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EFFECT OF LONG TERM FERTILIZATION ON GRAIN YIELD AND YIELD COMPONENTS OF WINTER TRITICALE

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ABSTRACT

Investigation about effect of high amounts of nitrogen and source of nutrition on winter triticale productivity was carried out in a stationary field trial in the Sumadija region, in Central Serbia. This study was conducted over a period of three years (2009-2011) on a vertisol soil to evaluate the effect of different fertilization methods on grain yield and yield components of winter triticale variety. Treatments included control and six fertilization variants with different combinations of NPK fertilizers (N, NK, NP_1, NP_2, NP_1K, and NP_2K). Investigation showed a considerable variation of grain yield depending on mineral nutrition. The highest and statistically significant average grain yields were achieved under NP_1K (4.105 t ha^{-1}) and NP_2K (4.050 t ha^{-1}) treatments. The combined use of NP_1K fertilizers (120 kg N ha^{-1}, 60 kg P_2O_5 ha^{-1}, 60 kg K_2O ha^{-1}) and NP_2K treatment (120 kg N ha^{-1}, 100 kg P_2O_5 ha^{-1}, 60 kg K_2O ha^{-1}) represented the excellent base for optimum stock of major nutrients, resulting in maximum grain yield. Thousand grain weight of triticale significantly varied across years, the highest average 1000-grain weight of winter triticale investigated was achieved in the NP_1K variant (44.81 g). Grain yield was significantly positively correlated with 1000-grain weight only in all years.

Key words: fertilization, yield, quality, triticale

INTRODUCTION

Triticale is cereal species gained by interspecies hybridization of wheat and rye. Triticale potential for grain yield, grown under optimal conditions, is similar to wheat potential, and much higher under less favorable growing conditions (Brown and Graham, 1978). Triticale expresses high tolerance the acidic soils, as well as good productive results on sandy soils. New perspective triticale lines and varieties have more and better filled grain, higher grain yield, grain mass and farinaceous content, while amounts of proteins and lysine are smaller compared with older varieties (Đekić, 2010; Djekic *et al*., 2011; Milovanovic *et al.,* 2011). Several factors are decisive in increasing small grains (wheat, triticale, oats, barley) yields: the cultivar, cultural practices, local climatic and soil characteristics, mineral nutrition and adequate plant protection against diseases, pests and weeds (Jelic *et al*., 2015; Kendal and Sayar, 2016).

Triticale is a crop of worldwide importance and it is susceptible to the prevailing weather conditions (such as rainfall) and, for this reason, understanding the effects of climate changes on it's production is important (Márton *et al*., 2007; Kádár *et al*., 2008; Đekić *et al*., 2010; Jamil *et al*., 2017). The desirable cultivars for high grain yield and quality traits need to express genetic potential in the different environment of growing (Claudio *et al*., 2010; Kendal and Sayar, 2016). High temperatures after anthesis have negative influence during grain filling phase (Đekić *et al*., 2010; Popovic *et al*., 2013).

Understanding the aforementioned effects have been a continuous impetus toward improving farming technology to reduce the negative impacts of these factors and to increase crop yield (Djekic *et al*., 2011). The absence of record yields indicates that an answer could be sought in soil, the main substrate for field crop production. The use of incomplete production technology in previous decades had definitely affected the potential and actual soil fertility. Second, it is evident that soil management recommendations, which are based on scientific research and professional experience, are disregarded for a large measure in the agricultural practice in Serbia (Malesevic, 2008, Jelic *et al*., 2013).

Plant nitrogen nutrition has a great impact on the technological quality of triticale cultivars. Nitrogen, in interaction with other elements of mineral nutrition, plays a significant role in the triticale yield and quality (Đekić *et al*., 2014). For high yield and grain quality, it is necessary to adopt nitrogen by plants during the whole vegetation period (Nikolic *et al*., 2012). Nitrogen is an essential nutrient for food and bioenergy production that can be highly pollutant to aquatic organisms and the atmosphere if not properly used in agriculture. Significant yield responses to N fertilization have been reported, as well as possible residual effects of repeated N applications on triticale cycles (Marton, 2002).

The objective of this study was optimizing fertilization in the future triticale production on a vertisol soil of Central Serbia based on the evaluation of the effect of different fertilization systems on the grain yield and quality.

MATERIALS 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 at Kragujevac location, (44° 22′ N, 20° 56′ E**,** 173-220 m a. s. l.), in a temperature continental climate having an average annual temperature of 11.76°C, typical of Sumadija district in Republic of Serbia and a rainfall amount of about 550 mm. The soil type was smonitza in degradation (Vertisol). Plot size was 50 m^2 (5 m x 10 m). The winter triticale cultivar used in the experiment was Favorit, the dominant cultivar in the production regions of Serbia. Six variants of mineral nutrition N (120 kg N ha^{-1}), NK (120 kg N ha^{-1}, 60 kg K_2O ha^{-1}), NP_1 (120 kg N ha^{-1}, 60 kg P_2O_5 ha^{-1}), NP_2 (120 kg N ha^{-1}, 100 kg P_2O_5 ha^{-1}), NP_1K (120 kg N ha^{-1}, 60 kg P_2O_5 ha^{-1}, 60 kg K_2O ha^{-1}) and NP_2K (120 kg N ha^{-1}, 100 kg P_2O_5 ha^{-1}, 60 kg K_2O ha^{-1}) and untreated control were tested in the experiment. The rate of nitrogen application was 120 kg N ha^{-1}, and it was applied either individually or in combination with two phosphorus rates and a potassium fertilizer. A non-fertilized variant served as a control. 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. Triticale cultivar (Favorit) was sown at the experimental field. Sowing in all three analyzed years was carried out in the second half of October, at a spacing between rows with of 12 cm, with a seed density of 600 germinating grains per m^2. Triticale sowing was done on two separated stationary fields (A and B) with corn rotation system. The trial was designed in a randomized blocks with five replications. Total amounts of phosphorus and potassium fertilizers and half the nitrogen rate are regularly applied during pre-sowing cultivation of the soil. Conventional production technology was employed.

The crops was harvested at full maturity using (dates of harvesting 21.07.2009, 28.07.2010 and 07.07.2011). Grain yield was harvested and reported at 14% moisture. Three parameters, grain yield (t ha^{-1}), test weight (kg hl^{-1}) and 1000-grain weight (g) were analysed.

Meteorological conditions: The data in Table 1 for the investigated period (2008-2011) clearly indicate that the years in which the researches were conducted differed from the typical multi year average of Kragujevac region. The moderate continental climate is prevalent in the Kragujevac area and the general feature is an uneven distribution of rainfall by month. The average air temperature in 2008/09, 2009/10 and 2010/11 was higher by 0.96ºC, 0.37ºC and 0.16ºC respectively. The sum of rainfall precipitation in 2009/10 was higher by 612,1 mm and with uneven distribution of precipitation per month, whereas the sum of rainfall in 2008/09 and 2010/11 was 0.9 and 86.2 mm respectively, lower than the average of many years. Spring months April and May 2009/10 were with over precipitation, which affected unfavorably on the crops. During the April 2009/10 it was 142.2 mm of rainfall, which was 90.3 mm more compared with the perennial average. In May 2009/10 it was 116.7 mm of rainfall, which was 59.1 mm more compared with the perennial average. In May 2010/11 the amount of rainfall was 8.2 mm respectively higher compared to the average precipitation, while during 2008/09 it was lower by 11.6 mm compared to the perennial average. In the second year of investigation there were recorded higher rainfalls in April and May, which led to a lodging of crops and lower yield (Table 1).

Soil analysis: The soil was analysed using standard physical methods (soil texture, by pipette method, a modified pyrophosphate method by Zivkovic, 1966); chemical methods (soil pH was determined in a 1:2.5 soil-1 M KCl suspension after a half-hour equilibration period; hydrolytic acidity and sum of adsorbed base cations were determined by Kappen’s method; humus content by Kotzmann’s method, total nitrogen by the Kjeldahl method, and available P_2O_5 and K_2O levels by the Egner-Riehm Al method).

The trial was conducted on a vertisol soil in a process of degradation, with undesirable physical properties. 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: Experimental data were analysed by descriptive and analytical statistics using the statistics module Analyst Program SAS/STAT (SAS Institute, 2000) for Windows. The significance of differences among the mean values of the different factors studied in the paper (year and nutritional treatment) was tested by two-factor analysis of variance (ANOVA, Maletic, 2005). 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 obtained coefficients were tested at the 5% and 1% levels of significance. The results were presented in tabular form.

RESULTS AND DISCUSSION

Grain yield: The study showed that within applied fertilization variants in the three-year period (Table 2), the highest average grain yield 4.105 t ha^{-1} was achieved in NP_1K variant (120 kg ha^{-1} nitrogen rate, phosphorus rate of 60 kg ha^{-1} P_2O_5 and potassium rate of 60 kg ha^{-1} K_2O).

The grain yield of triticale significantly varied across years, from 2.056 t ha^{-1} in 2009/10 to 4.291 t ha^{-1} in 2010/11. The average grain yield was lowest in the unfertilized control (1.247 t ha^{-1}) and significantly higher in fertilized treatments, 4.050 t ha^{-1} (NP_2K-treatment) and 4.105 t ha^{-1} (NP_1K-treatment).

During the first year of investigation, the highest average value of grain yield achieved by the NP_1 and NP_2-treatments (4.262 t ha^{-1} and 4.230 t ha^{-1}). During the second year of investigation (2009/10), the highest average value of grain yield achieved the NP_2K treatment (2.816 t ha^{-1}), while in the third year (2010/11), the highest average value of grain yield achieved by the NP_1K and NP_2K treatments (5.922 t ha^{-1} and 5.371 t ha^{-1}). Favorable distribution and amount of rainfall over the growing season 2010/11 resulting in increased yields in this year indicated the high importance of sufficient rainfall amounts during the spring months. Meteorological conditions recorded high variability during the year (Jelic *et al*., 2013; Popovic *et. al*., 2013; Đekić *et al*., 2014).

Application of this mineral elements, particularly on acid soils poorly supplied with these nutrients, has a significant effect on the grain yield of oats and other cereal crops (Bolton, 2009, Jelić *et al*., 2013, 2015; Jamil *et al*., 2017).

The analysis of variance indicated significant effects of year (Y) and fertilization (F), while their interaction (YxF) was not significant as shown in Table 3. The significantly lower triticale grain yields achieved in the NK trial variant compared with the NPK and NP variants resulted from the existing phosphorus deficit in the soil, and low pH and high content of mobile Al in soil solution (Jelic *et al*., 2015). The studied combined NPK, lime and manure treatment almost completely eliminated Al presence in the grain of all winter wheat cultivars (0.14 to 1.33 mg 100 g^{-1}). Differences in unhusked grain yields between trial years are a result of different weather conditions (Đekić *et al*., 2014; Jelic *at al*., 2013; Popovic *et al*., 2013).

Based on the results of this study it may be stated that both weather conditions, drought and abundant rainfall, may intensify negative effects on crop yields with nearly all fertilization rates, as also reported by Márton (2008).

1000-grain weight: Average thousand grain weight (Table 4) in the test period was the highest in 2008/09 (45.98 g), higher than the three-year period average by 2.99 g. During the first year of investigation, the highest average value of 1000-grain weight achieved the NP_1-treatment (48.14 g), while in the second year of investigation, the highest average value of 1000-grain weight achieved the NP_1K treatment (44.00 g). During the third year the highest average value of 1000-grain weight achieved the NP_1K (43.64 g) and NP_1 and NP_2-treatments (42.54 g).

Đurić *et al*. (2013) underlined that 1000-grain weight is a cultivar-specific trait, with considerably higher variations influenced by genetic factors rather than by treatments or by environmental factors.

Furthermore, 1000-grain weight was highly significant among the year x fertilization interaction (Table 5). In all years, the use of different treatments induced a significant increase in 1000-grain weight. The results of investigation are in agreement with opinions of many authors that the traits analysed are genetically determined but are strongly modified by the nutrient status of the environment and weather conditions (Popovic *et al*., 2011; Jelic *et al*., 2013; Đekić *et al*., 2014).

Hectoliter weight: During the first year, achieved the highest test weight at NP_1K variant (67.72 kg hl^{-1}), while the lowest test weight was the NK treatment (63.56 kg hl^{-1}). During the second year of investigation, the test weight of NP_2 was the highest with 69.81 kg hl^{-1}, while the slightly lower test weight was realized by N and NP_2K variants (69.49 kg hl^{-1} and 69.41 kg hl^{-1} respectively). During the third year, the highest test weight was achieved at NP_2-treatment (73.49 kg hl^{-1}), while the lowest test weight was at NK-treatment (71.01 kg hl^{-1}). The average three-year value of test weight at NP_1K-treatment was (69.89 kg hl^{-1}), while the lowest average value was at NK treatment (67.86 kg hl^{-1}) (Table 6).

Environmental factors showed significant effects on alterations of test weight in triticale grain (Table 7). Based on analysis of variance results (Table 7), there are evident highly significant differences in test weight between years, and insignificant between fertilizations. Dual interaction of test weight and year x fertilization, did not show statistical significance ($p > 0.05$).

Correlations between the analysed traits: Triticale yield in 2008/09 was positively correlated with test weight (0.22) and positively but strong-dependent significantly correlated with 1000-grain weight (0.79**) (Table 8). Test weight was positively correlated with 1000-grain weight (0.08).

During the second year of investigation (2009/10), correlations between 1000-grain weight and test weight were not statistically significant. Triticale grain yield was positively but significantly correlated with 1000-grain weight (0.38*) and test weight (0.49*) (Table 8).

Correlation coefficients between grain yield in 2010/11 were positively and significantly correlated with 1000-grain weight (0.74*). Correlations between grain yield and 1000-grain weight were positively but not statistically significant (0.01). Test weight was positively but not significantly correlated with 1000-grain weight (0.15) as shown in Table 8.

Recorded significant correlations between analysed traits are in agreement with investigations of other authors (Jelic *et al*., 2013; Đekić *et al*., 2014). Positive correlation between grain yield and stress conditions has been established (Khan and Mohammad, 2016).

Significant negative correlations were observed between 1000-grain weight and test weight in all treatments (Table 9). Triticale grain yield and test weight were positively correlated but without statistical significance in all treatments. Negative and very strong correlations were also found between test weight and 1000-grain weight in the NK treatment (r=-0.94***). Strong and negative correlations were also found between test weight and 1000-grain weight in the NP_1 and NP_2 treatments (r=-0.76**), control and N treatments (r=-0.82** and r=-0.81**). The values of the coefficients of correlation and weak negative correlation among the grain yield and 1000-grain weight for investigated nutrition treatments were indicated the absence of statistical significant as shown in Table 9. Significant and positive correlation between grain yield and nitrogen levels has been established Đekić *et al*. (2014) and Khan *et al.* (2017).

However, continuous monitoring of the farm microclimate includes first of all measuring of precipitation, soil properties and the supply of soil nutrients. Depending on the current precipitation situation, the crop fertilization system may be adjusted based on the correlations presented (Table 8 and 9) in order to achieve the expected optimal grain yield. If natural precipitation surpasses the water required for maximum yield, nutrient supply must be reduced, because in this case surplus of fertilizers could lead to economic losses and ecological damage due to nutrients flushing.

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

Months	Mean monthly air temperature (ºC)				The amount of rainfall (mm)			
	2008/09	2009/10	2010/11	Average	2008/09	2009/10	2010/11	Average
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
Average	9.83	9.24	9.03	8.87	467.1	1080.1	381.8	468.0

Table 2. Grain yield of winter triticale in Kragujevac, Serbia.

Fertilization	Years						Average	
	2008-2009		2009-2010		2010-2011			
	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$	S
Control	1.242	0.618	0.744	0.114	1.755	0.869	1.247	0.715
N	3.055	0.753	2.177	0.568	3.996	1.603	3.076	1.257
NK	1.959	0.906	1.866	0.619	2.535	0.848	2.120	0.802
NP_1	4.262	1.295	1.990	0.558	5.335	1.624	3.862	1.845
NP_2	4.230	1.273	2.184	0.751	5.122	0.904	3.845	1.574
NP_1K	3.779	1.565	2.614	0.957	5.922	1.340	4.105	1.867
NP_2K	3.964	0.797	2.816	0.455	5.371	1.756	4.050	1.514

Table 3. The analysis of variance for grain yield in Kragujevac, Serbia.

Effect	df	Mean sqr Effect	Mean sqr Error	F	p-level
Year, (Y)	2. 102	43.7130	2.205306	19.8218**	0.000000
Fertilization, (F)	6. 98	18.47955	2.05602	8.988024**	0.000000
Year x Fertilization, (YxF)	12. 84	1.757084	1.106891	1.587406	0.110930

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

Table 4. 1000-grain weight of winter triticale in Kragujevac, Serbia.

Fertilization	Years						Average	
	2008-2009		2009-2010		2010-2011			
	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$	S
Control	41.84	0.770	40.90	0.308	36.32	1.224	39.69	2.618
N	45.72	0.729	42.38	0.487	41.52	0.363	43.21	1.943
NK	44.24	2.024	40.32	0.904	38.42	1.452	40.99	2.881
NP_1	48.14	0.733	42.44	0.666	42.54	1.454	44.37	2.913
NP_2	47.68	2.319	41.00	0.255	42.54	0.871	43.74	3.242
NP_1K	46.78	2.173	44.00	1.223	43.64	1.094	44.81	2.056
NP_2K	47.46	3.163	43.74	0.627	41.22	0.801	44.14	3.193

Table 5. The analysis of variance for 1000-grain weight in Kragujevac, Serbia.

Effect	df	Mean sqr Effect	Mean sqr Error	F	p-level
Year, (Y)	2. 102	247.4498	5.574454	44.3900**	0.000000
Fertilization, (F)	6. 98	55.11121	7.47782	7.369953**	0.000002
Year x Fertilization, (YxF)	12. 84	7.207254	1.802857	3.997684**	0.000069

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

Table 6. Hectoliter weight of winter triticale in Kragujevac, Serbia.

Fertilization	Years						Average	
	2008-2009		2009-2010		2010-2011			
	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$	S
Control	64.24	1.043	68.75	1.145	71.65	1.166	68.21	3.322
N	66.83	1.597	69.49	1.081	71.65	1.720	69.32	2.464
NK	63.56	1.734	69.01	1.081	71.01	1.802	67.86	3.569
NP_1	65.69	1.054	68.85	0.632	71.81	1.889	68.78	2.853
NP_2	64.48	1.706	69.81	1.187	73.49	1.431	69.26	4.059
NP_1K	67.72	1.056	69.25	1.876	72.69	1.639	69.89	2.592
NP_2K	64.49	2.735	69.41	1.711	72.25	1.249	68.72	3.799

Table 7. The analysis of variance for hectoliter weight in Kragujevac, Serbia.

Effect	df	Mean sqr Effect	Mean sqr Error	F	p-level
Year, (Y)	2. 102	407.0007	2.820735	144.2888**	0.000000
Fertilization, (F)	6. 98	7.18311	10.80222	0.664966	0.678066
Year x Fertilization, (YxF)	12. 84	4.185277	2.314203	1.808519	0.059616

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

Table 8. Correlations between the traits analyzed.

Traits	Grain yield	1000-grain weight	Hectoliter weight
Correlations between the traits analyzed in 2008-2009			
Grain yield ($t\ ha^{-1}$)	1.00	0.79^{**}	0.22^{ns}
1000-grain weight (g)		1.00	0.08^{ns}
Hectoliter weight ($kg\ hl^{-1}$)			1.00
Correlations between the traits analyzed in 2009-2010			
Grain yield ($t\ ha^{-1}$)	1.00	0.38^{*}	0.49^{*}
1000-grain weight (g)		1.00	-0.09^{ns}
Hectoliter weight ($kg\ hl^{-1}$)			1.00
Correlations between the traits analyzed in 2010-2011			
Grain yield ($t\ ha^{-1}$)	1.00	0.74^{*}	0.01^{ns}
1000-grain weight (g)		1.00	0.15^{ns}
Hectoliter weight ($kg\ hl^{-1}$)			1.00

Table 9. Correlation coefficients for the traits analyzed across treatments.

	Grain yield	1000-grain weight	Hectoliter weight
Correlations between the traits analyzed in the unfertilized control			
Grain yield ($t\ ha^{-1}$)	1.00	-0.37^{ns}	0.21^{ns}
1000-grain weight (g)		1.00	-0.82^{**}
Hectoliter weight ($kg\ hl^{-1}$)			1.00
Correlations between the traits analyzed in the N			
Grain yield ($t\ ha^{-1}$)	1.00	-0.10^{ns}	0.30^{ns}
1000-grain weight (g)		1.00	-0.81^{**}
Hectoliter weight ($kg\ hl^{-1}$)			1.00
Correlations between the traits analyzed in the NK			
Grain yield ($t\ ha^{-1}$)	1.00	-0.03^{ns}	0.14^{ns}
1000-grain weight (g)		1.00	-0.94^{***}
Hectoliter weight ($kg\ hl^{-1}$)			1.00
Correlations between the traits analyzed in the NP_1			
Grain yield ($t\ ha^{-1}$)	1.00	0.19^{ns}	0.16^{ns}
1000-grain weight (g)		1.00	-0.76^{**}
Hectoliter weight ($kg\ hl^{-1}$)			1.00
Correlations between the traits analyzed in the NP_2			
Grain yield ($t\ ha^{-1}$)	1.00	0.41^{ns}	0.14^{ns}
1000-grain weight (g)		1.00	-0.76^{**}
Hectoliter weight ($kg\ hl^{-1}$)			1.00
Correlations between the traits analyzed in the NP_1K			
Grain yield (tha^{-1})	1.00	-0.05^{ns}	0.50^{ns}
1000-grain weight (g)		1.00	-0.59^{*}
Hectoliter weight ($kg\ hl^{-1}$)			1.00
Correlations between the traits analyzed in the NP_2K			
Grain yield ($t\ ha^{-1}$)	1.00	-0.09^{ns}	0.18^{ns}
1000-grain weight (g)		1.00	-0.71^{*}
Hectoliter weight ($kg\ hl^{-1}$)			1.00

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

Conclusions: The results of this study showed that the triticale responds differently to intensive nitrogen nutrition in the agroecological conditions of Kragujevac, Serbia. Important variations were registered in the main yield components. The highest yield was obtained by applying 120 kg N ha^{-1}, 60 kg P_2O_5 ha^{-1} and 60 kg K_2O ha^{-1} in the three-year period. The results can be of great importance for the Serbia region's production practices but also wider.

Viable solutions could be devised at the national level by organizing a network of long-term stationary trials and by adopting a multidisciplinary approach to the problem.

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