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IMPACT OF FERTILIZATION ON GRAIN YIELD IN BARLEY PLANT GROWN ON SOIL TYPE VERTISOL

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ABSTRACT

Tests were carried out on stationary field trial, soil type vertisol in the process of degradation, characterized by low pH (pH<5.0). The dose of nitrogen was 80 kg/ha N, which was administered in combination with phosphorous and potassium fertilizer. The average grain yield and 1000 grain weight of all treatments in 2010/11 growing season was significantly greater than in 2009/10, mostly as the result of highly favourable weather conditions at major stages of plant development. The yield, thousand grain weight and test weight of barley significantly varied across years and treatments. Barley yield was the highest in the NP_1K and NP_2K (4.171 and 4.318 t/ha) treatments. Variance analysis showed statistically very significant differences for grain yield and test weight between the vegetation seasons and very significant differences for grain yield and 1000 grain weight between the effects of fertilization. Variance analysis showed significant differences for yield between the interaction of the vegetation seasons and variants of fertilization.

Key words: *barley, fertilization, mineral nutrition, yield*

INTRODUCTION

Climate changes on the global level conditioning hotter summers and mild winters, which will lid to the alterations in sowing and heading dates in the future, as well as a production region of barley. In Serbia, drought is present almost every year. In years with normal spring precipitations, winter barley is finishing vegetation mostly before first severe moisture deficiency, in the opposite, it is using moisture accumulated during the winter (Pržulj, 2001; Pržulj et al., 2013; Đekić et al., 2017; Bratković et al., 2018).

Variations in the temperature, in the amount of precipitation during vegetation as well as in the moisture content in the soil are the most important factors of the instability of the barley grain yield. In ecological conditions of Serbia, high temperatures and the water deficiency during the June result in yield decreasing and deterioration of technological properties of grain and malt, so prolonged vegetation and grain filling period do not contribute to yield increasing (Popović et al., 2011; Bratković et al., 2014; Pržulj et al., 2014; Jelić et al., 2015; Đekić et al., 2019).

Vertisol soil type is distinguished by very unfavorable physical, agrochemical, and microbiological properties. The greatest problem of this soil type is low pH value and further increasing of its acidity, mostly because of the irregular application of fertilizers during the years (Jelić et al., 2012). Low production ability of pseudogley is result of poor physical-mechanical, thermal and water-air properties (Jelić et al., 2014). Hence, production of winter barley as a sensitive plant species on this soil type is low and non-profitable.

Time of application of mineral fertilizers necessary for forming of high and quality grain yield of barley as well as amounts and types of mineral fertilizers are differ depending on soil fertility (Jelić et al., 2014). Efficacy of the nitrogen utilization from mineral fertilizers is decreasing with increasing of the nitrogen fertilizing level (Đekić et al., 2014; Jelić et al., 2017; Terzic et al., 2018). Nutrient utilization from fertilizers and yield forming are under the important influence of weather conditions and specific characteristics of the location (Paunovic et al., 2007; Đekić et al., 2015; Popović et al., 2015; Bratković et al., 2018).

The basic aim of this research was a determination of the impact of nitrogen application in a dosage of 80 kg/ha N, applied in combination with phosphorus and potassium fertilizers on the yield of winter barley, during two vegetation seasons.

MATERIAL AND METHODS

Experimental design

Effects of mineral nutrition efficiency of barley have been studied at the stationary field trial of the Small Grains Research Centre in Kragujevac (Serbia) for two years (2009/10 and 2010/11). The experiment was laid out in a randomised block design with five replications and a plot size of 10 m^2 (5 m x 2 m). In all years, winter barley was sown in the second half of October at a row spacing of 12.5 cm. The rates of nitrogen application were

80 kg/ha N. The barley cultivar used in the experiment was Rekord. Six variants of mineral nutrition C (control), N (80 kg/ha N), NP_1 (80 kg/ha N and 60 kg/ha P_2O_5), NP_2 (80 kg/ha N and 100 kg/ha P_2O_5), NP_1K (80 kg/ha N, 60 kg/ha P_2O_5 and 60 kg/ha K_2O) and NP_2K (80 kg/ha N, 100 kg/ha P_2O_5 and 60 kg/ha K_2O) were tested in the experiment.

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 analysed. 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.

Meteorological conditions

Kragujevac area is characterized by a moderate continental climate, which general feature is uneven distribution of rainfall by month. Data in Table 1 for the investigated period (2010-2011) clearly indicate that the years in which the researches were conducted differed from the typical multi-year average for Kragujevac region, regarding the meteorological conditions.

Table 1. Mean monthly air temperatures and precipitation in Kragujevac, Serbia

Months	X	XI	XII	I	II	III	IV	V	VI	VII	Average
Mean monthly air temperature (^oC)											
2009/10	11.7	8.8	2.6	0.9	3.2	7.2	12.1	16.5	20.2	23.1	10.63
2010/11	10.2	11.4	2.4	0.9	0.5	7.2	12.0	15.8	20.9	22.8	10.41
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)											
2009/10	102.6	77.5	194.2	57.0	150.5	43.3	142.2	116.7	196.7	14.8	1095.5
2010/11	86.9	27.9	50.1	29.1	48.5	20.4	20.8	65.8	32.3	62.4	444.2
Average	45.4	48.9	56.6	58.2	46.6	32.4	51.9	57.6	70.4	46.6	514.6

The average air temperature in 2009/10 was higher by 0.37°C and 2010/11 was higher by 0.16°C than the average of many years. The sum of rainfall precipitation in 2009/10 was higher by 612.1 mm, where the sum of rainfall in 2010/11 was 86.2 mm lower 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 (Paunovic et al., 2007; Madić et al., 2014; Pržulj et al., 2014; Jelic et al., 2014, 2015; Đekić et al., 2014, 2015; Popović et al., 2016; Terzic et al., 2018).

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_2O 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^{-1} soil) in the N and NK trial variants to very high (26.9 mg P_2O_5 100 g^{-1} soil) in the NPK variants of fertilization. Available potassium contents are high, ranging from 19.5 to 21.0 mg K_2O 100 g^{-1} 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

Grain yield, 1000 grain weight and test weight

Table 2 presents average values for gran yield, thousand grain weight and test weight significantly varied across years and treatments during the study.

Table 2. Mean values for grain yield, 1000 grain weight and test weight

Fertilization	Years								
	2009-2010			2010-2011			Average		
	x	S	Sx	x	S	Sx	x	S	Sx
Grain yield, t/ha									
C	0.605^{C}	0.260	0.116	0.933^{D}	0.255	0.114	0.769^{C}	0.298	0.094
N	1.876^{BC}	0.784	0.351	3.270^{C}	0.333	0.149	2.573^{B}	0.929	0.294
NP_1	2.221^{BC}	0.491	0.219	3.569^{BC}	0.237	0.106	2.895^{B}	0.798	0.252
NP_2	2.562^{B}	0.482	0.215	4.002^{B}	0.416	0.186	3.282^{B}	0.869	0.275
NP_1K	3.429^{A}	0.408	0.182	4.912^{A}	0.506	0.226	4.171^{A}	0.893	0.282
NP_2K	3.403^{A}	0.423	0.189	5.232^{A}	0.380	0.170	4.318^{A}	1.036	0.328
1000 grain weight, g									
C	39.30^{B}	1.288	0.576	41.06^{B}	0.773	0.346	40.18^{C}	1.365	0.432
N	40.64^{AB}	1.358	0.607	41.44^{B}	1.101	0.492	41.04^{BC}	1.239	0.392
NP_1	40.74^{AB}	0.838	0.375	42.60^{B}	1.786	0.799	41.67^{BC}	1.640	0.519
NP_2	41.02^{AB}	1.741	0.779	43.02^{B}	1.653	0.739	42.02^{BC}	1.916	0.606
NP_1K	42.64^{AB}	3.346	1.496	44.12^{AB}	1.839	0.822	43.38^{AB}	2.662	0.842
NP_2K	44.36^{A}	5.080	2.272	46.88^{A}	4.544	2.032	45.62^{A}	4.734	1.497
Hectoliter weight, kg/hl									
C	61.51^{B}	1.221	0.546	63.54^{B}	2.361	1.056	62.52^{B}	2.070	0.655
N	63.51^{A}	1.656	0.741	65.39^{AB}	2.228	0.996	64.45^{AB}	2.099	0.664
NP_1	63.95^{A}	1.493	0.668	65.73^{AB}	2.394	1.071	64.84^{A}	2.102	0.665
NP_2	64.26^{A}	1.538	0.688	67.02^{AB}	3.320	1.485	65.64^{A}	2.839	0.898
NP_1K	64.62^{A}	0.976	0.436	67.72^{A}	1.444	0.646	66.17^{A}	2.005	0.634
NP_2K	65.22^{A}	1.009	0.451	68.00^{A}	3.153	1.410	66.61^{A}	2.649	0.838

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

The highest grain yield had variety Rekord application of NP_2K in a quantity of 80 kg/ha N, 100 kg/ha P_2O_5 and 60 kg/ha K_2O (4.318 t/ha). The grain yield of the barley was significantly lower in control. Average grain yield of treatments ranged from 0.605 t/ha (control) to 3.429 t/ha (NP_1K) in 2009/10 and 0.933 t/ha (control) to 5.232 t/ha (NP_2K) in 2010/11. In all years, NP_1K and NP_2K treatments produced significantly higher grain yields compared in the other treatments. Considerable variation in yield depending on years of research have established Popović et al. (2011), Jelić et al. (2014), Madić et al. (2014) and Đekić et al. (2019).

During the 2009/10 and 2010/11, thousand grain weight was significantly greater in NP_2K treatment (44.36 g and 46.88 g) than in the other treatments. The average 1000 grain weight of all treatments in the 2010/11 growing season was significantly greater than in the 2009/10 year, mostly as the result of highly favourable weather conditions at major stages of plant development. Averaged across years, significantly higher values for 1000 grain weight were found in NP_2K treatment (45.62 g). Average 1000 grain weight of treatments ranged from 39.30 g (control) to 44.36 g (NP_2K) in 2009/10 and 41.06 g (control) to 46.88 g (NP_2K) in 2010/11.

Table 2 presents average values for grain yield, thousand grain weight and test weight across years and treatments during the two vegetation sesons. The test weight varied across years and treatments. Average test weight of treatments ranged from 61.51 kg/hl (control) to 65.22 kg/hl (NP_2K) in 2009/10 and 63.54 kg/hl (control) to 68.00 kg/hl (NP_2K) in 2010/11.

Analysis of variance the analysed traits

Table 3 shows the impact of the year, fertilization and interaction of year x fertilization on yield, 1000 grain weight and test weight. Analysis of variance was found highly significant effect of year on the grain yield ($F=15.397^{**}$) and test weight ($F=15.871^{**}$) and significantly effect of 1000 grain weight ($F=5.295^{*}$). Analysis of variance was found highly significant effect of fertilization on the grain yield ($F=23.791^{**}$), 1000 grain weight ($F=5.728^{**}$) and test weight ($F=4.028^{**}$). Based on the analysis of variance, it can be concluded that there are significant differences in grain yield regard the interaction year x fertilization (Table 3).

Table 3. 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)	1, 58	25.489	1.655	15.397	0.0002
Fertilization, (F)	5, 54	16.714	0.702	23.791	0.0000
Year x Fertilization, (YxF)	5, 48	0.644	0.192	3.352	0.0112
The analysis of variance for 1000 grain					
Year, (Y)	1, 58	45.240	8.545	5.295	0.0250
Fertilization, (F)	5, 54	37.488	6.544	5.728	0.0003
Year x Fertilization, (YxF)	5, 48	0.821	6.334	0.130	0.9849
The analysis of variance for test weight					
Year, (Y)	1, 58	85.514	5.388	15. 871	0.0002
Fertilization, (F)	5, 54	21.625	5.368	4.028	0.0035
Year x Fertilization, (YxF)	5, 48	0.776	4.177	0.186	0.9666

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

Correlations between the analysed traits

Table 4 shows the grain yield was in a positive correlation with the 1000 grain weight as well as with the test weight. Barley yield in 2009/10 was positively and highly significant correlated with 1000 grain weight (0.476**) and test weight (0.634**). Yield in the 2010/11 vegetation season grain yield in was positively and highly significant correlation with the 1000 grain weight (0.548**) and test weight (0.488**). Thousand grain weight in 2009/10 and 2010/11 was positively and significantly correlated with test weight (0.405* and 0.434*).

The positively and significant correlation with grain yield and thousand grain weight have established Đekić et al. (2014) and Terzić et al. (2018). Đekić et al. (2014) state negatively and significant correlation of thousand grain weight and test weight. Grain yield depends directly on the the thousand grain weight (Đekić et al., 2014, 2019; Terzić et al., 2018).

Table 5 shows the correlation coefficients between the studied fertilization treatments and analysed traits. Positive correlations were observed between grain yield and thousand grain weight in all treatments, except in the treatment with nitrogen. Positively and significant correlations were observed between grain yield and thousand grain weight in the NP_1 (r=0.667*). Positively and strong correlations were observed between thousand grain weight and test weight in the unfertilized control (r=0.829**) and positively and significant correlations in the treatment NP_1K (r=0.696*).

Table 4. Correlations between the traits analyzed by two vegetation seasons

Correlations between the traits analyzed in 2009/10			
	Grain yield	1000 grain weight	Test weight
Grain yield (t/ha)	1.00	0.476**	0.634**
1000 grain weight (g)		1.00	0.405*
Test weight (kg/hl)			1.00
Correlations between the traits analyzed in 2010-2011			
	Grain yield	1000 grain weight	Test weight
Grain yield (t/ha)	1.00	0.548**	0.488**
1000 grain weight (g)		1.00	0.434*
Test weight (kg/hl)			1.00

ns-non significant; *-significant at 0.05; **-significant at 0.01;

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 (Popović et al., 2011; Đekić et al., 2017; Jamil et al., 2017; Terzic et al., 2018).

Table 5. 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)	1.00	0.534	0.149
1000 grain weight (g)		1.00	0.829**
Test weight (kg/hl)			1.00
Correlations between the traits analyzed in the N			
Grain yield (t/ha)	1.00	-0.078	0.326
1000 grain weight (g)		1.00	0.444
Test weight (kg/hl)			1.00
Correlations between the traits analyzed in the NP_1			
Grain yield (t/ha)	1.00	0.667*	0.365
1000 grain weight (g)		1.00	-0.264
Test weight (kg/hl)			1.00
Correlations between the traits analyzed in the NP_2			
Grain yield (t/ha)	1.00	0.443	0. 441
1000 grain weight (g)		1.00	0.087
Test weight (kg/hl)			1.00
Correlations between the traits analyzed in the NP_1K			
Grain yield (t/ha)	1.00	0.140	0.696*
1000 grain weight (g)		1.00	0.505
Test weight (kg/hl)			1.00
Correlations between the traits analyzed in the NP_2K			
Grain yield (t/ha)	1.00	0.398	0.452
1000 grain weight (g)		1.00	0.414
Test weight (kg/hl)			1.00

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

CONCLUSION

Effects of mineral nutrition efficiency of barley have been studied at the stationary field trial of the Small Grains Research Centre in Kragujevac (Serbia) for two years (2009/10 and 2010/11). Nitrogen had a most

significant impact on the yield of wheat. Averaged across treatment, thousand grain weight and test weight were significantly greater in 2010/11 than in the previous year. Averaged across years, grain yield and 1000 grain weight was significantly greater in NP_1K and NP_2K than in the other treatments. Regardless of year, NP_1K and NP_2K treatments had significantly higher values for 1000 grain weight compared to the other treatments.
Grain yield shows a tendency to grow in years with higher levels and better rainfall during critical stages of plant development. Analyzing variances is a very significant effect of fertilization on grain yield, 1000 grain weight and test weight barley, while the impact of growing seasons on all the characteristics of the barley was statistically significant.

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