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RATIONALIZATION IN THE USE OF MINERAL FERTILIZER IN SOYBEAN PRODUCTION

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Abstract

The effect of different dosages of nitrogen fertilizers applied to the previous crop and seed inoculation with microbial fertilizer NS-Nitragin on soybean yield and consumption of mineral nitrogen from the soil was studied. The experiment was set up in the field of the Institute of Field and Vegetable Crops in four replications. Inoculation of seeds prior to sowing led to statistically highly significant yield increase in all four years of research, while the highest dosages of nitrogen contributed to a significant increase in consumption of mineral nitrogen from the soil and reduction in nitrogen fixation.
***Key words**: nitrogen fertilizer, nitrogen fixation, inoculation, mineral nitrogen, yield, soybean*

Introduction

Intensive crop production requires significant quantities of mineral fertilizers. Nitrogen is the main biogenic element and the most limiting factor in achieving high yields. Plant accessible nitrogen, the mineral form of nitrogen is subject to leaching losses due to its mobility in soil and denitrification, as well as increasing the content due to mineralization of organic matter in soil, resulting in specific nitrogen application for sustainable soybean production *(Malešević et al., 2005)*.

Soybean can reasonably be called a plant of the twentieth century, as it had previously been known and grown only in China *(Hrustić et al., 2006)*. The economic importance of soybean results from its chemical composition of grain, which contains approx. 40% of protein, all of the essential amino acids and approx. 20 -25% of oil with

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desirable fatty acid composition, and an abundance of minerals and vitamins *(Baranova and Lukomca, 2005)*. Soybean today has become one of the most important industrial plant from which more than 20,000 different products are obtained *(Davidenko, et al., 2004)*.

Soybean has a great importance for soil management, as it is enriching soil with nitrogen and maintains the soil in good physical condition, which makes it very desirable component in crop rotation. It is well known that the soil must have good physical properties, such as structure of aggregates and capillarity for achieving high yields *(Krmpotić et al., 2003)*. Plowed crop residues, such as soybean root and nodules, enrich the soil with organic matter, which have positive effects on its biological value and fertility.

The amount of mineral nitrogen in the soil is highly variable and depends on many factors: soil type, fertility, structure, biological value of the soil, crop residues, plowing, the input of organic matter, fertilization, nutrient losses by crop and previous crop removal, land utilization, processing system, climatic conditions and soil moisture and temperatures during vegetation and winter period *(Starcevic et al., 2003)*.

Nitrogen fertilization of soybean is very specific due to it's ability of biological nitrogen fixation and good use of residual nitrogen from the soil. *Bradyrhizobium japonicum*, *Bradyrhizobium elkani,* and *Sinorhizobium fredi (Martinez Romero and Caballero-Mellado, 1996)* are capable of forming symbiotic association with soybean plants. During symbiosis with plants, rhizobia live in specialized root nodules known to be able to fix some 180 kg N ha^{-1} per year. These bacteria produce growth promoting substances, such as gibberellins and indole, which stimulate the growth of host plants. Soils usually have inadequate number of bacteria from the genus *Bradyrhizobium*, so when soybean is sown it is recommended to inoculate the seed with microbiological fertilizers based on these bacteria. Process of biological nitrogen fixation provides the soybean plants with 50-70% of the total nitrogen needed for obtaining high yield *(Krmpotić et al., 2003)*. Soybean responds to the increased content of available nitrogen in the soil by diminishing biological nitrogen fixation and yield reducing. Proper selection of appropriate doses of nitrogen depends on soil type, existing nitrogen present in the soil, weather and many other factors that directly or indirectly affect the yield *(Djukic et al., 2010)*. To exhibit the full effect of nitrogen fertilizer, it is necessary that all cultivation practices are carried out in a timely and quality manner *(Crnobarac et al., 2000)*, under optimal environmental conditions.

The main idea of this study was to examine how the soybean responds to different doses of nitrogen fertilizer applied under the previous crop (maize), in combination with inoculation of seeds and plowed crop residues in order to achieve high and stable yields, with the rationalization use of mineral nitrogen fertilizers.

Material and methods

To study the effect of fertilization with different doses of nitrogen applied under the previous crop and the impact of the application of microbiological fertilizer Nitragin on soybean yield and consumption of mineral soil nitrogen, a four-year field trial was conducted on experimental plots of the Institute of Field and Vegetable Crops. The experiment was designed as three crop rotation cycles (corn - soybean - wheat), with four replications, and samples were arranged in a randomized block design. The treatments were: 0 kg ha-1 nitrogen with crop residues not incorporated into the soil, 0 kg ha-1 nitrogen (control), 50 kg ha-1 nitrogen and 150 kg ha^{-1} nitrogen, 250 kg ha^{-1} nitrogen with incorporated crop residues. The second treatment related to the inoculation and the absence of inoculation of soybean seeds with Nitragin - the microbiological fertilizer.

Nitrogen fertilization of the previous crop was applied, except in control. Immediately after wheat harvest and prior to stubble peeling, 50 kg ha^{-1} N (KAN 27%) was applied to prevent nitrogen depression. The same amount of phosphorus and potassium fertilizers (80 kg per ha P_2O_5 and K_2O) were applied for all treatments. Phosphate (18%) and potassium fertilizers (40%) and half of the total amount of nitrogen (KAN 27%) were incorporated into the soil prior to primary tillage for corn, and the remaining amount of nitrogen (KAN 27%) was applied just prior to corn planting. depending on the scenario. No mineral fertilizer was applied to soybean.

Cultivar Proteinka (0 maturity group) and microbiological fertilizer Nitragin, developed at the Institute of Field and Vegetable Crops in Novi Sad were selected for this research. This microbial inoculant is characterized by a large number of highly potent strains of rhizobia (*Bradyrhizobium japonicum)*.

Dimensions of the basic plot were 5 m x 3 m, covering an area of $15m^2$. The experiments were protected with four soybean rows of the same cultivar, as a safety zone around the experiment. Plant density was 50 x 3.5 cm (571,430 plants per ha). One of each boundary rows of the plot was regarded as isolation, and as such discarded, and four central rows were taken for analysis.

During the four years of experiment the standard cultural practices for soybean production were applied: autumn plowing at a 25 cm depth, seedbed preparation and cultivation. Sowing was done using seeder machine and harvesting of the four central rows was done using micro plots harvester. All yield data were calculated on 14% moisture basis.

At the time of soybean planting and soybean maturity stage, the soil samples were taken to a depth of 90 cm (at interval layers of 30 cm) to determine the content of mineral nitrogen. The consumption of mineral nitrogen from the soil was calculated on the basis of differences found between mineral nitrogen in spring and autumn, corrected for yield and average nitrogen mineralization for this type of soil.

The results were analyzed statistically with the analysis of variance (ANOVA-2) program of MSTAT-C and the least significant difference (LSD) test.

Results and discussion

Weather conditions prevailing during the growing season of soybean in the investigated period are shown in Table 1.

Table 1. Weather conditions during the years of research

Month	Average monthly temperature (°C)				**average**	Rainfall (mm)				**average**
	2005	2006	2007	2008	**1964-2004**	2005	2006	2007	2008	**1964-2004**
IV	11,8	12,7	13,4	13,0	**11,4**	33,0	66,0	0,0	21,9	**48,8**
V	17,0	16,5	18,5	18,4	**16,8**	38,1	70,1	98,6	46,2	**59,5**
VI	19,3	19,7	22,1	21,8	**19,9**	135,4	104,3	71,1	115,9	**85,9**
VII	21,4	23,6	23,3	21,7	**21,4**	122,5	30,9	38,8	41,6	**68,2**
VIII	19,4	19,6	22,7	22,2	**21,0**	133,9	124,9	79,6	14,0	**56,9**
IX	17,3	17,9	14,6	15,2	**16,8**	67,0	23,8	78,8	93,6	**45,1**
	17,7	18,3	19,1	18,7	**17,9**	529,9	420,0	366,9	333,2	**364,4**

The most precipitations occurred in year 2005, when the highest soybean yield was achieved. The lowest yield was achieved in year 2006, with extremely high July temperatures and lack of rainfall, which led to the pod and flower abortion. During 2007 and 2008 growing season, temperatures were higher than the average while the rainfall was at the multi-year average level, but with an irregular schedule. In 2007 there was no precipitation in April, while the mean daily temperatures were higher by two degrees, compared to the multi-year average temperature, which had a negative effect on soybean emergence and impact on yield losses.

Annual variation of soybean yield was statistically highly significant (Table 2), which can be explained by different environmental conditions. The highest yield was achieved in 2005 (3805.6 kg ha^{-1}), which had the highest rainfall, as compared to other years of study. These results were consistent with the results of *Dozet (2009)*.

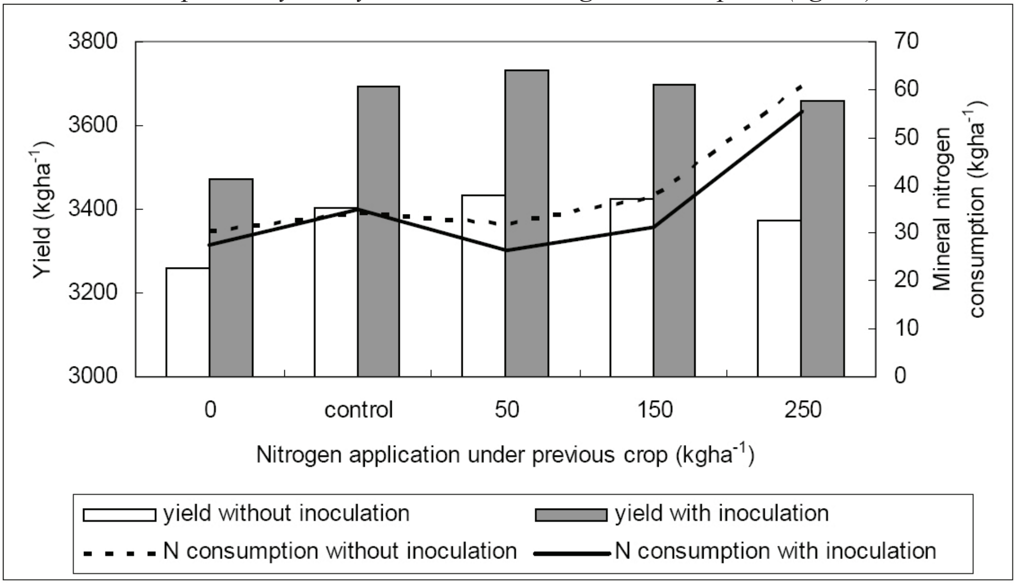
Table 2. Effect of nitrogen fertilization and seed inoculation on soybean yield (kgha[-1])

Year (A)	Fertilizer (kgha-1) (B)	Seed inoculation (C)		Average AB	Average A
		Without inoculation	With inoculation		
2005	control	3663,3	3721,5	**3692,4**	**3805,6**
	0N	3662,5	4008,8	**3835,7**	
	50N	3725,3	3921,5	**3823,4**	
	150N	3630,5	4061,3	**3845,9**	
	250N	3679,0	3982,3	**3830,7**	
	Average AC	**3674,3**	**3993,5**		
2006	control	2819,8	3137,5	**2978,7**	**3088,3**
	0N	3057,3	3408,8	**3233,1**	
	50N	2788,3	3292,3	**3040,3**	
	150N	3023,5	3080,5	**3052,0**	
	250N	3023,8	3250,8	**3137,3**	
	Average AC	**2973,2**	**3258,1**		
2007	control	3243,8	3358,0	**3300,9**	**3442,6**
	0N	3188,8	3354,8	**3271,8**	
	50N	3373,8	3406,8	**3390,3**	
	150N	3578,0	3691,3	**3634,7**	
	250N	3557,5	3673,3	**3615,4**	
	Average AC	**3424,5**	**3531,6**		
2008	control	3303,5	3676,7	**3490,1**	**3723,8**
	0N	3711,7	3995,3	**3853,5**	
	50N	3847,5	4308,3	**4077,9**	
	150N	3471,5	3956,3	**3713,9**	
	250N	3232,0	3735,5	**3483,8**	
	Average AC	**3565,7**	**3998,9**	**Average B**	
Average BC	control	**3257,6**	**3473,4**	**3365,5**	
	0N	**3405,1**	**3691,9**	**3548,5**	
	50N	**3433,7**	**3732,2**	**3583,0**	
	150N	**3425,9**	**3697,4**	**3561,6**	
	250N	**3373,1**	**3660,5**	**3516,8**	
	Average C	**3379,1**	**3651,1**		
Average 2005-2008				**3552,5**	

LSD	Treatments						
	A	B	C	AxB	AxC	BxC	AxBxC
1%	254	397	142	585	186	352	525
5%	198	196	94	441	153	284	396

Observation of different rates of nitrogen variations (Figure 1) showed that application of 50 and 150 kg ha^{-1} nitrogen (3583.0 and 3561.6 kg ha^{-1}) led to significantly higher yield in comparison to control (3365.5 kg ha^{-1}).

Graph1 - Soybean yield and soil nitrogen consumption (kgha^{-1})



In treatments with no nitrogen and in those with nitrogen applied in the previous crop, inoculation of seeds with microbiological fertilizer (Nitragin) applied prior to planting had contributed to the increase in yield (3651.1 compared to 3379.1 kg ha^{-1}). In all four years, this increase in yield caused by applying Nitragin was statistically significant. These results were consistent with the results obtained by *Milic et al. 2003*, *Pušić et al. 2008, Djukic et al. 2008*. Consumption of mineral nitrogen from the soil when 250 kg ha^{-1} of nitrogen was applied to the previous crop was the largest, and the yield was at the level of treatment with no fertilization and the plowed crop residues (Figure 1). Treatments with application of Nitragin inoculants showed lower consumption of mineral nitrogen from the soil and higher yield, in contrast to the treatments with no Nitragin application. This indicates that soybean uses nitrogen from the atmosphere more than that from the soil, which significantly affects the yield increase. Microbial inoculants allow the replacement of mineral nitrogen fertilizer, which has economic and environmental effects, because the incorporation of microorganisms reducing the use of mineral nitrogen fertilizer, does not pollute the soil, improves soil structure, increasing organic matter content and positively affecting the physical properties of the soil *(Milic et al., 2004)*. In the treatment where 50 kg ha^{-1} of nitrogen was applied, the highest yield was achieved in this four-year period, as in treatments with and without inoculation. By increasing the nitrogen rate applied to the previous crop, a yield reduction and a significant increase in consumption of mineral nitrogen from the soil and decrease in nitrogen fixation were noticed. If the soil containing 65 kg ha^{-1} or more mineral nitrogen at the depth of 0-90 cm prior to soybean planting, additional nitrogen fertilization to achieve high soybean yield should be avoided *(Dozet, 2009)*.

In developed countries, 25% of energy needed in agriculture is used for production of nitrogen fertilizers, which implicate the importance of soybean and biological nitrogen fixation (*Адамень i sar*., *2003*).

Conclusion

Based on the four-year results regarding application of mineral nitrogen fertilizers to the previous crop in soybean production, the following conclusions can be drawn:

Plowing of crop residues contributed to increased crop yields in the treatments with and without application of microbial fertilizer Nitragin.

Inoculation of soybean seed prior to planting is a reasonable measure in crop cultivation, which contributed to increased soybean yield, regardless of the amount of nitrogen applied to the previous crop. Amounts of nitrogen applied to the previous crop in dosages ranging from 50 to 150 kg ha^{-1} resulted in yield increase, while the amount of 250 kg ha^{-1} reduced the yield.

Use of large quantities of nitrogen fertilizers has increased the consumption of mineral nitrogen from the soil, without increasing the yield of soybean.

It is possible to achieve significant savings in the production of soybeans by inoculation of soybean seed, plowing of crop residues and taking advantage of residual nitrogen which remains in the soil after cropping.

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