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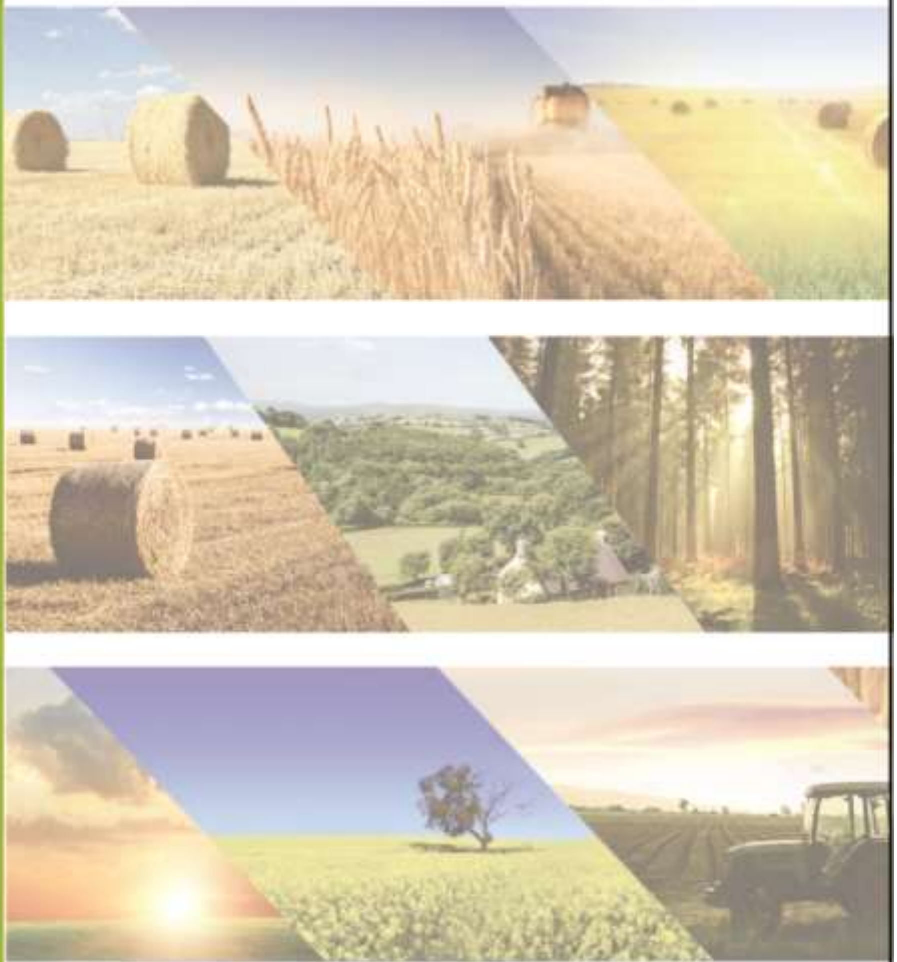

XIV International Scientific Agriculture Symposium
"Agrosym 2023"
Jahorina, October 05-08, 2023

Agro sym 2023

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XIV International Scientific Agriculture Symposium
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Jahorina, October 05 - 08, 2023

Impressum

XIV International Scientific Agriculture Symposium „AGROSYM 2023“

Book of Proceedings Published by

University of East Sarajevo, Faculty of Agriculture, Republic of Srpska, Bosnia
University of Belgrade, Faculty of Agriculture, Serbia
Mediterranean Agronomic Institute of Bari (CIHEAM - IAMB) Italy

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Website:
http://agrosym.ues.rs.ba

CIP - Каталогизација у публикацији
Народна и универзитетска библиотека
Републике Српске, Бања Лука

631(082)(0.034.2)

INTERNATIONAL Scientific Agriculture Symposium "AGROSYM" (14 ; 2023 ; Jahorina)
Book of Proceedings [Електронски извор] / XIV International Scientific Agriculture Symposium "AGROSYM 2023", Jahorina, October 05 - 08, 2023 ; [editor in chief Dusan Kovacevic]. - Onlajn izd. - El. zbornik. - East Sarajevo : Faculty of Agriculture, 2023. - Ilustr.

Sistemski zahtjevi: Nisu navedeni. - Način pristupa (URL): https://agrosym.ues.rs.ba/article/showpdf/BOOK_OF_PROCEEDINGS_2023_FINAL.pdf. - El. publikacija u PDF formatu opsega 1377 str. - Nasl. sa naslovnog ekrana. - Opis izvora dana 15.12.2023. - Bibliografija uz svaki rad. - Registar.

ISBN 978-99976-816-1-4

COBISS.RS-ID 139524097

EFFECTS OF THE USE OF DIFFERENT FERTILIZATION RATES AND MICROBIOLOGICAL PRODUCTS ON WHEAT YIELDS

Vojin CVIJANOVIĆ[1], Marija BAJAGIĆ[2], Mladen PETROVIĆ[1], Nenad ĐURIĆ[3], Igor ĐURĐIĆ[4], Miloš STANKOVIĆ[5]

[1]Institute for Science Application in Agriculture, 68b Blvd. despota Stefana, Belgrade, Serbia
[2] Faculty of Agriculture, University of Bijeljina, Pavlovića put bb, Bijeljina, Bosnia and Herzegovina
[3] Institute of Vegetable Growing, Karađorđeva 71, S. Palanka, Serbia
[4] University of East Sarajevo, Faculty of Agriculture, Vuka Karadžića 30, East Sarajevo, Bosnia and Herzegovina
[5] Faculty of Management and Economics, Karađorđeva 52, Kragujevac, Serbia
*Corresponding author: cvija91@yahoo.com

Abstract

Common wheat (*Triticum aestivum* L.) is a crop predominantly used in food and feeds. Modern agricultural production implies rather an irrational use of large amounts of pesticide and mineral fertilizers, significantly diminishing the quality of agricultural land, and negatively affecting the environment, food quality and human health. In order to diminish adverse effects of intensive agricultural production, farmers around the world incline to an increased use of microorganisms to reduce the use of mineral fertilizers and pesticides to some extent. Agricultural production is facing certain requirements to reduce chemical inputs in order to protect the environment, produce safe and profitable food. This situation is additionally aggravated by climate changes that require many practices to adapt accordingly. The experimental research was carried out during 2016-2019 at the "PKB Agroekonomik" Institute. Field operations were done with typical agricultural practices, and four variants of fertilization were set up. Prior to sowing, 400 kg ha-1 NPK 15:15:15 was applied. Different rates of UREA 46% N were used in spring top-dressing of the crops. Aside of mineral fertilizer, microbiological products with active microorganisms were also used for top-dressing. Two wheat varieties – Ratarica and Pobeda were used. The goal of the research was to determine the impact of different rates of fertilizer and microbiological products on productive and morphological properties of wheat.

Keywords: *wheat, effective microorganisms, yield, fertilizer*

Introduction

Rice, wheat and maize are most grown crops for human diet. Wheat is the most important and most wide-spread cereal in the world. According to the botanical classification, wheat belongs to family *Gramineae*, tribe *Triticeae*, comprising about 300 different species (Clayton and Renvoize, 1986; Đurić et al.. 2017). Wheat is characterized by great polymorphism, due to its winter and spring varieties. As a staple bread crop, wheat in developed countries comprises 53% and in undeveloped countries 85% of the total world's production (Pena, 2007). Wheat is grown on all continents, including high altitude parts in the tropics and sub-tropics (Додиг, 2010; Đurić et al. 2017). The use of microbiological fertilizer in sustainable systems is an imperative in production of safe food (Cvijanović et al. 2013). There have been a growing number of research over the previous years on the interaction between plants and certain group of microorganisms to obtain environmentally-friendly yet profitable production (Cvijanović et al. 2012). Production of high yielding wheat of good quality is possible only if

use quality varieties and provide proper growing conditions and production technology (Đurić et al. 2015).
The most populated countries, such as China, India and Russia had, on average, the largest plots under wheat. In China, wheat was sown on 24,340,440 ha and the average yield was 5.17 t ha^{-1}. India had 29,973,890 ha of plots under wheat, with the average yield of 3.07 t ha^{-1}. Russia had 24,688,890 ha of plots with a rather low average yield of 2.40 t ha^{-1}. In Europe there were 59,235,220 ha of plots under wheat averaged 3.96 t ha^{-1} of yields.

Table 1. Areas under wheat, yields and production worldwide

Region		2010	2011	2012	2013	2014	2015	2016	2017	2018
Globally	000 ha	215,602	220,263	217,917	218,868	219,750	223,476	219,096	218,424	214,291
	t ha^{-1}	2.97	3.16	3.09	3.25	3.32	3.32	3.42	3.54	3.43
	000 t	640,802	696,898	673,728	710,397	728,730	741,643	748,392	773,476	734,045
China	000 ha	24,257	24,272	24,270	24,119	24,071	24,599	24,698	24,510	24,268
	t ha^{-1}	4,75	4.84	4.99	5.06	5.24	5.39	5.40	5.48	5.42
	000 t	115,186	117,414	121,030	121,930	126,215	132,646	133,277	134,340	131,447
India	000 ha	28,457	29,068	29,860	29,650	30,470	31,470	30,420	30,790	29,580
	t ha^{-1}	2.84	2.99	3.18	3.15	3.15	2.75	3.03	3.20	3.37
	000 t	80,803	86,874	94,880	93,510	95,850	86,530	92,290	98,510	99,700
Russia	000 ha	21,639	24,835	21,277	23,371	23,907	25,870	27,312	27,517	26,472
	t ha^{-1}	1.92	2.26	1.77	2.23	2.50	2.39	2.69	3.13	2.73
	000 t	41,507	56,239	37,719	52,090	59,711	61,784	73,345	86,004	72,136
Europe	000 ha	55,811	59,278	54,892	57,869	58,717	61,475	62,585	61,879	60,611
	t ha^{-1}	3.61	3.78	3.55	3.91	4.25	4.19	4.03	4.40	4.00
	000 t	201,373	224,032	195,046	226,103	249,253	257,461	252,156	272,381	242,139

(Source: http://www.fao.org/faostat/en/#data)

In Serbia, in the period 2009-2018, wheat was sown on 565,745 ha of plots, with the average production of 2,278,110 t and average yield of 4.33 t ha^{-1}. The largest wheat plots were recorded in 2018, amounting to 643,083 ha, as well as the highest yield 4.57 t ha^{-1}, which resulted in the highest grain production of 3,941,601 metric tons, making Serbia the ten largest wheat producer in the world.

Material and methods

In order to perceive the effect of using NPK fertilizer and microbiological product "EM Aktiv“ (trademark) on wheat yields, a three-year trial was set up on demonstrational plots of the "PKB Agroekonomik" Institute in Padinska Skela, using two wheat varieties, four different fertilization variants in four replications. Two wheat varieties PKB Ratarica and NS Pobeda, selected in Serbian institutes ("PKB Agroekonomik" Institute and the Institute for Field and Vegetable Crops in Novi Sad) were used as research material during 2016/2017, 2017/2018 and 2018/2019. The plots were set up in a randomized design with four replications. During all three years of the research, the preceding crop was maize. All practices in terms of production technology (tillage, sowing, spring top-dressing, and harvest) were carried out within the optimal time window. The crop samples were taken from the middle of each plot. The grain samples necessary for calculating productive and qualitative properties of grains were taken after harvest from the whole plots. To ensure proper dressing, NPK 15:15:15 mineral fertilizer was applied during the basic tillage. Prior to sowing, 400 kg ha^{-1} NPK was introduced into the soil, in amounts calculated according to the area of the demonstrational plot (Table 5).

Table 2. Fertilizer variants on the experimental plot

Treatments	Prior to sowing: NPK (kg ha^{-1})	Top-dressing: UREA (kg ha^{-1})	EM Aktiv (6 l ha^{-1})	Total N : P_2O_5 : K_2O
T 1	400	150	-	129 : 60 : 60
T 2	400	150	1 time	129 : 60 : 60
T 3	400	100	2 times	106 : 60 : 60
T 4	400	50	3 times	83 : 60 : 60

Results and discussion

A grain yield comes as a result of various physiological changes that occur during crop growth being directly affected by numerous factors. Grain yields are affected by different factors, primarily genotype characteristics, soil fertility and cropping practices used.

During the period 2017-2019, the grain yield was 6.58 t·ha^{-1} (Table 5). Affecting by weather conditions, the obtained yields varied with no statistical significance. In 2017, the achieved grain yield was 6.79 t·ha^{-1}, in 2018 it was 6.54 t·ha^{-1}. The highest yield of 6.95 t·ha^{-1}was recorded in 2019.

The varieties (B) and variety x fertilizer treatment interaction had a statistically highly significant effect on the yield. The Ratarica variety had the highest yield in all years of research. It averaged 7.02 t·ha^{-1}, which is the highest average yield. The Pobeda variety yielded 6.50 t·ha^{-1}, which was 7.40% lower.

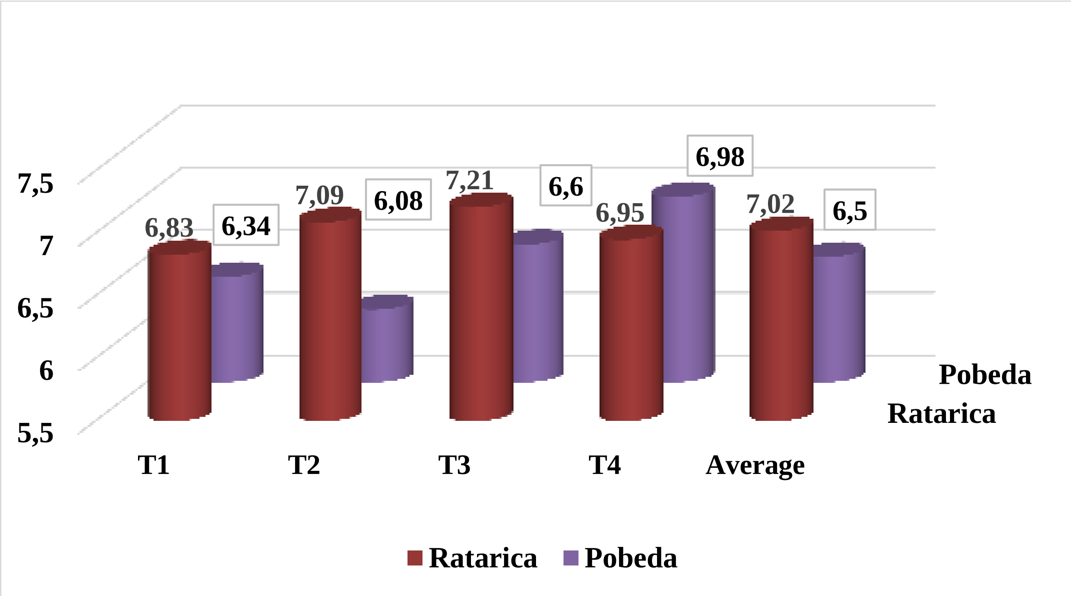
The yield was significantly affected by top-dressing treatments (factor C). The highest average grain yield of both varieties were detected under treatments T2 and T4. The grain yield under treatment T4 was 6.63 t·ha^{-1}, and under treatment T2 it was 6.47 t·ha^{-1}; the differences were not statistically significant, since the differences between the grain yields were small. When compared to treatment T1, there was 3.59% increase in grain yield, and compared to T3 it was 10.31%. Yields definitely depends on variety properties. Royo et al. (2005) determined that yields of 12 wheat varieties grown on 24 sites were dependent on basic yield-affecting parameters. Sugár et al. (2016) came to a conclusion that maximum grain yield was achieved under 80 and 160 kg ha^{-1} nitrogen treatments and an increase in nitrogen rates did not result in increased yields in any year (Đurić et al., 2018; Jelic et al. 2015; Terzić et al., 2018; Rajicic et al., 2020).

Graph 26 shows yields of each variety per treatment. Under all treatments, the Ratarica variety had highest yields, ranging from 6.83 t ha^{-1} under treatment T1 to 7.21 t·ha^{-1} under treatment T3. Yields of the Pobeda variety ranged from 6.08 t·ha^{-1} to 6.98 t·ha^{-1}.

Table 3. Effect of the factors on grain yield of wheat (t ha^{-1})

Year (A)	Variety (B)	Fertilization (C) T1	T2	T3	T4	x̄ A x C	x̄ A
2017	Ratarica	6.63	7.07	7.38	6.85	**6.98**	**6.79**
	Pobeda	6.46	6.17	6.62	7.13	**6.60**	
	x̄ B x C	**6.55**	**6.62**	**7.00**	**6.99**		
x̄ A x B x C		**6.19**	**6.41**	**6.78**	**6.64**		
2018	Ratarica	6.63	7.13	6.78	6.82	**6.84**	**6.54**
	Pobeda	6.28	5.65	6.18	6.88	**6.25**	
	x̄ B x C	**6.46**	**6.39**	**6.48**	**6.85**		
x̄ A x B x C		**6.19**	**6.13**	**6.01**	**6.27**		
2019	Ratarica	7.24	7.06	7.47	7.18	**7.24**	**6.95**
	Pobeda	6.28	6.43	7.01	6.91	**6.66**	
	x̄ B x C	**6.76**	**6.75**	**7.24**	**7.05**		

$\bar{x}$ A x B x C		**6.82**	**6.87**	**7.25**	**7.00**	**$\bar{x}$ C**	**$\bar{x}$ B**
$\bar{x}$ B x C	Ratarica	6.83	7.09	7.21	6.95	**7.02**	**6.76**
	Pobeda	6.34	6.08	6.6	6.98	**6.50**	
	$\bar{x}$ B x C	**6.59**	**6.59**	**6.91**	**6.97**		
	$\bar{x}$ C	**6.40**	**6.47**	**6.01**	**6.63**		
						Average 2017-2019	**6.76**



Graph 1. Average grain yield (t·ha^{-1}) of both wheat variety in the investigated period, depending on the treatments

Table 4: The analysis of price sensitivity and wheat yield in terms of gross margin

		Price (RSD/kg)				
		-20%	-10%	Average	10%	20%
Yield (kg/ha)		**13.88**	**15.62**	**17.35**	**19.09**	**20.82**
-20%	**5,408.00**	-10,758.39	-1,375.51	8,007.37	17,390.25	26,773.13
-10%	**6,084.00**	-1,375.51	9,180.23	19,735.97	30,291.71	40,847.45
Average	**6,760.00**	8,007.37	19,735.97	31,464.57	43,193.17	54,921.77
10%	**7,436.00**	17,390.25	30,291.71	43,193.17	56,094.63	68,996.09
20%	**8,112.00**	26,773.13	40,847.45	54,921.77	68,996.09	83,070.41

Source: Authors’ calculations based on the questionnaires on wheat production gross margins in the period 2017 – 2019

Table 6 shows the analysis of price sensitivity and wheat yield and their effect on gross margin per hectare. Based on gross margin questionnaires, it was determined that the average gross margin in wheat production in the period 2017 – 2019 was 31,464.57 RSD/ha, with the average yield of 6,760 kg/ha and price of 17.35 RSD/kg. Price sensitivity analysis comprised changes in gross margin when wheat price and/or yield increase or decrease 10% and 20%. From the obtained data it can be concluded that gross margin in wheat production is sensitive to change in price and yields to a great extent. The lowest positive gross margin could be obtained if the price or yield decreased 20%, amounting to 8,007.37 RSD/ha. If one factor decreased 20% and another 10%, wheat production would not be profitable, resulting in a negative gross margin (-1,375.51 RSD/ha). The lowest gross margin would come as result of 20% decrease in both price and yield, amounting to -10,758.39 RSD/ha. On the other hand, an increase in wheat yields and price would have greater effects on gross margin. A 20% increase in yields and price would lead to more than a 150% increase in gross margin, amounting to 83,070.41 RSD/ha. This paper shows gross margin sensitivity upon change in factors affecting production value, yet production costs can also have a great impact on it. In wheat production, those costs are costs of crop protection and fertilization, but there are also transportation costs that can be significant, depending on the distance between the plot itself and the storage place (Savić et al., 2020.).

Conclusion

Based on the three-year research on the effect of top-dressing and the use of microbiological fertilizer on grain yield of wheat *(Triticum aestivum sp.)*, it can be said that grain yield averaged 6.76 $t \cdot ha^{-1}$ with some significant differences caused by treatments and genotype domination. The Ratarica variety had higher yields than the Pobeda variety. In general, both varieties yielded less at higher density planting. Statistically significant differences in yields by fertilization were recorded. The highest yield was achieved under treatments with less fertilizer and more foliar treatments (6.46 and 6.41 $t \cdot ha^{-1}$). To conclude, the varieties Ratarica and Pobeda under different agricultural and meteorological conditions exhibited great stability in their morphological and productive properties. The use of microbiological products in wheat production can provide stable production and high grain yields, which is very important in terms of human diet.

Acknowledgements

This paper is a result of the research conducted within the contract on the implementation and financing of scientific research in 2023, between the Institute for Science Application in Agriculture, Belgrade and the Ministry of Science, Technological Development and Innovation of the Republic of Serbia, contract number: 451-03-47/2023-01/ 200045.

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