in a process of degradation, with heavy texture and very coarse and unstable structure. The humus content in the surface layer of soil was low (2.22%). The reduced humus content in field vertisols profiles suggests the necessity of involving humification when planning fertilization systems and soil ameliorative operations to be used to maintain and improve the soil adsorption complex. Soil pH indicates high acidity (pH in H<sub>2</sub>O 5.19; pH in KCl 4.27), nitrogen content in soil is medium (0.11-0.15%), while the content of available phosphorus ranges from very low (1.7-2.9 mg 100 g<sup>-1</sup> soil) in the N and NK trial variants to very high (26.9 mg P<sub>2</sub>O<sub>5</sub> 100 g<sup>-1</sup> soil) in the NPK variants of fertilization. Available potassium contents are high, ranging from 19.5 to 21.0 mg K<sub>2</sub>O 100 g<sup>-1</sup> soil.

### Statistical Analysis

On the basis of achieved research results the usual variational statistical indicators were calculated: average values and standard deviation. Experimental data were analysed by descriptive and analytical statistics using the statistics module Analyst Program SAS/STAT (SAS Institute, 2000) for Windows. All evaluations of significance were made on the basis of the ANOVA test at 5% and 1% significance levels. Relative dependence was defined through correlation analysis (Pearson's correlation coefficient), and the coefficients that were obtained were tested at the 5% and 1% levels of significance.

## RESULTS AND DISCUSSION

### Meteorological conditions

This study was conducted over a three-year period in the Sumadija region, Central Serbia, on a Vertisol soil, at Kragujevac location, (44° 22' N, 20° 56' E, 173-220 m a. s. l.), in a temperate continental climate having an average annual temperature of 11.76°C, typical of Sumadija district in Serbia and a rainfall amount of about 550 mm.

Table 1. Precipitation sum and average monthly temperature in Kragujevac, Serbia

Months	Mean monthly air temperature (°C)				The amount of rainfall (mm)			
	2008/09	2009/10	2010/11	Average	2008/09	2009/10	2010/11	Aver.
X	13.1	11.7	10.2	12.5	31.3	102.6	86.9	45.4
XI	8.5	8.8	11.4	6.9	30.6	77.5	27.9	48.9
XII	4.4	2.6	2.4	1.9	29.7	194.2	50.1	56.6
I	2.3	0.9	0.9	0.5	57.7	57.0	29.1	58.2
II	2.0	3.2	0.5	2.4	76.9	150.5	48.5	46.6
III	6.8	7.2	7.2	7.1	40.3	43.3	20.4	32.4
IV	13.4	12.1	12.0	11.6	16.8	142.2	20.8	51.9
V	17.8	16.5	15.8	16.9	46.0	116.7	65.8	57.6
VI	20.2	20.2	20.9	20.0	137.8	196.7	32.3	70.4

Aver.	9.83	9.24	9.03	8.87	467.1	1080.1	381.8	468.0
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Meteorological conditions recorded high variability during year. The average air temperature was higher by 0.8°C in 2008/09, by 0.37°C in 2009/10 and was higher by 0.16°C in 2010/11 than the average of many years. The sum of rainfall precipitation was higher by 612.1 mm in 2009/10, where the sum of rainfall was lower by 0.9 mm in 2008/09 and was lower by 86.2 mm in 2010/11 than the average of many years and with a very uneven distribution of precipitation per months. During the April and May in 2009/10 it was 142.2 mm and 116.7 mm of rainfall, what was 90.3 mm and 59.1 mm more compared with the perennial average. During the June in 2009/10 it was 196.7 mm of rainfall, what was 126.3 mm more compared with the perennial average. Regard the high importance of sufficient rainfall amounts during the spring months, particularly. Namely, the total amount of precipitation is reflected on the multi annual average, but the distribution, especially at critical stages of development, is significantly disturbed in the 2009/10 year. In addition to the necessary reserve for the spring part of the vegetation, winter precipitation greatly influences the distribution of easily accessible nitrogen in the soil (Đekić *et al.*, 2014, 2017b, 2019; Jelic *et al.*, 2014, 2015; Milivojević *et al.*, 2018; Popovic *et al.*, 2016, 2017; Terzić *et al.*, 2018a,b).

Table 2. The analysis of variance for the tested parameters in Kragujevac, Serbia

Effect	df	Mean sqr Effect	Mean sqr Error	F	p-level
The analysis of variance for grain yield					
Year, (Y)	2, 117	23.437	2.708	8.656**	0.000
Fertilization, (F)	7, 112	38.949	0.813	47.931	0.000
Year x Fertilization, (YxF)	14, 96	0.7955	0.344	2.314**	0.009
The analysis of variance for 1000-grain weight					
Year, (Y)	2, 117	0.715	3.344	0.214	0.808
Fertilization, (F)	7, 112	7.213	3.056	2.360*	0.027
Year x Fertilization, (YxF)	14, 96	16.33799	1.167429	13.99485	0.000
The analysis of variance for test weight					
Year, (Y)	2, 117	279.970	4.938	56.698**	0.000
Fertilization, (F)	7, 112	11.567	9.435	1.226	0.294
Year x Fertilization, (YxF)	14, 96	2.659	4.787	0.555	0.893

<sup>ns</sup>non significant; \* significant at 0.05; \*\* significant at 0.01;

Data in Table 2 for the investigated period (2009-2011) clearly indicate that the was found highly significant effect of year on the grain yield ( $F=8.656^{**}$ ) and test weight ( $F=56.698^{**}$ ). Furthermore, 1000-grain weight was significant among the fertilization. The use of different treatments induced a significant increase in 1000-grain weight. Furthermore, test weight was highly significant among the year x fertilization interaction. Considerable variation in yield depending on years of research has been established by Đekić *et al.* (2014; 2017a), Jelic *et al.* (2015) and Terzić *et al.* (2018a). The present results confirm

the opinion of many authors that the traits analyzed are genetically determined but are strongly modified by the nutrient status of the environment and weather conditions (Đekić et al. 2014, 2017a; Jelic et al., 2014, 2015; Milivojević et al., 2018; Popovic et al., 2017; Stevanović et al., 2018; Ugrenović et al., 2018; Terzić et al., 2018a). Đekić et al. (2014) and Terzić et al. (2018a) find that the application of mineral fertilizers has a significant impact on the weight of 1000 grains, i.e. the grain weight is significantly higher in more intensively fertilized variants especially fertilized with nitrogen.

Table 3 presents average values for grain yield, 1000-grain weight and test weight across years and treatments during the study. The tests showed a significant grain yield and test weight. The highest values of grain yield were established in the year with moderate temperatures and high precipitation in the vegetation year 2008/09. The highest average grain yield of 4.611 t/ha of studied wheat treatments was recorded in vegetation season 2008/09 and it was significantly higher than the yield in 2009/10 (3.080 t/ha) and the yield in 2010/11 (3.827 t/ha). The 1000-grain weight of winter wheat significantly varied across treatments, from 38.25 g in treatment control to 40.00 g in treatment NPK, in a quantity of 120 kg N/ha, 100 kg/ha P<sub>2</sub>O<sub>5</sub> and 60 kg/ha K<sub>2</sub>O. The test weight in year 2010/11 (78.10 kg/hl) was significantly higher compared to 2008/09 and 2009/10 (76.28 kg/hl and 72.88 kg/hl). The highest grain yield had wheat application of NPK in a quantity of 120 kg/ha N, 100 kg/ha P<sub>2</sub>O<sub>5</sub> and 60 kg/ha K<sub>2</sub>O (5.528 t/ha).

Table 3. Mean values for grain yield, 1000-grain weight and test weight

Years	Grain yield (t/ha)		1000-grain weight (g)		Test weight (kg/hl)	
	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$	S
2008/09	4.611 <sup>a*</sup>	1.673	39.12 <sup>a</sup>	2.259	76.28 <sup>b</sup>	2.531
2009/10	3.080 <sup>c</sup>	1.435	39.30 <sup>a</sup>	0.851	72.88 <sup>c</sup>	2.312
2010/11	3.827 <sup>b</sup>	1.807	39.05 <sup>a</sup>	2.051	78.10 <sup>a</sup>	1.750
Treatments						
C	1.292 <sup>d</sup>	0.339	38.25 <sup>c</sup>	2.411	76.91 <sup>a</sup>	3.046
N <sub>120</sub>	3.750 <sup>b</sup>	0.777	38.29 <sup>c</sup>	1.448	75.42 <sup>ab</sup>	2.804
P <sub>60</sub>	2.281 <sup>c</sup>	0.865	39.75 <sup>ab</sup>	1.831	76.00 <sup>ab</sup>	3.128
P <sub>100</sub>	2.574 <sup>c</sup>	0.858	39.64 <sup>abc</sup>	2.127	76.82 <sup>ab</sup>	3.017
N <sub>120</sub> P <sub>60</sub>	4.932 <sup>a</sup>	1.006	38.55 <sup>bc</sup>	1.746	75.01 <sup>ab</sup>	2.966
N <sub>120</sub> P <sub>100</sub>	5.101 <sup>a</sup>	0.983	39.39 <sup>abc</sup>	1.574	74.31 <sup>b</sup>	3.729
N <sub>120</sub> P <sub>60</sub> K <sub>60</sub>	5.258 <sup>a</sup>	1.155	39.39 <sup>abc</sup>	1.165	76.01 <sup>ab</sup>	3.392
N <sub>120</sub> P <sub>100</sub> K <sub>60</sub>	5.528 <sup>a</sup>	0.991	40.00 <sup>a</sup>	1.332	75.54 <sup>ab</sup>	2.291

<sup>0</sup> Means within columns followed by different lowercase letters are significantly different (P<0.05) according to the LSD test.

Table 4 presents average values for grain yield, 1000-grain weight and test weight across years and treatments during the three vegetation seasons. During the first years (2008/09) grain yield significantly varied across treatments, from

1.671 t/ha in control to 6.305 t/ha in treatment N<sub>120</sub>P<sub>100</sub>K<sub>60</sub>. During the second years (2009/10) grain yield significantly varied across treatments, from 0.951 t/ha in control to 4.438 t/ha in treatment N<sub>120</sub>P<sub>60</sub>K<sub>60</sub>. During the 2010/11 years grain yield significantly varied across treatments, from 1.254 t/ha in control to 5.915 t/ha in treatment N<sub>120</sub>P<sub>100</sub>K<sub>60</sub>.

Table 4. Mean values of yield and quality of fertilization and vegetation seasons

	Grain yield (t/ha)		1000-grain weight (g)		Test weight (kg/hl)	
	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$	S
2008/09						
C	1.671 <sup>d*</sup>	0.190	40.50 <sup>ab</sup>	0.962	77.44 <sup>a</sup>	2.942
N <sub>120</sub>	4.410 <sup>b</sup>	0.583	37.03 <sup>de</sup>	1.507	75.82 <sup>a</sup>	2.257
P <sub>60</sub>	3.341 <sup>c</sup>	0.463	41.62 <sup>a</sup>	0.691	75.83 <sup>a</sup>	4.029
P <sub>100</sub>	3.185 <sup>c</sup>	0.216	42.00 <sup>a</sup>	0.418	77.91 <sup>a</sup>	1.873
N <sub>120</sub> P <sub>60</sub>	5.854 <sup>a</sup>	0.138	36.42 <sup>e</sup>	1.244	76.61 <sup>a</sup>	1.081
N <sub>120</sub> P <sub>100</sub>	5.971 <sup>a</sup>	0.280	37.86 <sup>cde</sup>	1.835	74.93 <sup>a</sup>	2.086
N <sub>120</sub> P <sub>60</sub> K <sub>60</sub>	6.149 <sup>a</sup>	0.355	38.44 <sup>cd</sup>	0.573	75.42 <sup>a</sup>	2.866
N <sub>120</sub> P <sub>100</sub> K <sub>60</sub>	6.305 <sup>a</sup>	0.460	39.07 <sup>bc</sup>	1.718	76.26 <sup>a</sup>	2.522
2009/10						
C	0.951 <sup>e</sup>	0.172	39.04 <sup>bc</sup>	0.639	74.01 <sup>a</sup>	1.552
N <sub>120</sub>	2.936 <sup>bc</sup>	0.524	39.46 <sup>ab</sup>	0.555	72.37 <sup>a</sup>	1.180
P <sub>60</sub>	1.606 <sup>de</sup>	0.284	39.12 <sup>bc</sup>	1.250	73.69 <sup>a</sup>	1.539
P <sub>100</sub>	2.542 <sup>cd</sup>	1.228	38.22 <sup>c</sup>	0.415	73.57 <sup>a</sup>	2.748
N <sub>120</sub> P <sub>60</sub>	3.750 <sup>ab</sup>	0.641	39.16 <sup>bc</sup>	0.230	71.81 <sup>a</sup>	3.144
N <sub>120</sub> P <sub>100</sub>	4.054 <sup>a</sup>	0.602	39.96 <sup>ab</sup>	0.297	70.88 <sup>a</sup>	3.007
N <sub>120</sub> P <sub>60</sub> K <sub>60</sub>	4.438 <sup>a</sup>	1.429	39.22 <sup>b</sup>	0.965	73.33 <sup>a</sup>	2.763
N <sub>120</sub> P <sub>100</sub> K <sub>60</sub>	4.363 <sup>a</sup>	0.693	40.26 <sup>a</sup>	0.451	73.41 <sup>a</sup>	1.220
2010/11						
C	1.254 <sup>c</sup>	0.103	35.21 <sup>d</sup>	0.616	79.28 <sup>a</sup>	1.879
N <sub>120</sub>	3.902 <sup>c</sup>	0.312	38.38 <sup>c</sup>	1.029	78.07 <sup>abc</sup>	0.656
P <sub>60</sub>	1.896 <sup>de</sup>	0.409	38.51 <sup>c</sup>	1.702	78.48 <sup>abc</sup>	1.118
P <sub>100</sub>	1.994 <sup>d</sup>	0.363	38.71 <sup>bc</sup>	2.216	78.98 <sup>ab</sup>	0.521
N <sub>120</sub> P <sub>60</sub>	5.192 <sup>b</sup>	0.469	40.02 <sup>abc</sup>	0.468	76.61 <sup>c</sup>	0.727
N <sub>120</sub> P <sub>100</sub>	5.277 <sup>ab</sup>	0.767	40.35 <sup>ab</sup>	0.858	77.12 <sup>abc</sup>	3.195
N <sub>120</sub> P <sub>60</sub> K <sub>60</sub>	5.187 <sup>b</sup>	0.816	40.52 <sup>a</sup>	0.847	79.29 <sup>a</sup>	1.249
N <sub>120</sub> P <sub>100</sub> K <sub>60</sub>	5.915 <sup>a</sup>	0.332	40.67 <sup>a</sup>	1.154	76.94 <sup>bc</sup>	1.323

\*Means within columns followed by different lowercase letters are significantly different (P<0.05) according to the LSD test.

The 1000-grain weight of winter wheat significantly varied across years and treatments. During the 2008/09 years 1000-grain weight significantly varied across treatments from 36.42 g in treatment N<sub>120</sub>P<sub>60</sub> to 40.50 g in control. During the 2009/10 years 1000-grain weight significantly varied across treatments from 38.22 g in treatment P<sub>60</sub> to 40.26 g in N<sub>120</sub>P<sub>100</sub>K<sub>60</sub>. During the 2010/11 years

1000-grain weight significantly varied across treatments from 35.21 g in control to 40.67 g in N<sub>120</sub>P<sub>100</sub>K<sub>60</sub>.

The test weight of winter wheat significantly varied across years and treatments. Averaged across 2008/09 years, significantly higher values for test weight were found in the treatment P<sub>60</sub> (77.91 kg/hl), in 2009/10 in the control (74.01 kg/hl) and in 2010/11 in the control and treatment N<sub>120</sub>P<sub>60</sub>K<sub>60</sub> (79.28 kg/hl and 79.29 kg/hl).

Table 5. Correlations between the traits analyzed by three vegetation seasons

Traits	Grain yield	1000-grain weight	Test weight
Correlations between the traits analyzed in 2008/2009			
Grain yield (t ha <sup>-1</sup> )	1.00	-0.562**	-0.242 <sup>ns</sup>
1000-grain weight (g)		1.00	0.113 <sup>ns</sup>
Test weight (kg hl <sup>-1</sup> )			1.00
Correlations between the traits analyzed in 2009/2010			
Grain yield (t ha <sup>-1</sup> )	1.00	0.450*	-0.050 <sup>ns</sup>
1000-grain weight (g)		1.00	0.045 <sup>ns</sup>
Test weight (kg hl <sup>-1</sup> )			1.00
Correlations between the traits analyzed in 2010/2011			
Grain yield (t ha <sup>-1</sup> )	1.00	0.711**	-0.443*
1000-grain weight (g)		1.00	-0.284 <sup>ns</sup>
Test weight (kg hl <sup>-1</sup> )			1.00

Table 5 presents the correlation coefficients between the years and examined traits. Test weight in 2008/09 was positively correlated with 1000-grain weight ( $r=0.113$ ) and negatively but dependent significantly correlated with grain yield and 1000-grain weight ( $r=-0.562^{**}$ ). Wheat yield in 2009/10 was positively and significantly correlated with 1000-grain weight ( $r=0.450^*$ ). The correlative dependence of the grain yield in the 2010/11 vegetation season in was positively and highly significant correlation with the 1000-grain weight ( $r=0.711^{**}$ ). Grain yield depends directly on the number of grains per spike and the 1000-grain weight (Hristov et al., 2011; Đekić et al., 2014, 2017a; Terzić et al., 2018a).

Table 6 presents the correlation coefficients between the treatments and examined traits. The correlative dependence of the grain yield in the treatment P<sub>1</sub> in was positively and highly significant correlation with the 1000-grain weight ( $r=0.806^{**}$ ). Positive correlations were observed between grain yield and test weight in all treatments. Positively and medium significantly correlations were also found between grain yield and test weight in the N ( $r=0.533^*$ ) and positively but strong significantly correlated were also found in the NP<sub>1</sub> ( $r=0.846^{**}$ ) treatments. Negative correlation between 1000-grain weight and test weight has been established (Đekić et al., 2017c; Terzić et al., 2018a).

Table 6. Correlation coefficients for the traits analyzed across treatments

	Grain yield	1000-grain weight	Test weight
Correlations between the traits analyzed in the unfertilized control			
Grain yield (t ha <sup>-1</sup> )	1.00	0.343 <sup>ns</sup>	0.450 <sup>ns</sup>
1000-grain weight (g)		1.00	-0.344 <sup>ns</sup>
Test weight (kg hl <sup>-1</sup> )			1.00
Correlations between the traits analyzed in the N			
Grain yield (t ha <sup>-1</sup> )	1.00	-0.463 <sup>ns</sup>	0.533 <sup>*</sup>
1000-grain weight (g)		1.00	-0.409 <sup>ns</sup>
Test weight (kg hl <sup>-1</sup> )			1.00
Correlations between the traits analyzed in the P <sub>1</sub>			
Grain yield (t ha <sup>-1</sup> )	1.00	0.806 <sup>**</sup>	0.169 <sup>ns</sup>
1000-grain weight (g)		1.00	-0.158 <sup>ns</sup>
Test weight (kg hl <sup>-1</sup> )			1.00
Correlations between the traits analyzed in the P <sub>2</sub>			
Grain yield (t ha <sup>-1</sup> )	1.00	0.501 <sup>ns</sup>	0.094 <sup>ns</sup>
1000-grain weight (g)		1.00	0.300 <sup>ns</sup>
Test weight (kg hl <sup>-1</sup> )			1.00
Correlations between the traits analyzed in the NP <sub>1</sub>			
Grain yield (t ha <sup>-1</sup> )	1.00	-0.481 <sup>ns</sup>	0.846 <sup>**</sup>
1000-grain weight (g)		1.00	-0.131 <sup>ns</sup>
Test weight (kg hl <sup>-1</sup> )			1.00
Correlations between the traits analyzed in the NP <sub>2</sub>			
Grain yield (t ha <sup>-1</sup> )	1.00	-0.458 <sup>ns</sup>	0.364 <sup>ns</sup>
1000-grain weight (g)		1.00	-0.111 <sup>ns</sup>
Test weight (kg hl <sup>-1</sup> )			1.00
Correlations between the traits analyzed in the NP <sub>1</sub> K			
Grain yield (t ha <sup>-1</sup> )	1.00	-0.072 <sup>ns</sup>	0.167 <sup>ns</sup>
1000-grain weight (g)		1.00	0.675 <sup>*</sup>
Test weight (kg hl <sup>-1</sup> )			1.00
Correlations between the traits analyzed in the NP <sub>2</sub> K			
Grain yield (t ha <sup>-1</sup> )	1.00	-0.094 <sup>ns</sup>	0.461 <sup>ns</sup>
1000-grain weight (g)		1.00	-0.288 <sup>ns</sup>
Test weight (kg hl <sup>-1</sup> )			1.00

<sup>ns</sup>non significant; <sup>\*</sup>significant at 0.05; <sup>\*\*</sup>significant at 0.01;

## CONCLUSIONS

Effects of mineral nutrition efficiency of wheat have been studied at the stationary field trial of the Institute of Small Grains Research Centre in Kragujevac (Serbia) for three years (2008/09, 2009/10 and 2010/11). Nitrogen had a most significant impact on the yield of wheat. The average grain yield of all treatments in the 2008/09 growing season was significant greater than in the following years. The highest average yields were gained by N<sub>120</sub>P<sub>100</sub>K<sub>60</sub> treatment (5.528 t/ha), N<sub>120</sub>P<sub>60</sub>K<sub>60</sub> treatment (5.258 t/ha) and N<sub>120</sub>P<sub>100</sub> treatment



(5.101 t/ha) in three-year period. The analysis of variance indicated highly significant effects of year on the grain yield and test weight. Effects of fertilization on the 1000-grain weight were statistically significant. Interaction between the analysed factors (year x fertilization) shows a highly significant effect on 1000-grain weight in wheat. The average grain yield was significantly higher in 2008/09, while in 2010/11 of test weight was significantly higher.

In 2008/09 a negatively and medium-dependent significant correlation was found between grain yield and 1000-grain weight ( $-0.562^{**}$ ) as well as a significant positive correlation in 2009/10 ( $0.450^{*}$ ), while these positive and strong correlations in 2010/11 were highly significant ( $0.711^{**}$ ).

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