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IMPACT OF LONG-TERM FERTILIZATION ON YIELD IN WHEAT GROWN ON SOIL TYPE VERTISOL

SUMMARY

Experiments were carried out at stationary in Kragujevac, in Serbia, during the three growing seasons. The primary aim of the research was perceiving of the influence of long-term usage of the same amounts and rates of nitrogen, phosphorus and potassium on the yield and grain quality of winter wheat variety „Kruna“. Uptake NPK uptake by wheat ranged from 120 kg ha^{-1} nitrogen, from 60 to 100 kg ha^{-1} phosphorus and 60 kg ha^{-1} potassium, respectively, depending on treatments type. The grain yield of the wheat was significantly lower in control (treatment without fertilizer). The three-year grain yield of winter wheat was the highest in the NP$_1$K and NP$_2$K (4.367 and 4.531 t ha^{-1}) treatments. In terms of investigated traits, particularly grain yield and test weight fertilizer expressed more efficiency in the 2014/2015. Variance analysis showed statistically very significant differences for grain yield, 1.000-grain weight and test weight between the vegetation seasons and very significant differences for grain yield and 1000-grain weight between the variants of fertilization. Variance analysis showed very significant differences for 1000-grain weight between the interaction of the vegetation seasons and variants of fertilization.

It could be concluded that the grain yield in all treatments in the 2014/2015 growing season was significantly greater than in the other examined years, mostly as the result of highly favorable weather conditions at major stages of plant development wheat.

Keywords: fertilization, mineral nutrition, yield, wheat, correlation.

INTRODUCTION

In the last few decades, large experimental material about mineral nutrition and fertilizing of wheat was gathered. However, taking into account the dominant influence of the mineral nutrition in the synthesis of primary production of the

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organic matter and yield forming, this problem, intensively researched until now, will stay in the focal point of researchers and practitioners as long as plants cultivated (Knežević et al., 2015). A constant advance in the selection and creation of new varieties represents the strong impetus to research of different problems of the mineral nutrition of wheat (Perišić et al., 2016; Khan et al., 2017; Djuric et al., 2018; Jordanovska et al., 2018; Terzić et al., 2018a; Rajičić et al., 2019). With the appearance of the new wheat variety (essentially distinguished in a number of useful traits, a higher yield potential on the first place), it turned out their demands are more pronounced according to mineral nutrition (Knežević et al., 2007; Jelić et al., 2016; Khan and Mohammad, 2016; Đekić et al., 2017a; Tmušić et al., 2018).

Winter wheat use relatively large amounts of mineral elements during vegetation and have high demands according to soil fertility (Jelić et al., 2014; Đekić et al., 2017b). From the numerous macroelements from the soil, wheat use nitrogen the most, something less potassium, even less phosphorus and the least sulfur, magnesium, and calcium (Milivojević et al., 2018). Amounts of nutritional elements from the soil used by wheat during vegetation mostly depend on the grain yield level and the vegetative mass. In Serbia, the most often amounts of nitrogen needed to be applied for high yield are ranged between 80-120 kg ha-1 depending on agrochemical properties of the soil (Malešević et al., 2010; Popović et al., 2011; Đekić et al., 2014; Jelic et al., 2015; Terzic et al., 2018b; Rajičić et al., 2019).

From the numerous macroelements, nitrogen, phosphorus, and potassium are the most important for wheat growth and development and in certain quantities and rates must be incorporated in almost all soil types, regardless it represents direct nutrient usage or usage in preceding cultivated species (Popović et al., 2011). Between the elements of mineral nutrition, the nitrogen has the greatest role in yield increases of cultivated species (Knežević et al., 2007; Đekić et al., 2014; Terzic et al., 2018b; Madić et al., 2019), especially in wheat (Jelic et al., 2015; Khan and Mohammad, 2016; Đekić et al., 2017a; Rajičić et al., 2020). Nitrogen is showing the greatest effect through the joint usage with phosphorus and potassium (Popović et al., 2011; Đekić et al., 2014; Jelić et al., 2014; Khan et al., 2017; Terzic et al., 2018b; Knežević et al., 2019; Rajičić et al., 2019).

The primary aim of the research was perceiving of the influence of long-term usage of the same amounts and rates of nitrogen, phosphorus and potassium on the yield and grain quality of winter wheat variety „Kruna“, during the three growing seasons (2012/13, 2013/14 and 2014/15) on location Kragujevac in Republic of Serbia.

MATERIAL AND METHODS

Experimental design

Effects of mineral nutrition efficiency of wheat have been studied at the stationary field trial of the Small Grains Research Centre at Kragujevac location, (44° 22′ N, 20° 56′ E, 173-220 m a. s. l.) of Šumadija district in Republic of

Serbia, for three years period from 2013 to 2015. The winter wheat cultivar used in the experiment was Kruna, the dominant cultivar in the production region of Šumadija in Republic of Serbia. Fertilization was regular and followed a long-time scheme. Wheat sowing was done on two separated stationary fields (A and B) with corn rotation system.

Because of appearance of new demanded cultivars at permanent changes in soil fertility level and environmental conditions, still exist need to researches mineral nutrition of wheat, as well as determine optimal rates and balanced nutrition ratios in concrete agro ecological conditions. The rates of nitrogen application were 120 kg ha^{-1} 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. Eight variants of mineral nutrition N (120 kg ha^{-1} N), P_1 (60 kg ha^{-1} P_2O_5), P_2 (100 kg ha^{-1} P_2O_5), NP_1 (120 kg ha^{-1} N and 60 kg ha^{-1} P_2O_5), NP_2 (120 kg ha^{-1} N and 100 kg ha^{-1} P_2O_5), NP_1K (120 kg ha^{-1} N, 60 kg ha^{-1} P_2O_5 and 60 kg ha^{-1} K_2O), NP_2K (120 kg ha^{-1} N, 100 kg ha^{-1} P_2O_5 and 60 kg ha^{-1} K_2O) and untreated control were tested in the experiment. The fertilizers applied were complex NPK fertilizers (15:15:15), superphosphate (17% P_2O_5) and CAN (calcium ammonium nitrate) as a nitrogen fertilizer containing 27% N. Total amounts of phosphorus and potassium fertilizers and half the nitrogen rate are regularly applied during pre-sowing cultivation of soil.

Sowing in all three analyzed years was carried out in the second half of October, at spacing between rows with of 12 cm, with a seed density of 500 germinating grains per m^2. The trial was designed in a randomized block with five replications. The crops were harvested at full maturity using (dates of harvesting 17.07.2012, 15.07.2013 and 04.07.2014). Three parameters, namely grain yield (t ha^{-1}), 1000-grain weight (g) and test weight (kg hl^{-1}) were analyzed. Grain yield was harvested and reported at 14% moisture. The 1000-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 (humus 2.2%, nitrogen 0.13%, phosphorus 2.0 mg 100 g^{-1} soil, potassium 20.0 mg K2O 100 g^{-1} soil and pH in H_2O 5.19).

Statistical analysis

The results were analyzed by the method of analyzing the variance of a single-factorial trial (ANOVA) using the statistics module Analyst Program SAS/STAT (SAS Institute, 2000). The significance of differences in mean values of the treatments was tested by the LSD test. 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.

Meteorological conditions

This study was conducted over a three-year period in the Šumadija region, Central Serbia, on a Vertisol soil, at Kragujevac location (Table 1).

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

Months	X	XI	XII	I	II	III	IV	V	VI	VII	Aver.
Mean monthly air temperature (°C)											
2012/13	13.5	9.5	1.7	2.9	4.0	6.5	13.4	18.2	19.9	21.9	11.15
2013/14	13.5	9.2	2.4	5.0	6.9	9.0	12.2	15.3	19.7	21.8	11.50
2014/15	12.6	9.1	3.5	3.0	3.2	6.7	19.8	17.4	19.9	24.4	11.96
Average	12.5	6.9	1.9	0.5	2.4	7.1	11.6	16.9	20.0	22.0	10.18
The amount of precipitation (mm)											
2012/13	56.2	17.7	16.4	65.8	84.4	102.9	41.2	70.8	85.4	60.6	601.4
2013/14	41.7	61.2	6.4	21.2	9.0	67.1	129	227	45.8	138.6	747.0
2014/15	50.4	18.9	98.7	44.9	46.2	98.8	35.8	93.6	113	25.4	625.7
Average	45.4	48.9	56.6	58.2	46.6	32.4	51.9	57.6	70.4	46.6	514.6

Data in Table 1 for the investigated period clearly indicate that meteorological conditions recorded high variability during research. The average air temperature was higher by 0.97°C, 1.32°C and 1.78°C in 2012/13, 2013/14 and 2014/15 than the average of many years. The sum of rainfall precipitation was higher by 86.8 mm, 232.4 mm and 111.1 mm in 2012/13, 2013/14 and 2014/15 than the average of many years and with a very uneven distribution of precipitation per months. During the April and May in 2013/14 it more of rainfall what for 77.1 mm and 169.4 mm compared with the perennial average. 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 (Dodig et al., 2008; Hristov et al., 2011; Iftikhar et al., 2012; Jelic et al., 2015; Terzić et al., 2018a; Grčak et al., 2019; Biberdzic et al., 2020).

RESULTS AND DISCUSSION

Grain yield, 1000-grain weight and test weight

Table 2 presents average values for grain yield, 1000-grain weight and test weight across years and treatments during the study. The highest three-year wheat grain yield of 3.787 t ha^{-1} was recorded in vegetation season 2014/15 and it was significantly higher than the yield in 2013/14 (2.382 t ha^{-1}). The three-year grain yield significantly varied across treatments, from 1.156 t ha^{-1} in control to 4.531 t ha^{-1} in treatment NP_2K with 120 kg ha^{-1} N, 100 kg ha^{-1} P_2O_5 and 60 kg ha^{-1} K_2O.

The average three-year 1000-grain weight significantly varied across years from 37.19 g in 2014/15 to 40.77 g in 2012/13. The 1000-grain weight of winter wheat significantly varied across treatments, from 34.87 g in control to 41.01 g in treatment in treatment NP_2K with 120 kg ha^{-1} N, 100 kg ha^{-1} P_2O_5 and 60 kg ha^{-1} K_2O.

The highest three-year wheat test weight in year 2014/15 (76.34 kg hl^{-1}) was significantly higher compared to 2012/13 and 2013/14 (71.80 and 72.25 kg hl^{-1}). The highest test weight had the wheat application in treatment NP$_1$K in a quantity of 120 kg ha^{-1} N, 60 kg ha^{-1} P$_2$O$_5$ and 60 kg ha^{-1} K$_2$O (74.54 kg hl^{-1}).

Table 2. The mean values for traits analyzed in Kragujevac, Serbia

Years	Grain yield (t ha^{-1})		1000-grain weight (g)		Test weight (kg hl^{-1})	
	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$	S
2012/13	3.233^{B*}	1.445	40.77^{A}	2.505	71.80^{C}	2.236
2013/14	2.382^{C}	0.934	39.30^{AB}	2.278	72.25^{B}	2.510
2014/15	3.787^{A}	1.569	37.19^{B}	3.502	76.34^{A}	2.346
Treatments						
C	1.156^{c}	0.498	34.87^{c}	3.620	72.79^{a}	3.308
N	2.837^{b}	0.690	39.97^{ab}	2.135	73.58^{a}	3.322
P$_1$	2.226^{b}	0.619	38.34^{b}	2.917	72.37^{a}	3.059
P$_2$	2.247^{b}	1.242	38.61^{b}	2.140	73.69^{a}	3.330
NP$_1$	3.803^{a}	1.156	40.59^{a}	2.140	73.36^{a}	2.518
NP$_2$	3.904^{a}	0.933	40.97^{a}	1.853	73.73^{a}	3.254
NP$_1$K	4.367^{a}	1.053	38.33^{b}	2.702	74.54^{a}	3.516
NP$_2$K	4.531^{a}	1.075	41.01^{a}	2.646	73.65^{a}	2.764

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

Table 3 presents average values for grain yield, 1000-grain weight and test weight across years and treatments during the study. The yield during the 2012/13 significantly varied across treatments and the highest yield of 4.385 t ha^{-1} and 4.779 t ha^{-1} of was recorded in the NP$_1$K and NP$_2$K treatments. During the 2013/14 year, the yield significantly varied across treatments, and the highest average grain yield was recorded in the NP2K treatment (3.456 t ha^{-1}). During the 2014/15 grain yield significantly varied across treatments and the highest yield was in the NP$_1$K and NP$_2$K treatments (5.493 and 5.357 t ha^{-1}).

The 1000-grain weight of winter wheat significantly varied across all years and treatments as presented in Table 3. During the 2012/13 and 2013/14 1000-grain weight significantly varied across treatments and the highest 1000-grain weight was in the NP$_2$K treatment (43.36 g and 41.62 g). During the 2014/15 1000-grain weight significantly varied across treatments from 31.16 g in control to 40.84 g in NP$_2$. The contribution of fertilization in the 1000-grain weight was 15% more at control (treatment without fertilizer) compared to N treatment (under low or high nitrogen content) in grain yield variation (Rajičić et al., 2019).

The test weight in 2012/13 year varied across treatments, from 70.25 kg hl^{-1} in P$_2$ to 73.41 kg hl^{-1} in NP$_2$K treatments (Table 3). The higher values for test weight in 2013/14 year were found in the P$_2$ treatment (73.97 kg hl^{-1}). During the third year of examination (2014/15), significantly higher values for test weight were found in the NP$_1$K treatment (78.48 kg hl^{-1}).

The present results confirm the opinion of many authors that the GY and TGW are genetically determined but are strongly modified by the weather conditions and soil nutrient availability (Đekić et al., 2014; Jelić et al., 2014; Khan and Mohammad, 2016; Khan et al., 2017; Terzic et al., 2018b; Knežević et al., 2019; Rajičić et al., 2020).

Table 3. Mean values for traits analyzed of years and fertilization in Kragujevac, Serbia

2012/13	Grain yield (t ha^{-1})		1000-grain weight (g)		Test weight (kg hl^{-1})	
	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$	S
C	1.006^{d}	0.338	39.20^{b}	0.485	70.73^{a}	1.197
N	2.970^{bc}	0.683	42.14^{a}	0.297	72.13^{a}	2.305
P_1	2.381^{c}	0.590	40.16^{b}	1.335	70.77^{a}	3.012
P_2	2.501^{c}	2.131	39.92^{b}	1.616	70.25^{a}	2.289
NP_1	3.785^{ab}	0.261	42.28^{a}	0.973	72.69^{a}	1.931
NP_2	4.054^{ab}	0.692	42.52^{a}	0.968	72.37^{a}	1.988
NP_1K	4.385^{a}	0.482	36.62^{c}	3.268	72.05^{a}	2.638
NP_2K	4.779^{a}	0.615	43.36^{a}	0.713	73.41^{a}	1.565
2013/14						
C	0.806^{f}	0.186	34.24^{c}	0.532	72.45^{a}	2.698
N	2.338^{cd}	0.363	39.98^{b}	0.657	71.17^{a}	1.368
P_1	1.855^{de}	0.584	40.24^{ab}	1.276	71.25^{a}	2.209
P_2	1.656^{ef}	0.249	39.52^{b}	1.045	73.97^{a}	2.270
NP_1	2.738^{bc}	0.508	39.26^{b}	1.571	71.89^{a}	2.308
NP_2	2.986^{ab}	0.243	39.56^{b}	1.499	72.37^{a}	3.457
NP_1K	3.224^{ab}	0.524	39.98^{b}	1.083	73.09^{a}	1.972
NP_2K	3.456^{a}	0.538	41.62^{a}	0.350	71.80^{a}	3.647
2014/15						
C	1.657^{c*}	0.473	31.16^{e}	2.054	75.18^{ab}	4.122
N	3.203^{b}	0.754	37.80^{bc}	1.912	77.43^{ab}	1.738
P_1	2.442^{bc}	0.625	34.62^{d}	0.646	75.09^{b}	2.184
P_2	2.584^{bc}	0.379	36.40^{cd}	1.744	76.85^{ab}	1.020
NP_1	4.886^{a}	1.211	40.24^{ab}	2.585	75.49^{ab}	2.051
NP_2	4.671^{a}	0.831	40.84^{a}	1.824	76.46^{ab}	2.685
NP_1K	5.493^{a}	0.392	38.38^{abc}	2.575	78.48^{a}	1.625
NP_2K	5.357^{a}	1.001	38.06^{abc}	2.373	75.73^{ab}	1.110

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

Analysis of variance the analyzed traits

The analysis variance of yield, 1000-grain weight and test weight of wheat depending on the level of nitrogen, phosphorus and potassium fertilization on the yield and grain quality of wheat at Kragujevac in Serbia during three growing seasons, are shown in table 4. Data in Table 4 for the investigated period (2013-2015) clearly indicate that highly significant effect of year was found on grain yield (F=11.069**), 1000 grain-weight (F=16.445**) and test weight (F=44.664**). Furthermore, grain yield (F=24.371**) and 1000-grain weight (F=9.528**) was highly significant among the fertilization. The 1000-grain weight was highly significant regarding the interaction years and different treatments. The present results confirm the opinion of many authors that the grain yield and 1000-grain weight are genetically determined but are strongly modified by the weather conditions and soil nutrient availability (Đekić et al. 2014, 2017a; Jelic et al., 2014, 2015; Khan et al., 2017; Milivojević et al., 2018; Popovic et. al., 2017; Terzić et al., 2018a; Tmušić et al., 2018; Rajičić et. al., 2019). Application of mineral fertilizers has a significant impact on 1000-grain weight which is significantly higher in more intensively fertilized variants as observed by Đekić et al. (2014), Terzić et al. (2018a) and Rajičić et al. (2020).

Table 4. 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	20.014	1.808	11.069**	0.000
Fertilization, (F)	7. 112	21.695	0.890	24.371**	0.000
Year x Fertilization, (YxF)	14. 96	0.629	0.530	1.188	0.297
The analysis of variance for 1000-grain weight					
Year, (Y)	2. 117	130.056	7.908	16.445**	0.000
Fertilization, (F)	7. 112	63.204	6.634	9.528**	0.000
Year x Fertilization, (YxF)	14. 96	17.105	2.535	6.747**	0.008
The analysis of variance for test weight					
Year, (Y)	2. 117	250.198	5.602	44.664**	0.000
Fertilization, (F)	7. 112	6.417	9.919	0.647	0.716
Year x Fertilization, (YxF)	14. 96	5.631	5.538	1.017	0.444

^{ns}non significant; *significant at 0.05; **significant at 0.01;

Table 5. Correlations between for traits analyzed by vegetation seasons

Correlations between the traits analyzed in 2012/13			
Traits	Grain yield (t ha^{-1})	1000-grain weight (g)	Test weight (kg hl^{-1})
Grain yield (t ha^{-1})	1.00	0.219^{ns}	0.374*
1000-grain weight (g)		1.00	0.170^{ns}
Test weight (kg hl^{-1})			1.00
Correlations between the traits analyzed in 2013/14			
Grain yield (t ha^{-1})	1.00	0.683**	-0.022^{ns}
1000-grain weight (g)		1.00	-0.143^{ns}
Test weight (kg hl^{-1})			1.00
Correlations between the traits analyzed in 2014/15			
Grain yield (t ha^{-1})	1.00	0.733**	0.094^{ns}
1000-grain weight (g)		1.00	0.565^{ns}
Test weight (kg hl^{-1})			1.00

^{ns}non significant; *significant at 0.05; **significant at 0.01;

Correlations between the analyzed traits

Table 5 presents the correlation coefficients between the years and examined traits. Positive and significant correlation coefficients, in 2012/13, were found between grain yield and test weight (r=0.374*). Highly significant and positive correlation coefficients, in 2013/14, as presented in Table 5, were found between grain yield and 1000-grain weight (r=0.683**). Highly significant and positive correlation coefficients, in 2014/15, were found between grain yield and 1000-grain weight (r=0.733**), Table 5. The correlative dependence of the grain yield in the vegetation seasons was positive and highly significant with 1000 grain weight as established by Iftikhar et al. (2012), Đekić et al. (2014) and Terzić et al. (2018a). Grain yield depends directly on the number of grains per spike and the 1000 grain weight (Hristov, 2011; Iftikhar et al., 2012; Khan and Mohammad, 2016; Đekić et al., 2017a; Khan et al., 2017; Djuric et al., 2018; Terzić et al., 2018a).

Table 6. Correlation coefficients for the traits analyzed across treatments

Correlations between the traits analyzed in the unfertilized control			
	Grain yield (t ha^{-1})	1000-grain weight (g)	Test weight (kg hl^{-1})
Grain yield (t ha^{-1})	1.00	-0.299^{ns}	0.383^{ns}
1000-grain weight (g)		1.00	-0.440^{ns}
Test weight (kg hl^{-1})			1.00
Correlations between the traits analyzed in the N			
Grain yield (t ha^{-1})	1.00	-0.365^{ns}	0.344^{ns}
1000-grain weight (g)		1.00	-0.596*
Test weight (kg hl^{-1})			1.00
Correlations between the traits analyzed in the P_1			
Grain yield (t ha^{-1})	1.00	-0.216^{ns}	0.186^{ns}
1000-grain weight (g)		1.00	-0.707**
Test weight (kg hl^{-1})			1.00
Correlations between the traits analyzed in the P_2			
Grain yield (t ha^{-1})	1.00	-0.067^{ns}	0.188^{ns}
1000-grain weight (g)		1.00	-0.628*
Test weight (kg hl^{-1})			1.00
Correlations between the traits analyzed in the NP_1			
Grain yield (t ha^{-1})	1.00	0.471^{ns}	0.286^{ns}
1000-grain weight (g)		1.00	-0.044^{ns}
Test weight (kg hl^{-1})			1.00
Correlations between the traits analyzed in the NP_2			
Grain yield (t ha^{-1})	1.00	0.536*	0.193^{ns}
1000-grain weight (g)		1.00	-0.145^{ns}
Test weight (kg hl^{-1})			1.00
Correlations between the traits analyzed in the NP_1K			
Grain yield (t ha^{-1})	1.00	-0.162^{ns}	0.603*
1000-grain weight (g)		1.00	0.021^{ns}
Test weight (kg hl^{-1})			1.00
Correlations between the traits analyzed in the NP_2K			
Grain yield (t ha^{-1})	1.00	-0.133^{ns}	0.468^{ns}
1000-grain weight (g)		1.00	-0.316^{ns}
Test weight (kg hl^{-1})			1.00

^{ns}non significant; *significant at 0.05; **significant at 0.01;

Table 6 presents the correlation coefficients between the treatments and examined traits. The correlative dependence of the grain yield in the treatment NP_2 in was positive and medium significant correlation with the 1000-grain weight ($r=0.536^{*}$). Positive correlations were observed between grain yield and test weight in all treatments. Negative and medium significant correlation coefficients were found between 1000-grain weight and test weight in treatments N ($r=-0.596^{*}$) and P_2 ($r=-0.628^{*}$) and negative but strong highly significant correlation were in the treatment P_1 ($r=-0.707^{**}$).

The present results confirm the statement of many authors that the traits analyzed and their correlations are genetically determined but are strongly modified by the nutrient status of the environment and weather conditions (Đekić et al., 2014; Khan and Mohammad 2016; Terzic et al., 2018b; Lakić et al., 2018; Nazarenko et al., 2019; Rajičić et al., 2019).

CONCLUSIONS

Because of appearance of new demanded cultivars at permanent changes in soil fertility level and environmental conditions, still exist need to researches mineral nutrition of wheat, as well as determine optimal rates and balanced nutrition ratios in concrete agro ecological conditions. Effects of mineral nutrition efficiency of wheat have been studied at the stationary field trial of the Small Grains Research Centre in Kragujevac (Serbia) from 2012/2013 to 2014/2015. Nitrogen had a most significant impact on the yield of wheat. The average grain yield of all cultivars in the 2014/15 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 highest average yields were gained by NP1K (4.367 t ha-1) and NP2K (4.531 t ha-1) treatment in three-year period.

The analysis of variance showed very significant differences of vegetation seasons on the grain yield, 1000-grain weight and test weight. The analysis of variance showed statistically highly significant differences for grain yield and 1000-grain weight between the fertilization. Mineral nutrition in study significantly increased the yield of winter wheat.

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REFERENCES

Biberdzic, M., Barac, S., Lalevic, D., Djikic, A., Prodanovic, D., Rajicic, V. (2020): Influence of soil tillage system on soil compactionand winter wheat yield. Chilean Journal of Agricultural Research, 80 (1): 80-89.

Dodig D., Zorić M., Knežević D., King S., Šurlan-Momirović G. (2008): Genotype x environment interaction for wheat yield in different drought stress conditions and agronomic traits suitable for selection. *Aust. J. Agr. Res.*, 59: 536-545.

Đekić V., Milovanović M., Popović V., Milivojević J., Staletić M., Jelić M., Perišić, V. (2014): Effects of fertilization on yield and grain quality in winter triticale. Rom. Agric. Res., 31: 175-183.

Đekić V., Jelić M., Milivojević J., Popović V., Branković S., Staletić M., Terzić D. (2017a): Winter wheat yield and yield components depending on the level of nitrogen, phosphorus and potassium fertilization. Proceedings, VIII International Scientific Agriculture Symposium "Agrosym 2017", 05-08 October, Jahorina, 650-657.

Đekić V., Milivojević J., Jelić M., Popović V., Branković S., Biberdžić M., Terzić D. (2017b): Effects of fertilization on production traits of Takovčanka cultivar of winter wheat. Proceedings, 2nd International and 14th National Congress of Soil Science Society of Serbia “Solutions and Projections for Sustainable Soil Management”. NSoil 2017, 25-28th September 2017, Novi Sad, Serbia, 49-54.

Djuric N., Prodanovic S., Brankovic G., Djekic V., Cvijanovic G., Zilic S., Dragicevic V., Zecevic V., Dozet G. (2018): Correlation-Regression Analysis of Morphological-Production Traits of Wheat Varieties. Rom. Biotech. Lett. 23 (2): 13457-13465.

Grčak M., Grčak D., Grčak D., Aksić M., Gudžić S., Nikolić K., Rajičić V. (2019): Phosphorus, potassium and nitrogen abundance in soil of Doljevac municipalit. Proceedings, X International Scientific Agriculture Symposium "Agrosym 2019", Jahorina, October 03-06, 2019, 1169-1173.

Hristov N., Mladenov N., Kondić-Špika A. (2011): Effect of environmental and genetic factors on the correlation and stability of grain yield components in wheat. Genetika, 43 (1): 141-152.

Iftikhar R., Khaliq I., Ijaz M., Rahman A.M. (2012): Association analysis of grain yield and its components in spring wheat (*Triticum aestivum* L.). Amer. Euras. J. Agric. Envir. Sci., 12 (3): 289-392.

Jelić M., Milivojević J., Đekić V., Paunović A., Tmušić N. (2014): Impact of liming and fertilization on grain yield and utilization of nitrogen and phosphorus in wheat plant grown on soil type pseudogley. Proceedings of research papers PKB Agroekonomik, Belgarde, 20 (1-4): 49-56.

Jelic M., Milivojevic J., Nikolic O., Djekic V., Stamenkovic S. (2015): Effect of long-term fertilization and soil amendments on yield, grain quality and nutrition optimization in winter wheat on an acidic pseudogley. Rom. Agric. Res., 32: 165-174.

Jelić M., Milivojević J., Paunović A., Madić M., Đekić V. (2016): Adaptation of winter wheat genotypes to low ph and high mobile al content in the soil. Proceedings, VII International Scientific Sympozium "Agrosym Jahorina 2016", AGROSYM, 06-09. October, Jahorina, 762-767.

Jordanovska S., Jović Z., Dolijanović Ž., Dragičević V., Branković G., Đekić V. (2018): Nutritional properties of Macedonian landraces of small grain cereals as a source of new genetic variability. Genetika, 50 (3): 863-883. doi: 10.2298/GENSR1803863J

Knezevic D., Paunovic A., Madic M., Djukic N. (2007): Genetic analysis of nitrogen accumulation in four wheat cultivars and their hybrids. Cereal Res. Commun., 35 (2): 633-336.

Knežević D., Radosavac A., Zelenika M. (2015): Variability of grain weight per spike of wheat grown in different ecological conditions. Acta Agriculturae Serbica, 20 (39): 85-95.

Knežević D., Paunović A., Kondić D., Radosavac A., Laze A., Kovačević V., Mićanović D. (2019): Variability in seed germination of barley cultivars (*Hordeum vulgare* L.) grown under different nitrogen application rates. Acta Agriculturae Serbica, 24 (47): 61-69. doi: 10.5937/AASer1947061K

Khan F.U. and F. Mohammad (2016): Application of stress selection indices for assessment of nitrogen tolerance in wheat (*Triticum aestivum* L.). The J. Anim. Plant Sci., 26 (1): 201-210.

Khan F.U., Mohammad F., Raziuddin. Z., Shah M., Ahmad M., Shah Z. (2017): Genotypic differences and genotype × nitrogen interactions for yield traits in bread wheat. The J. Anim. Plant Sci., 27 (4): 1264-1268.

Lakić Ž., Glamočlija Đ., Kondić D., Popović V., Pavlović S. (2018): Krmne biljke i žita u funkciji zaštite zemljišta od degradacije. Monografija. Poljoprivredni fakultet Banja Luka. ISBN 978-99938-93-47, p. 1 - 405.

Madić, M., Knežević, D., Đurović, D., Paunović, A., Stevović, V., Tomić, D., Đekić V. (2019): Assessment of the correlation between grain yield and its components in spring barley on an acidic soil. Acta agriculturae Serbica, 24 (47): 41-49. doi: 10.5937/AASer1947041M

Malešević M., Glamočlija Đ., Pržulj N., Popović V., Stanković S., Živanović T., Tapanarova A. (2010): Production characteristics of different malting barley genotypes in intensive nitrogen fertilization. Genetika, Belgrade, 42(2): 323-330.

Milivojević J., Bošković-Rakočević Lj., Đekić V., Luković K., Simić Z. (2018): Cultivar-specific accumulation of iron, manganese, zinc and copper in winter wheat grain (*Triticum aestivum* L.). J. Centr. Eur. Agric., 19 (2): 423-436. doi: 10.5513/JCEA01/19.2.2051

Nazarenko, M., Mykolenko, S., Chernysky, V. (2019): Modern Ukrainian winter wheat varieties grain productivity and quality at ecological exam. Agriculture and Forestry, 65 (1): 127-136. DOI:10.17707/AgricultForest.65.1.13

Perišić V., Perišić V., Živanović T., Milovanović M., Đekić V., Staletić M., Luković K. (2016): Comparative stability analysis of yield components of wheat genotypes. Proceedings, XX International Eco-Conference® 2016, 9th Eco-Conference® on Safe Food, 28-30. September 2016, Novi Sad, Serbia, 63-72.

Popović, V., M. Tatić, V. Spalević, V. Rajičić, V. Filipović, LJ. Šarčević-Todosijević and P. Stevanović (2017): Effect of nitrogen fertilization on soybean plant height in arid year. Proceedings, 2nd International and 14th National Congress of Soil Science Society of Serbia “Solutions and Projections for Sustainable Soil Management”. 25-28th September 2017, Novi Sad, Serbia, 65-73.

Rajičić V., Milivojević J., Popović V., Branković S., Đurić N., Perišić V., Terzić D. (2019): Winter wheat yield and quality depending on the level of nitrogen, phosphorus and potassium fertilization. Agriculture and Forestry, 65 (2): 79-88. DOI: 10.17707/AgricultForest.65.2.06

Rajičić, V., Popović, V., Perišić, V., Biberdžić, M., Jovović, Z., Gudžić, N., Mihailović, V., Čolić, V., Đurić, N., Terzić, D. (2020): Impact of Nitrogen and Phosphorus on Grain Yield in Winter Triticale Grown on Degraded Vertisol. *Agronomy,* 2020, 10 (6): 757.

SAS/STAT (2000): User's Guide, Version 9.1.3. SAS Institute Inc.

Terzić D., Đekić V., Milivojević J., Branković S., Perišić V., Perišić V., Đokić D. (2018a): Yield components and yield of winter wheat in different years of research. Biologica Nyssana, 9 (2): 119-131. doi: 10.5281/zenodo.2538604

Terzic D., Đekić V., Jevtic S., Popovic V., Jevtic A., Mijajlovic J., Jevtic A. (2018b): Effect of longterm fertilization on grain yield and yield components in winter triticale. The J. Anim Plant Sci. 28(3): 830-836.

Tmušić N., Knežević J., Đekić V., Nikolić K. (2018): The influence of weather conditions and fertilizing method on plant height at different cultivars of winter wheat. Proceedings, IX International Scientific Agriculture Symposium "Agrosym 2018", Jahorina, October 04-06, 2018; 385-389.