Mineral and bacterial fertilization effects on chemical composition and yield of wheat

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Abstract

The aim of this study was to evaluate the influence of an application of different rates of mineral fertilizers and their combination with selected bacterial inoculants (N-fixing *Klebsiella planticola* and *Enterobacter* spp.) on chemical composition and yield of the grain of wheat.

The studied soil type was Eutric Cambisol. The experiment was set up in a randomized block design with three replicates, based on the following variants: control (Ø, non-fertilized soil); 60 kg·ha^{-1} N and P_2O_5, and 40 kg K_2O ha^{-1} (low rates of mineral fertilizers); 120 kg·ha^{-1} N, P_2O_5 and K_2O (high rates of mineral fertilizers); *Enterobacter* sp. strains + 60 kg·ha^{-1} N and P_2O_5, and 40 kg K_2O ha^{-1}; *Enterobacter* sp. strains + 120 kg·ha^{-1} N, P_2O_5 and K_2O; *K. planticola* + 60 kg·ha^{-1} N and P_2O_5, and 40 kg K_2O ha^{-1}; *K. planticola* + 120 kg·ha^{-1} N, P_2O_5 and K_2O. Winter wheat (cv. Evropa 90) was used as a test plant. Measuring of the yield of crop was carried out at the end of the vegetation.

The results of the study showed that an application of high rates of mineral fertilizers and their combination with bacterial inoculants resulted in increased contents of nitrogen, phosphorus, potassium and proteins in the grains of the crop studied. The highest increase in the yield of the wheat was obtained by the same mentioned treatments, although the combination of bacterial inoculants and low rates of mineral fertilizers resulted in higher yields comparing to the application of lower rates of the pure mineral nutrients.

Concluding, it was estimated that the studied bacterial inoculants can be used to supplement the use of urea-N, helping to ensure that the supply of nutrients contributing to optimized yield is maintained.

Key words: mineral fertilizers, bacterial inoculants, wheat, chemical composition, yield

Introduction

Wheat, *Triticum aestivum* L., is one of the major crop in agricultural production of Serbia. Generally speaking, in this country the cultivation of wheat occupies an area of 600,000 to 900,000 ha with an average yield of 3.92 to 6.42 t·ha^{-1} (Denčić et al., 2005).

Increasing the yield and improving the quality of crops have been the challenges for sustainable agriculture (Yu-kui et al., 2009). The yield of crops, in addition to varietal characteristics, largely depends on the tillage, chemical, physical and microbiological properties of the soil (Jeličić et al., 1997). Fertilization, among other factors, was one of the reasons that pushed crop production (Salvagiotti et al., 2010), whereas the traits of the cumulative effect of fertilizers (the change of biological and chemical soil properties, the content of biogenic elements and heavy metals etc.) have often been disregarded. Regardless of their major role in crop productivity and soil fertility, increased use of mineral fertilizers (particularly nitrogen) in agricultural production has however raised concerns, because the nitrogen surplus is at risk of leaving the plant-soil system and thereby causing environmental contamination (Acosta-Martinez and Tabatabai, 2000; Alizadeh and Ghadeai, 2006). Thus, sustainable agriculture in Serbia should not be only a steady and substantial increase in crop yields, but also the management and conservation of soil and water. The problems concerned can be overcome by partial replacement of these fertilizers by application of microbial inoculants, in order to inhibit or stimulate certain cellular processes, including mineralization ones, thus leading to the improvement of physical, chemical and biological soil properties (Milošević et al., 2003).

The plant production systems, type and rate of applied fertilizers and climate characteristics affect greatly on intensity of the N, P and K uptake by agricultural crops and their yield. Hence, having in mind the above mentioned, the aim of this investigation was to examine the influence of different rates of mineral fertilizers and their combination with selected soil bacterial inoculants on chemical composition and yield of the grain of wheat cultivated on eutric cambisol type of soil.

Material and methods

The investigation was conducted on Mladenovac experimental station of Institute of Soil Science, located 55 km from Belgrade in Serbia, during the year 2007. Mean monthly air temperatures and precipitation sums for the study year are presented in Table 1.

Table 1. Mean monthly air temperature and precipitation summ for the study year

Month	Year 2007		Mean 1990-2007	
	Temperature (°C)	Precipitation (mm)	Temperature (°C)	Precipitation (mm)
January	7.6	49.3	1.8	41.9
February	7.2	56.0	3.7	36.8
March	10.2	99.6	8.0	42.8
April	14.9	3.8	12.8	54.6
May	19.5	79.0	18.2	51.4
June	23.8	107.6	21.6	94.8
July	25.8	17.5	23.2	66.1
August	24.2	72.5	23.1	60.1
September	16.2	84.1	17.6	63.8
October	11.8	103.6	13.1	53.8
November	5.2	131.5	7.4	55.6
December	1.1	34.5	2.3	61.5
Mean	14.0	-	12.7	-
Total	-	839.0	-	683.2

The studied soil type was Eutric Cambisol. The experiment was set up in a randomized block design with three replicates, based on the following variants: control (Ø, non-fertilized soil); 60 kg·ha^{-1} N and P_2O_5, and 40 kg K_2O ha^{-1} (N1, low rates of mineral fertilizers); 120 kg·ha^{-1} N, P_2O_5 and K_2O (N2, high rates of mineral fertilizers); *Enterobacter* sp. strains + 60 kg·ha^{-1} N and P_2O_5, and 40 kg K_2O ha^{-1} (ES+N1); *Enterobacter* sp. strains + 120 kg·ha^{-1} N, P_2O_5 and K_2O (ES+N2); *Klebsiella planticola* + 60 kg·ha^{-1} N and P_2O_5, and 40 kg K_2O ha^{-1} (KP+N1); *Klebsiella planticola* + 120 kg·ha^{-1} N, P_2O_5 and K_2O (KP+N2). Winter wheat (cv. Evropa 90) was used as a test plant.

Nitrogen fertilizer was applied in the form of urea with 46% N, phosphorus – in the form of monoammonium phosphate with 52% P_2O_5 and 11% N, and potassium – as a 40% potassium salt (KCl).

The pure culture of an associative N-fixing bacterium *K. planticola* was obtained from the stock culture of the Microbiology Laboratory of Faculty of Agronomy (Čačak, Serbia), while the *Enterobacter* strains (KG-75 and KG-76) were obtained from the stock culture of the Microbiology Laboratory in the Center for Small Grains (Kragujevac, Serbia), where they have been isolated from the rhizosphere of wheat.

Pure liquid inoculums of *K. planticola* and *Enterobacter* spp. were made using fermentors with suitable nutrient broth and incubated with aeration for 48 h at 28°C ± 1. The inoculation of the soil under young, 2-3 leaves formed plants of wheat was carried out using plastic haversack sprinkler with 300.00 cm^3/m^2 of diluted liquid bacterial inoculums, previously made by adding the tap water in the pure bacterial liquid inoculums.

The preliminary observation of the soil studied included the analysis of the following soil chemical parameters: soil acidity - potentiometrically, using glass electrode; available phosphorus and potassium -

spectrophotometrically and flame-photometrically, respectively, using Al-method by Egner-Riehm (Riehm, 1958); humus content, using Tiurin's method, modified by Simakov (Ostrowska et al., 1991); soil total nitrogen, using elemental CNS analyzer, Vario model EL III (Nelson and Sommers, 1996).

In the full grain maturity stage of winter wheat the grains were taken and weighed before and after drying at 105ºC. For all the plant samples from all the variants studied the chemical analyses of the grains were done. Phosphorus was determined by spectrophotometer with molybdate, and potassium – by flame emission photometry (Maksimović et al., 2008). The content of nitrogen was analyzed on elemental CNS analyzer, Vario model EL III (Nelson and Sommers, 1996), while the content of the crude proteins in dry matter was calculated on the basis of N content (Licitra et al., 1996).

Statistical analysis of the results obtained from the chemical analyses of the grains was performed using SYSTAT - 16 software (SPSS Inc., 2007). The statistical significance (P-value) in effects of different fertilization variants on all the variables tested was determined using Analysis of Variance (ANOVA) method. The effects of applied fertilizers on the chemical composition of wheat were evaluated using Duncan's Multiple Range Test (DMRT) at P = 0.05 and P = 0.01.

The data on the grain yield were adjusted to 14% moisture content and presented graphically.

Results and discussion

The main chemical characteristics of the study soil are presented in Table 2. The soil is characterized by acid reaction, high available potassium and medium available phosphorus, humus and total nitrogen supply.

By analyzing the contents of nitrogen, phosphorus, potassium and proteins in grains of wheat (Table 3), it was determined that an application of high rates of mineral fertilizers (120 kg·ha^{-1} N, P_2O_5 and K_2O) and their combination with bacterial inoculants has caused a significant increase in the share of nitrogen, phosphorus, potassium and protein in the grains of the crop studied compared to the other tested variants. Hence, the excess of microbiologicaly fixed nitrogen, with higher amounts of mineral nitrogen, influenced positively on the accumulation of the stated elements and compounds in the study plant material, which is in accordance with previous researches (Pandey et al., 1998).

Table 2. Main chemical characteristics of the studied Eutric Cambisol

Parameter		Mean	Standard deviation	Range
pH	nKCl	4.06	0.05	4.00-4.10
	H_2O	4.90	0.03	4.87-4.92
P_2O_5 (mg 100 g^{-1})		15.73	0.31	15.51-16.09
K_2O (mg 100 g^{-1})		25.30	0.30	25.08-25.65
Humus (%)		2.19	0.01	2.18-2.19
Total N (%)		0.136	0.005	0.132-0.141

Table 3. The effect of the fertilization variants on the average chemical composition of the grain of wheat (in %) in the study year

Variants	Total N (%)	P_2O_5 (%)	K_2O (%)	Proteins (%)
Ø	1.31 g	1.41 f	0.24 f	8.19 g
N1	1.49 f	1.54 e	0.41 e	9.31 f
N2	1.72 c	1.66 c	0.71 b	10.75 c
KP+N1	1.59 d	1.57 d	0.52 d	9.94 d
KP+N2	1.88 b	1.68 b	0.87 a	11.75 b
ES+N1	1.58 e	1.58 d	0.55 c	9.88 e
ES+N2	1.89 a	1.76 a	0.87 a	11.81 a
P value	***	***	***	***
LSD (0.05)	0.005	0.023	0.012	0.012
LSD (0.01)	0.007	0.032	0.017	0.016

DMRT was used to compare different variants at P = 0.05 and P = 0.01; *** indicates statistical significant differences at the P<0.05, P<0.01 and P<0.001 levels, respectively; LSD indicates least significant differences.

The analysis of the yield of wheat grain showed the noticeable yield differences between the applied fertilization treatments (Figure 1).

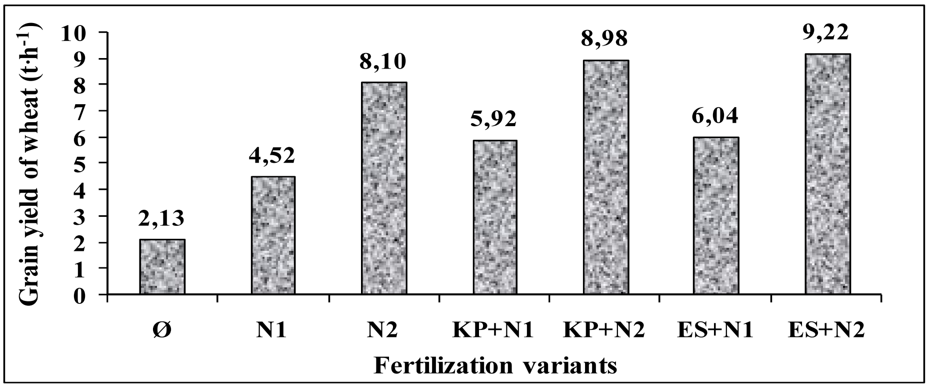

Figure 1. The effect of the fertilization variants on the grain yield of wheat (t·ha-1).

The highest increase in yield was obtained by combined application of bacterial inoculants used and high rates of mineral NPK fertilizers, although it should be noted that with combined usage of bacterial inoculants and low rates of mineral NPK fertilizers were obtained higher yields comparing to the application of low rates of the pure mineral nutrients (60 kg·ha^{-1} N and P_2O_5, and 40 kg K_2O ha^{-1}) in conditions of agricultural production typical for this study. Similar results were obtained in the study of El-Sirafy et al. (2006), in which a significant interaction effect of nitrogen fertilizers and microbial inoculation on wheat yield compared to the unfertilized variants was also found.

The character of the effects of the applied fertilizers on the yield of crop also depended also on the weather conditions specific to each year of study. Specifically, good distribution of rainfall and temperature during 2006/2007 contributed largely to the achieved high yields of wheat in the investigated agro-ecological conditions, as indicated by other authors (Josipović et al., 2005).

Conclusions

The results of the paper indicate that application of high rates of mineral fertilizers and their combination with bacterial inoculants has caused a significant increase in the share of nitrogen, phosphorus, potassium and proteins in the grains of the wheat compared to the other tested variants. In addition, the highest increase in yield was obtained by combined application of bacterial inoculants used and high rates of mineral fertilizers, although it should be noted that with combined usage of bacterial inoculants and low rates of mineral NPK fertilizers were obtained higher yields comparing to the application of low rates of the pure mineral nutrients (60 kg·ha^{-1} N and P_2O_5, and 40 kg K_2O ha^{-1}) in conditions of agricultural production typical for this study. Hence, it was estimated that the studied bacterial inoculants can be used to supplement the use of urea-N, helping to ensure that the supply of nutrients contributing to optimized yield is maintained.

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