THE INFLUENCE OF CALCIFICATION AND NPK FERTILIZERS ON THE ECONOMICS OF TRITICALE PRODUCTION

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A R T I C L E I N F O

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A B S T R A C T

The tests were performed on the property of the Agricultural and Chemical School "Doctor Djordje Radic" in Kraljevo, on pseudogley soil, during a two-year period (2015/16 and 2016/17). Based on the analysis of production value and total variable costs, a production calculation was made. Elements of economic efficiency (productivity, economy and profitability) were calculated for all four variants of fertilization. The tests showed a significant variation in grain yield in the tested fertilization variants. During the two-year research, the T2 variant fertilized with mineral nutrients with increased phosphorus dose (NP2K) had the most favorable values of economic efficiency indicators. Variant T2 can be considered the most profitable and most cost-effective, regardless of the fact that the yield and production value were the highest in variant T4, which is fertilized with a combination of mineral nutrients with increased doses of phosphorus, lime and organic fertilizers.

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Introduction

Triticale is a hybrid plant species that was developed by humans that tends to combine the advantageous traits of both wheat and rye. Triticale's capacity to absorb nutrients during the growth season is influenced by the height of the yield and the size of the vegetative organs. The most typical nitrogen applications in Serbia vary from 80 to 120 kg ha^{-1}, depending on the agrochemical characteristics of the soil (Đekić et al., 2014; Terzic et al., 2018; Rajičić et al., 2020a). Large volumes of fertilizers can reduce yields and be detrimental to the environment and the economy, which is a major cause of agroecosystem pollution (Đekić et al., 2016; Rajičić et al., 2019; Madić et al., 2020; Tmušić et al., 2021). Weather and particular site conditions have a big impact on how well fertilizers are used and how much produce is produced (Đekić et al., 2014; Đurić et al., 2016; Madić et al., 2018; Terzić et al., 2018; Rajičić et al., 2021). Effective nitrogen fertilization is essential for producing grains profitably, as well as safeguarding groundwater and surface waters from contamination brought on by nitrate leaching as a result of excessive and insufficient nitrogen application (Todorović and Filipović, 2009; Biberdžić et al., 2012; Babić et al., 2021). Triticale has fewer agro-technical investment requirements than other small grains and is more suited to unfavorable soil and environmental circumstances, which has led to an increase in its use in organic and sustainable agricultural production (Đurić et al., 2015; Rajičić et al., 2020a; Babić et al., 2021). When mineral fertilizers are applied to acidic soils in conjunction with lime and manure, the acidity of the soil is reduced, increasing the yield of farmed crops (Đurić et al., 2015; Rajičić et al., 2020b; Babić et al., 2021). Due to the higher cost of mineral, lime, and organic fertilizers as well as the higher cost of producing cereals on acidic soils, it is debatable if such practices are profitable. The examination of variable production costs can serve as a foundation for economic analysis in order to produce grains more efficiently and with the highest quality at the lowest possible cost (Vukoje et al., 2011; Biberdžić et al., 2012). Examining the triticale yield and the financial justification for using various fertilizer types and doses during the two growing seasons in the production of triticale on acidic soil were the main objectives of this study.

Material and methods

Experimental design

The tests were conducted over a two-year period (2015/16 and 2016/17) on the premises of the Agricultural-Chemical School "Dr Djordje Radic" in Kraljevo on pseudogley soil. Micro tests were performed on the winter triticale variety Trijumf, which was created at the Center for Small Grains in Kragujevac. The trials were set up using a randomized block system with five repetitions and a plot size of 5 x 10 m^2. The experiment included control (C) and four treatments of fertilizers and their combinations (T1-120 kg ha^{-1} N, 80 kg ha^{-1} P_2O_5 and 60 kg ha^{-1} K_2O; T2-120 kg ha^{-1} N, 100 kg ha^{-1} P_2O_5 and 60 kg ha^{-1} K_2O, T3-120 kg ha^{-1} N, 80 kg ha^{-1} P_2O_5 and 60 kg ha^{-1} K_2O and 5 t ha^{-1} lime and 20 t ha^{-1} manure and T4-120 kg ha^{-1} N, 100 kg ha^{-1} P_2O_5 and 60 kg ha^{-1} K_2O and 5 t ha^{-1} lime and 20 t ha^{-1} manure). According to the predetermined timetable, fertilization is carried out on a regular basis each year using the specified amounts of nutrients. Half of the nitrogen fertilizer, together with the total amount of phosphorus, potassium, lime, and manure fertilizers, is applied before sowing, and the remaining half is added all at once during the full-rooting phase, either at the end of winter or the start of spring. The second decade of October saw the completion of sowing. Standard maintenance practices were used throughout the vegetative season. After the triticale reached full maturity, it was harvested. During this time, the yield was assessed and the moisture content was corrected to 14%.

Soil analysis

The soil on which the experiment was placed belongs to the type of pseudogley soil, heavy mechanical composition and rough unstable structure. Soil fertility is moderate, low pH values (pH in H_2O = 5.24 in KCl<4.48), with a humus content of about 2.18% and a total nitrogen content of 0.10 to 0.14%. The easily accessible phosphorus content was low (7-8 mg 100 g^{-1} of P_2O_5 soil), while the easily accessible potassium content was moderate (13.8 mg of 100 g^{-1} K_2O soil).

Statistical analysis

Based on the achieved research results, the parameters of descriptive statistics were calculated: average values and standard deviation. Statistical data processing was performed in the Analyst module of the SAS/STAT program (SAS Institut, 2000).

Indicators of economic efficiency of triticale production

Based on the analysis of the value of triticale production and total variable costs, the calculation of production and elements of economic efficiency (productivity, economy and profitability) for all four variants of fertilization was done. Coverage of variable costs of triticale production per hectare was calculated based on the following formula:

CVC = Q - VC, when Q = (q • c)

CVC - coverage of variable costs

Q- value of production

VC- variable costs

q- quantity of product

c- price of the product per unit of measure

A calculation of triticale production was made on the basis of variable costs for all four variants of fertilization. Based on the obtained data, a comparison of triticale production was made between different fertilization variants.

Meteorological conditions

The research was conducted during two consecutive seasons (2015/16 and 2016/17) in the Raska district, Central Serbia, on the type of pseudogley soil, in the secondary agricultural school "Doctor Djordje Radic", in Kraljevo (43° 43´00´´N, 20° 40´60´´E). The study area is Kraljevo, located at an altitude of about 192-217 m in the zone of temperate continental climate, with an average annual temperature of 11.5°C and the amount of precipitation of about 580-790 mm.

Table 1. Mean monthly air temperatures and precipitation in Kraljevo, Serbia (2015-2017), in relation to many years average (1980-2010)

Interval	X	XI	XII	I	II	III	IV	V	VI	Average
Mean monthly air temperature (°C)										
2015/16	11.6	7.3	2.3	-0.1	8.8	7.8	14.1	15.5	21.3	9.84
2016/17	10.6	6.8	0.0	-5.0	4.5	10.3	11.3	16.2	24.2	8.77
Average	11.8	6.0	1.9	0.3	2.3	6.8	11.8	16.7	19.8	8.60
The amount of precipitation (mm)										
2015/16	56.8	64.0	9.0	86.2	52.7	157.9	39.9	135.9	48.6	651.0
2016/17	84.1	77.6	9.4	27.1	35.3	57.7	82.1	99.9	56.2	529.4
Average	57.3	56.6	56.1	45.1	45.4	52.9	62.6	71.2	92.2	539.4

Source: https://www.hidmet.gov.rs/ciril/meteorologija/agrometeorologija.php

The data shown in Table 1 for the studied vegetation period (2015-2017) clearly indicate that the years in which the tests were performed at average temperatures differed from the multi-year average, which is characteristic for the Kraljevo area. The average air temperature was higher for 1.24°C in 2015/16 and 0.17°C in 2016/17 than the multi-year average temperature.

Average amount of precipitation was 10.0 mm lower in 2016/17 and 111.6 mm higher in 2015/16. Starting from the fact that sufficient amounts of precipitation in March and May are very important for the successful production of small grains, it can be concluded that the first year of research (2015/16) had a better or more even distribution of precipitation by months, which increased yields.

It was found that newly created high-yielding varieties of triticale are less responsive to temperature deviations (except extremes) than is the case with precipitation (Djekic et al., 2011; Milovanović et al., 2011; Kendal et al., 2014; Đurić et al., 2016; Terzic et al., 2018). Namely, the total amount of precipitation is reflected in the multi-year average, but the schedule, especially in the critical phases of development, is significantly disturbed. It has been determined that winter precipitation significantly affects the realization of the production potential of wheat (Terzić et al., 2018; Rajičić et al., 2021). In addition to the necessary reserves for the spring part of the vegetation, winter precipitation greatly affects the distribution of easily accessible nitrogen in the soil (Kondić et al., 2012; Lalević et al., 2012; Jelić et al., 2013; Đekić et al., 2018; Djuric et al., 2018; Terzic et al., 2018; Rajičić et al., 2019).

Results and Discussion

Grain yield

The average values of grain yield with different variants of fertilization in winter triticale grown in the Agricultural and Chemical School "Doctor Djordje Radic" in Kraljevo, during the two growing seasons, are shown in Table 2. In the first year of research (2015/16), the Trijumf variety achieved the highest grain yield of 5.876 t ha^{-1} in the T4 treatment fertilized with 120 kg ha^{-1} N, 100 kg ha^{-1} P_2O_5, 60 kg ha^{-1} K_2O, with 5 t ha^{-1} $CaCO_3$ and 20 t ha^{-1} manure, and the lowest yield was achieved by the control (0.970 t ha^{-1}). In the second year of research (2016/17), the highest yield of 5.203 t ha^{-1} was in the T4 variant where a combination of NPK was applied with increased content of phosphorus, lime and organic fertilizers.

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

Fertilization	Years				Average	
	2015-2016		2016-2017			
	$\bar{x}$	Sd	$\bar{x}$	Sd	$\bar{x}$	Sd
C	0.970	0,198	0.810	0.219	0.890	0.214
T1	5.036	0.491	4.500	0.244	4.768	0.462
T2	5.304	0.395	4.761	0.387	5.032	0.467
T3	5.704	0.268	4.999	0.376	5.351	0.482
T4	5.876	0.315	5.203	0.276	5.540	0.452

Source: Authors

In the treatments T2 and T4 in which mineral nutrients with a higher dose of phosphorus were applied, good results in increasing the yield were showed, which is the result of lower content of available phosphorus and high acidity on the examined soil. Agronomic efficiency of phosphorus had a tendency to increase yields with increasing applied doses (Đekić et al., 2014; Terzic et al., 2018; Rajičić et al., 2020a). In studies conducted by Jelic et al. (2015), it is found that the largest increase in yield with one kilogram of nutrient used was in nitrogen, followed by phosphorus, and the least in potassium. Đekić et al. (2014) and Terzic et al. (2018), state that the yield and grain yield components of triticale vary significantly depending on the applied doses of nitrogen, phosphorus and potassium and their mutual combinations and conditions of the growing season, as well as on their complex interactions. In addition to the genotype, the grain yield of winter triticale is greatly influenced by the fertilization system, which is one of the key factors influencing the aount of the formed yield and its quality, but it should be harmonized with climatic and soil conditions and variety requirements (Milovanović et al., 2014; Kondić et al., 2012; Đurić et al., 2015; Đekić et al., 2016; Biberdžić et al., 2017; Madić et al., 2018; Terzic et al., 2018; Rajičić et al., 2020a; Babić et al., 2021). High influence on grain yield by application of mineral, lime and organic fertilizers on acid soils was established by Jelić et al. (2013) and Rajičić et al. (2020b), which is in accordance with our research.

Table 3. The analysis of variance for grain yieldin Kraljevo, Serbia

Effect	df	Mean sqr Effect	Mean sqr Error	F	p-level
Year, (Y)	1, 48	3.425	3.230	1.060	0.308
Fertilization, (F)	4, 45	37.564	0.183	205.383**	0.000
Year x Fertilization, (YxF)	4, 40	0.117	0.108	1.083	0.378

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

Source: Authors

During the two-year study, the yield of triticale was higher in all variants of fertilization compared to the control variant, which was confirmed by the analysis of variance where fertilization showed a very significant effect on grain yield (Table 3). Đekić et al. (2014), Jelic et al. (2015), Terzic et al. (2018), Rajičić et al. (2020b) and Tmušić et al. (2021) found that the application of mineral fertilizers had a significant impact on grain yield, ie the yield was significantly higher on variants that were fertilized more intensively. The highest average yield of triticale for all analyzed variants of fertilization was achieved in the production year 2015/16, which is significantly higher than the yield recorded in 2016/17. This is understandable, since in the vegetation year 2016, 121.6 mm more water sediment fell compared to the vegetation year 2017 (Table 1).

Economic efficiency of triticale production

Based on the value of triticale production per hectare, calculations based on variable costs were made. The value of production is determined by multiplying the quantity of products and their market price. The financial result or profit is obtained by subtracting variable costs from the value of production.

Table 4. Calculation of triticale production in T1 variant of fertilization (NP_1K)

Elements of calculation		2016					2017			
		Measure unit	Quantity	Price in RSD	Amount	Struct. cost %	Quantity	Price in RSD	Amount	Struct. cost %
a)	Value of production				85612				81000	
	Mercantile grain	kg	5036	17	85612		4500	18	81000	
b)	Raw material (1+2+3)				26660	58.39			27260	58.93
1.	Seeds	kg	300	45	13500	29.57	300	47	14100	30.48
2.	Mineral fertilizers									
	NP_1K	kg	260	41	10660	23.35	260	41	10660	23.04
3.	Means of protection	l	2.5	1000	2500	5.47	2.5	1000	2500	5.41
c)	Propulsion and labor services (4+5+6)				19000	41.61			19000	41.07
4.	Tractors				9000	19.71			9000	19.45

Elements of calculation		2016					2017			
		Mea-sure unit	Quantity	Price in RSD	Amount	Struct. cost %	Quantity	Price in RSD	Amount	Struct. cost %
5.	Combine harvester				6000	13.14			6000	12.97
6.	Workforce	h	20	200	4000	8.76	20	200	4000	8.65
d)	Total variable costs (b+c)				45660				46260	
e)	The corresponding part of the general costs				2500				2700	
f)	Total costs (d+e)				48160				48960	
g)	Profit (a-f)				37452				32040	

Source: Authors

Variable costs during the production of triticale are: costs of materials (seeds, fertilizers, and pesticides), costs of propulsion machines (tractors, combine harvesters) and labor. Since we examined four different variants of fertilization (without control), we made a separate calculation for each of them (Tables 4, 5, 6 and 7).

Table 5. Calculation of triticale production in T2 variant of fertilization (NP_2K)

Elements of calculation		2016					2017			
		Measure unit	quantity	Price in RSD	Amount	Struct costs %	quantity	Price in RSD	Amount	Struct. costs %
a)	Value of production				90168				85698	
	Mercantile grain	kg	5304	17	90168		4761	18	85698	
b)	Raw materials (1+2+3)				27480	59.12			28080	59.14
1.	Seeds	kg	300	45	13500	29.04	300	47	14100	29.69
2.	Mineral fertilizers									
	NP_2K	kg	280	41	11480	24.70	280	41	11480	24.18
3.	Means of protection	l	2,5	1000	2500	5.38	2.5	1000	2500	5.27
c)	Propulsion and labor services (4+5+6)				19400	40.88			19400	40.86
4.	Tractors				9000	18.97			9000	18.95
5.	Combine harvester				6000	12.64			6000	12.64
6.	Workforce	h	22	200	4400	9.27	22	200	4400	9.27
d)	Total variable costs (b+c)				46880				47480	
e)	The corresponding part of the general costs				2500				2700	
f)	Total costs (d+e)				49380				50180	
g)	Profit (a-f)				40788				35518	

Source: Authors

Based on the obtained data from the calculations of triticale production, in four different fertilization variants (Tables 4-7), we found that, during the research, the value of triticale production and grain yield was increased by applying larger quantities and types of fertilizers (from T1 to T4). The total profit for different fertilization variants during 2016 and 2017 increased from T1 to T2 variant, and then it decreased at T3 and T4 variant, where the profit was the lowest. The decrease in profits in fertilizer variants T3 and T4, in relation to variants T1 and T2, is a consequence of increased costs of mineral fertilizers for lime and organic fertilizers.

Table 6. Calculation of triticale production in T3 variant of fertilization ($NP_1K+CaCO_3$+manure)

Elements of calculation		2016					2017			
		Measure unit	quantity	Price in RSD	Amount	Struct costs %	quantity	Price in RSD	Amount	Struct costs %
a)	Value of production				96968				89982	
	Mercantile grain	kg	5704	17	96968		4999	18	89982	
b)	Raw materials (1+2+3)				59160	72.89			62260	73.89
1.	Seeds	kg	300	45	13500	16.63	300	47	14100	16.73
2.	Mineral fertilizers									
	NP_1K	kg	260	41	10660	13.13	260	41	10660	12.65
	$CaCO_3$	kg	5000	3	15000	18.48	5000	3	15000	17.80
	Manure	kg	20000	1	20000	24.64	20000	1	20000	23.74
3.	Means of protection	l	2.5	1000	2500	3.08	2.5	1000	2500	2.97
c)	Propulsion and labor services (4+5+6)				22000	27.11			22000	26.11
4.	Tractors				10000	12.33			10000	11.87
5.	Combine harvester				6000	7.39			6000	7.12
6.	Workforce	h	30	200	6000	7.39	30	200	6000	7.12
d)	Total variable costs (b+c)				81160				84260	
e)	The corresponding part of the general costs				3000				3300	
f)	Total costs (d+e)				84160				87560	
g)	Profit (a-f)				12808				2422	

Source: Authors

The established values of variable costs for different fertilizer variants, where the largest share falls on the cost of raw materials (seeds, mineral fertilizers, lime, manure and crop protection products), during 2016 varied from 58.39% for variant T1, which is fertilized with mineral nutrients with a lower dose of phosphorus, up to 73.44% in variant T4 which is fertilized with mineral nutrients with a higher dose of phosphorus, lime and manure. Also, the values of variable costs during 2017 varied and ranged from 58.93% for variant T1 to 73.89% for variant T3, which is fertilized with mineral nutrients with a lower dose of phosphorus, lime and manure.

Table 7. Calculation of triticale production in T4 variant of fertilization ($NP_2K+CaCO_3$+manure)

Elements of calculation		2016					2017			
		Measure unit	quantity	Price in RSD	Amount	Struct costs %	quantity	Price in RSD	Amount	Struct. costs %
a)	Value of production				99892				89982	
	Mercantile grain	kg	5876	17	99892		4999	18	89982	
b)	Raw materials (1+2+3)				62480	73.44			63080	73.63
1.	Seeds	kg	300	45	13500	15.87	300	47	14100	16.46
2.	Mineral fertilizers									
	NP_1K	kg	280	41	11480	13.49	280	41	11480	13.40
	$CaCO_3$	kg	5000	3	15000	17.63	5000	3	15000	17.51
	Manure	kg	20000	1	20000	23.51	20000	1	20000	23.34
3.	Means of protection	1	2.5	1000	2500	2.94	2.5	1000	2500	2.92
c)	Propulsion and labor services (4+5+6)				22600	26.56			22600	26.37
4.	Tractors				10000	11.31			10000	11.67
5.	Combine harvester				6000	7.05			6000	7.00
6.	Workforce	h	33	200	6600	7.76	33	200	6600	7.70
d)	Total variable costs (b+c)				85080				85680	
e)	The corresponding part of the general costs				3000				3300	
f)	Total costs (d+e)				88080				88980	
g)	Profit (a-f)				11812				1002	

Source: Authors

The costs of seeds and fertilizers had the highest costs for raw materials.Fertilizer costs varied depending on the type and quantity, so that in 2016 they were the lowest in the T1 variant (23.35%), and the highest in the T4 variant of fertilization (54.63%). In the second year of the research (2017), the costs of fertilizers were the lowest in the T1 variant (23.04%), and the highest in the T4 variant of fertilization (54.25%). With the increase of grain yield, with the increased quantities of applied fertilizers, the variable production costs are increased significantly.

A significant increase in fertilizer costs in wheat production, of 35.75%, was found by Todorović and Filipović (2009), and in triticale production of 57.53%, Biberdžić et al. (2012). In the production of triticale with different variants of fertilization, Biberdžić et al. (2012), point out that the lowest costs of fertilizers were in variant I, which was fertilized with mineral nutrients (28.61%), and the highest in variant III, which was fertilized with a combination of NPK, lime and organic nutrients (57.53%).

Other variable costs, during 2016, were the costs of propulsion machines (tractors and combines) and labor, and they ranged from 26.12% in the T4 variant to 41.61% in the T1 fertilization variant. During 2017, other variable costs ranged from 26.11% for the T3 variant to 41.07% for the T1 fertilization variant. The obtained results of variable costs are similar to the results obtained by Biberdžić et al. (2012), in triticale production and Ivanović et al. (2010) in wheat production in Serbia.

The total variable costs per hectare, in both years of research, were the lowest in the T1 variant of fertilization, and the highest in the T4 variant, which is understandable considering the quantities and prices of applied fertilizers. Increased amounts of applied fertilizers significantly affect the increase in yield (Biberdžić et al., 2017; Đekić et al., 2018; Madić et al., 2018; Terzic et al., 2018; Rajičić et al., 2020b). With the increase in the amount of applied fertilizers, the variable production costs increase, that is, the profitability of production increases (Todorović and Filipović, 2009; Ivanović et al., 2010; Biberdžić et al., 2012).

In order to get a more complete picture of the profitability of triticale production with different variants of fertilization, it is necessary to consider other indicators of success, that is, basic indicators of the degree of economic efficiency (productivity, economy and profitability).

Based on the obtained results in the calculations, a comparison of the obtained triticale yields for all four fertilization variants was performed.

Labor productivity was determined based on the amount of products obtained (grain yield) for all four variants of fertilization per unit time (Table 8).

In the variant T1 which was fertilized with 120 kg ha^{-1} N, 80 kg ha^{-1} P_2O_5 and 60 kg ha^{-1} K_2O during 2016, the highest labor productivity of 251.8 was achieved, and the lowest in the variant T4 (178.1) which was fertilized with 120 kg ha^{-1} N, 100 kg ha^{-1} P_2O_5; 60 kg ha^{-1} K_2O, 5 t ha^{-1} lime and 20 t ha^{-1} manure. This is expected, given that on the T4 variant were spent more hours of working (33 hours) than on the other variants.

During the second year of research, production conditions are worse (uneven amount of precipitation), which is reflected in the decline in yield, so with the same labor costs, in each of the observed variants of fertilization there is a decline in productivity.

Table 8. Production productivity in 2016 and 2017

Elements	Variants of fertilization							
	2016				2017			
	T1	T2	T3	T4	T1	T2	T3	T4
Quantity of obtained products	5036	5304	5704	5876	4500	4761	4999	5203
Total hours of work per hour	20	22	30	33	20	22	30	33
Labor productivity (kg/h) 1/2	251.8	241.1	190.1	178.1	225.0	216.4	166.6	157.7

Source: Authors

The economy of production, which is shown in Table 9, was obtained by comparing the realized value of production and the costs incurred during the production of triticale.

Table 9. Economy of production in 2016 and 2017

Elements	Variants of fertilization							
	2016				2017			
	T1	T2	T3	T4	T1	T2	T3	T4
The value of production (din/h)	85612	90168	96968	99892	81000	85698	89982	89982
Production costs (din/h)	48160	49380	84160	88080	48960	50180	87560	88980
Coefficient of economy 1/2	1.78	1.83	1.15	1.13	1.65	1.71	1.03	1.01

Source: Authors

Based on the obtained coefficients of economy from Table 9, we can conclude that for 1 dinar of invested funds, from 1.13 to 1.83 dinars was obtained of the production value, depending on the variant of fertilization. Triticale production in 2016 was economical, and the highest rate of economy was found in the T2 variant, which is fertilization with an increased dose of phosphorus (NP_2K). In the second year of research, the economy decreases in all variants of fertilization due to bad weather conditions, especially uneven amount of precipitation in critical phases of triticale growth, as well as due to a slight increase in the market price of triticale seeds. This causes a slight decline in the value of production, which is why the coefficient of economy tends to decline slightly. During 2017, as in 2016, the T2 variant (NP_2K) had the highest coefficient of economy (1.71). Biberdžić et al. (2012), found the highest production efficiency in the NP_2K variant fertilized with mineral nutrients with increased phosphorus dose (1.69). Slightly lower coefficients of economy of 1.32 for spelt and 1.20 for wheat, in the conditions of organic farming, were established by Vukoje et al. (2013). The ratio of the achieved financial result and the value of production represents the rate of profitability shown in Table 10.

In all tested fertilizer variants, the production of triticale in 2016 was profitable, which is shown by the rate of profitability, which ranged from 11.82% to 45.24%. The highest rate of profitability was found in the T2 variant, which is fertilization with increased phosphorus dose (NP_2K), and the lowest in the T4 variant, where a combination of NP_2K, lime and organic fertilizers was used. The low rate of profitability on the T4 variant is the result of a low financial result, that is, realized profit. During 2017, the T2 variant of fertilization also shows the highest rate of profitability.

When it comes to acid soils, their pedo-ameliorative repair measures and high yields, one should not always be guided by the highest yield, because it is often not the most profitable, as our research has shown. High prices of fertilizers significantly increase the price of production, so in order to achieve a satisfactory yield and the most profitable production, it is necessary to choose rational quantities of fertilizers.

Table 10. Profitability rate of production in 2016 and 2017

Elements	Variants of fertilization							
	2016				2017			
	T1	T2	T3	T4	T1	T2	T3	T4
Financial results (din/h)	37452	40788	12808	11812	32040	35518	2422	1002
The value of production	85612	90168	96968	99892	81000	85698	89982	89982
Profitability rate 1/2 x100	43.75	45.24	13.21	11.82	39.56	41.45	2.69	1.11

Source: Authors

In the production of winter triticale, the costs of mineral fertilizers form the largest part of direct costs (Bielski and Falkovski, 2017; Kadakoglu et al., 2021), so it is often not possible to compensate for such high costs with yields. In the conditions of manure application, there is an increase in costs, but also in an increase in yield and better financial results. It is an environmentally justified method that affects product quality (Jelić et al., 2015; Rajičić et al., 2020a).

Conclusions

Sustainable development of agriculture is not possible without the simultaneous achievement of environmental, economic and social goals. The profitability of agricultural production depends on the ratio of prices and production costs, so the reduction of inputs is a condition for achieving profitability in agriculture. More intensive technologies require high costs.

Based on the study of the effects of fertilization on yield, productivity, economy and profitability of triticale production on acidic soils, we have come to the following conclusions:

The value production and grain yield of triticale, during the two-year research (2016 and 2017), increased with the application of larger quantities and types of fertilizers. The total profit, in different variants of fertilization, increased from T1 to T2 variant, and then decreased in T3 and T4 variant, which is a consequence of increased costs of mineral fertilizers, lime and organic fertilizers. The value of variable costs is different, with different variants of fertilization, and the largest part falls on the cost of raw materials. The costs of seeds and fertilizers have the largest share in the costs of raw materials. With the increase of grain yield, and with the increased quantities of applied fertilizers, the variable production costs increase significantly. The total variable costs per hectare, in both years of research, were the lowest in the T1 variant of fertilization, and the highest in the variant T4, which is understandable considering the quantities and prices of applied fertilizers.Increased amounts of applied fertilizers significantly affect the increase in yield.

In the T1 variant which was fertilized with 120 kg ha^{-1} N, 80 kg ha^{-1} P_2O_5 and 60 kg ha^{-1} K_2O, the highest productivity was achieved, and the lowest in variant T4, which was fertilized with 120 kg ha^{-1} N, 100 kg ha^{-1} P_2O_5; 60 kg ha^{-1} K_2O, 5 t ha^{-1} lime and 20 t ha^{-1} manure. This is expected, as more hours of working were spent on the T4 variant than on the other variants.

The highest rates of economy and profitability were found in the T2 variant of fertilization, with increased dose of phosphorus (NP_2K), and the lowest in the T4 variant, where a combination of NP_2K, lime and organic fertilizers was used. Variant T2 can be considered the most profitable and most cost-effective, regardless of the fact that the yield and production value were the highest in variant T4, which was fertilized with a combination of mineral nutrients with increased doses of phosphorus, lime and organic fertilizers.

Our research points to the fact that on acidic soils, the highest yield is often not the most profitable, which is why a rational amount of fertilizer should be chosen.The combination of NPK, lime and organic fertilizers, as well as the application of NPK fertilizers with an increased dose of phosphorus, is necessary in order to increase the fertility of acid soils, and thus the yield of cultivated crops.

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Conflict of interests

The authors declare no conflict of interest.

References

1. Babić V., Rajičić V. & Đurić N. (2021): Economic significance, nutritional value and application of triticale. Economic of Agriculture, 68(4): 1089-1107. doi:10.5937/ekoPolj2104089B
2. Biberdžić, M., Maksimović, G., Barać, S. & Jovović, Z. (2012): Economic effects of triticale production on acid soils. Economic of Agriculture, 59(4): 579-587.
3. Biberdžić, M., Barać S., Prodanović D., Đikić A., Đekić V. & Lalević D. (2017): Impacts of liming and fertilization on yield of two triticale varieties. Proceedings of VIII International Scientific Agriculture Symposium "Agrosym 2017", Jahorina, October 05-08, 577-582.
4. Bielski, S., & Falkowski, J. (2017): Effect of the nitrogen and magnesium fertilization on yield and economic efficiency of winter triticale production. In Proceedings of the 8th International Scientific Conference Rural Development, Akademija, Lithuania, 23-24 November 2017, 17-23.
5. Vukoje, V., Bodroža-Solarov, M., Vučković, J., Košutić, M. & Živković, J. (2011): Economic effects of spelled production in organic farming system. Economics of Agriculture, 1: 80-87.
6. Vukoje, V., Psodorov, Đ. & Živković, J. (2013): Profitability of production of pasta from spelt flour. Economic of Agriculture, 60(2): 265-275.
7. Đekić, V., Milovanović, M., Popović, V., Milivojević, J., Staletić, M., Jelić, M. & Perišić, V. (2014): Effects of fertilization on yield and grain quality in winter triticale. *Romanian Agricultural Research*, 31: 175-183. https://www.incda-fundulea.ro/rar/nr31/rar31.22.pdf
8. Đekić, V., Milivojević, J., Perišić, V., Luković, K., Jelić, M., Janjić & S.,Terzić, D. (2016): Maximum profitability of triticale to optimizing nutrition. Correlations between the triticale yield of mineral nutrition. Proceedings, XX International Eco-Conference® 2016, 9th Eco-Conference® on Safe Food, 28-30. September 2016, Novi Sad, 251-260.
9. Djekic, V., Mitrovic S., Milovanovic M., Djuric N., Kresovic, B., Tapanarova, A., Djermanovic V. & Mitrovic M. (2011): Implementation of triticale in nutrition of non-ruminant animals. African Journal of Biotechnology, 10(30): 5697-5704, DOI: 10.5897/AJB10.986.
10. Đekić, V., Milivojević, J. & Branković, S. (2018): The interaction of genotype and environment on yield and quality components in triticale. Biologica Nyssana, 9(1): September 2018, 45-53, DOI: 10.5281/zenodo.1470850.
11. Djuric, N., Prodanovic, S., Brankovic G., Djekic V., Cvijanovic G., Zilic S., Dragicevic V., Zecevic V. & Dozet G. (2018): Correlation-Regression Analysis of Morphological-Production Traits of Wheat Varieties. Romanian Biotechnological Letters, 23(2): 13457-13465.

12. Đurić, N., Cvijanović, G., Matković, M., Dozet, G., Đekić, V. & Trkulja, V. (2016): Influence of year conditions on grain yield of some winter triticale varieties. Collection of scientific papers of the Institute PKB Agroekonomik, Belgrade, 24-25. February 2016, 22 (1-2): 37-42.
13. Đurić, N., Cvijanović, G., Dozet, G., Matković, M., Đekić, V. & Trkulja, V. (2015): New winter triticale species developed at Institute PKB Agroekonomik. Selekcija i Semenarstvo, 21(1): 9-16. DOI: 10.5937/SelSem1501009D
14. Ivanović L., Subić L. & Jeločnik M. (2010): Analysis of variable costscoverage in wheat production. XV Biotechnology consulting, 15(17): 665-670. Čačak.
15. Jelić M., Dugalić G., Milivojević J. & Đekić V. (2013): Effect of liming and fertilization on yield and quality of oat (Avena sativa L.) on an acid luvisol soil. Romanian Agricultural Research, 30: 249-258. http://incda-fundulea.ro/rar/nr30/rar30.32.pdf
16. Jelic, M., Jelena Milivojevic, Olivera Nikolic,Vera Đekić & Stamenkovic, S. (2015): Effect of long-term fertilization and soil amendments on yield, grain quality and nutrition optimization in winter wheat on an acidic pseudogley. Romanian Agricultural Research, 32: 165-174.
17. Kadakoglu, B., Karli, B., Gül, M. & Özuygur, A. (2021): Economic analysis of triticale production: a case study of Corum province, Turkey. Management, Economic Engineering in Agriculture & Rural Development, 21(3), 483-490.
18. Kendal, E., Tekdal, S. Aktas, H. & Karaman, M. (2014): Determınation Compliance Abilities of Some Triticale Varieties and Comparıson with Wheat in Southeastern Anatolia Condıtıons of Turkey. Communications in Agricultural and Applıed Biologıcal Science, 79(4): 192-200.
19. Kondić, D., Knežević, D. & Paunović, A. (2012): Grain weight of genotypes of triticale (x Triticosecale Wittmack) in agroekological conditions of Banja Luka. Genetics, 44(2): 419-428.
20. Lalević D., Biberdžić M., Jelić M. & Barać S. (2012): The characteristics of triticale cultivated in rural areas. Agriculture & Forestry, 58(2): 27-34.
21. Madić, M., Paunović, A., Đurović, D., Marković, G., Knežević, D., Jelić, M. & Stupar, V. (2018): Grain yield and its components in triticale grown on a pseudogley soil. Journal of Central European Agriculture, 18(5): 184-193.
22. Madić M., Biberdžić M., Đurović D., Paunović A., Knežević D., Stevović V., Tomć D. & Rajičić V. (2020): Grain yield of triticale varieties depending on mineral nutrition. Collection of works XXV Consultations on biotechnology with international participation, 13-14 Mart, Čačak, Serbia, 413-419.
23. Milovanović, M., Staletić, M., Đekić, V., Nikolić, O. & Luković, K. (2011): Seed production and contribution of KG varieties to biodiversity of small grains in the period 2006-2010. 01.-02. decembar 2011, Beograd, Economics of Agriculture, 2(58): 103-111.

24. Milovanovic M., Perishic V., StaleticM., Đekić V., Nikolic O., Prodanovic S. & Lukovic K. (2014): Diallel Analysis of Grain Number per Spike in Triticale. Bulgarian Journal of Agricultural Science, 20(5): 1109-1115. https://www.agrojournal.org/20/05-14.pdf
25. Rajičić V., Milivojević J., Popović V., Branković S., Đurić N., Perišić V. & Terzić D. (2019): Winter wheat yield and quality depending on the level of nitrogen, phosphorus and potassium fertilization. Agriculture and Forestry, 65(2): 79-88. DOI: 10.17707/AgricultForest.65.2.06
26. Rajičić, V., Popović, V., Perišić, V., Biberdžić, M., Jovović, Z., Gudžić, N., Mihailović, V., Čolić, V., Đurić, N. &Terzić, D. (2020a): Impact of Nitrogen and Phosphorus on Grain Yield in Winter Triticale Grown on Degraded Vertisol. Agronomy, 10(6): 757.
27. Rajičić V., Popović V., Terzić D., Grčak D., Dugalić M., Mihailović A., Grčak M. & Ugrenović V. (2020b): Impact of Lime and NPK Fertilizers on Yield and Quality of Oats on Pseudogley Soil and their valorisation. Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 48(4): 2134-2152. DOI:10.15835/48412106
28. Rajičić V., Terzić D., Babić V., Perišić V., Dugalić M., Đokić D. & Branković S. (2021): Yield components and genetic potential of winter wheat on pseudogley soil of Western Serbia. Biologica Nyssana, 12(2): 141-150. DOI: 10.5281/zenodo.5759859
29. Terzic, D., Đekic, V., Jevtic, S., Popovic, V., Jevtic, A., Mijajlovic, J. & Jevtic, A. (2018): Effect of long term fertilization on grain yield and yield components in winter triticale. *The Journal of Animal and Plant Sciences*, 28(3): 830-836.
30. Terzić, D., Đekić, V., Milivojević, J., Branković, S., Perišić, V., Perišić, V. & Đokić, D. (2018): Yield components and yield of winter wheat in different years of research. Biologica Nyssana, 9(2): 119-131.
31. Tmušić, N., Ćirić, S., Nikolić, K., Knežević, J. & Rajičić, V. (2021): Effects of different fertilization treatments on the yield performance, yield parameters and grain quality of winter wheat grown on vertisol soil type. *Applied Ecology and Environmental Research*, 19(6): 4611-4627. DOI: http://dx.doi.org/10.15666/aeer/1906_46114627
32. Todorović S., Filipović N. (2009): Economic analysis of wheat production on family farms. *Proceedings of the IV Symposium „Innovations in Crop and Vegetable Production“.* Faculty of Agriculture Belgrade, Serbia, pp. 64-65.
33. SAS/STAT (2000): User’s Guide, Version 9.1.3. SAS Institute Inc.