Organic spelt production systems: Productive and financial performance in three orographic regions

Željko Dolijanović,[1] Svetlana Roljević Nikolić,[2] Jonel Subić,[3] Zoran Jovović,[4] Jasmina Oljača,[1] Jasmina Bačić[2]

[1]Department of Agroecology, Faculty of Agriculture, University of Belgrade, Serbia; [2]Institute Tamiš, Pančevo, Serbia; [3]Institute of Agricultural Economics Belgrade, Serbia; [4]Biotechnical Faculty, University of Montenegro, Montenegro

Highlights

- *Organic fertilisers and soil conditioners affect spelt grain yield.*
- *The analysis of the economic effects of organic spelt production concluded that fertiliser application was not economically justified despite the increases in grain yield.*
- *Treatments in the plain region displayed the best production results compared to mountain region treatments, but these did not have the best benefit-cost ratio.*
- *Knowledge of production costs is an important element in improving the economic efficiency of organic farming systems.*

Abstract

A two-year field trial was conducted to study the effects of biohumus, biofertiliser, and soil conditioner application on spelt grain yield in different regions (plain, hilly, and mountainous regions) in Serbia. An analysis of economic efficiency indicators of spelt production in organic farming systems was also performed. The field experiment had a randomised complete block design with three replicates in each of the three regions. One winter spelt cultivar was also studied. The largest differences in spelt yield compared to control were found in the plain region in the biohumus + biofertiliser treatment (28.0%) and the hilly region in the organic fertiliser + zeolite treatment (28.8%). The differences in grain yield between control and treatment conditions in the mountain region were insignificant. Analysis of the economic effects of organic spelt production found a significantly lower gross margin in treatments with expensive organic fertilisers (3955.05 and 1104.75 € ha^{-1}) than the control (5094.31 and 1833.85 € ha^{-1}), leading to the conclusion that their application was not economically justified despite the increases in grain yield. The highest production costs (3569.71 € ha^{-1}) were observed in treatments in the hilly region, resulting in the lowest benefit-cost ratio (0.1), while the greatest benefit-cost ratio was recorded in treatments in the mountainous region (2.1). Following the economic analysis results, a significant negative correlation between the benefit-cost ratio and the total production costs (r= –0.91**) was determined and a positive correlation between the gross margin and grain yield (r=0.66*). These results lead to the conclusion that the management strategy of spelt production in organic farming systems should be harmonised with the soil and agro-ecological characteristics of the region and directed at decreasing the costs and share of external inputs. In this case, organic spelt production can be economically profitable.

Correspondence: Svetlana Roljević Nikolić, Institute Tamiš, Pančevo, Serbia.
Tel.: + 381.13.313.092. E-mail: roljevic@institut-tamis.rs

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Introduction

Intensive farming causes soil depletion, excessive water consumption, and greenhouse gas emissions, failing to provide the necessary sustainability for food production. Establishing alternative production systems, along with a drastic decrease in input material consumption, represents the crucial driving force of the agricultural sector's transformation towards an inclusive, resilient, and sustainable production system (Iocola *et al*., 2021). Although organic agriculture covers only 1.5% of the global agricultural land and accounts for less than 5% of retail sales in high-income countries (Willer *et al*., 2021), it is still a promising approach to achieving sustainable food systems (Muller *et al*., 2017). However, the main challenges of organic agriculture are increasing crop yield and maintaining soil fertility with adequate nutrient levels, primarily nitrogen. Some studies have shown that cover crops are more efficient in increasing the nitrogen content of the soil in comparison to mineral nitrogen fertiliser application (Ćupina *et al*., 2017). Also, the application of organic and microbiological fertilisers improves physicochemical properties of the soil rhizosphere and increases the biomass and microbial activity (Tobiašová, 2011), which has a positive impact on crop yield (Jablonskytė-Raščė *et al*., 2013; Cisse *et al*., 2019). Owing to high ion exchange capacity, some natural minerals, like zeolite, have an affinity towards large cations (Na^+, K^+, NH_4^+). Zeolite absorbs the large cations and prevents their fast release, thus prolonging the beneficial effects of the applied organic and mineral fertilisers while effectively decreasing their consumption (Mahesh *et al*., 2018).

Moreover, some studies have shown that zeolite can lower soil acidity (Szerement *et al*., 2014), stabilise heavy metals (Muhlbachova and Simon, 2003), and conserve soil moisture (Szerement *et al*., 2014). In regions with scarce water resources, the application of soil conditioners that can retain moisture and increase soil's water-holding capacity was also studied (Hardie, 2020). The application of zeolites can increase water-use efficiency due to enhanced water retention and storage in the soil (Ibrahim and Alghamdi, 2021). Also, it was observed that hydrogel application improved the water availability of sandy soils for a prolonged period but that it was unsuitable for black soils (Narjary *et al*., 2012).

Soil and climatic factors define the direction of development and profitability of plant production, with significant regional variation. Adaptation of agricultural production to local conditions has led to creating a wide range of agricultural landscapes across Europe, ranging from almost entirely artificial and intensively managed fields in the Netherlands to semi-natural extensive grazing areas in the Alps (Lefebvre *et al*., 2015). However, in the past two decades, a trend of aggregation of agricultural land within a small number of large farms has been noticed throughout European countries, especially in intensively managed fields. This trend negatively affects the development and economic strength of small farms, which cannot compete with large producers (Roljević Nikolić *et al*., 2021). In such market circumstances, especially in mountainous areas, the survival of small farms most likely involves the cultivation of locally higher value alternative crops adapted alternative crops which are not in competition with the conventional products (Ferreira *et al*., 2020).

According to altitude, terrain, and precipitation criteria, there are three macro-regions in Serbia - plain, hilly and hilly-mountainous macro-regions, and many micro-regions. The difference between the regions is reflected in soil quality, agro-ecological conditions, steepness of the slope, and access to agricultural technologies (Simane *et al*., 2016). Plain regions cover areas with an altitude up to 300 m, average air temperatures of 10.9°C and total annual precipitation of 540 to 820 mm, and a mild, temperate continental climate. The hilly regions include areas with an altitude of 300 to 500 m, an average annual temperature of about 10.0°C, total annual precipitation of 600 to 800 mm, and favourable conditions for the semi-intensive field, fruit, and vineyard production. Mountainous regions are found at altitudes above 1000 m, have an average annual temperature of about 6.0°C, annual rainfall of 700 to 1000 mm, and are dominated by livestock and extensive plant production. The two types of soil that dominate in hilly and mountainous regions are vertisol and fluvisol. Such regional specificities are an essential aspect of the development process and a standard tool to define similar policy needs and instruments (D'Amico *et al*., 2013). However, spatial variability in crop management systems is often neglected, and the same recommended or standardised practices are applied to a large part of the whole spatial extent (Leenhardt *et al*., 2010). Local adaptation of production is particularly important for organic agriculture, which relies entirely on natural inputs. Crop selection and adaptations of the cropping system according to the specific natural conditions are crucial for the productivity and profitability of organic systems. Kovačević *et al*. (2014) underline that choosing alternative crops in organic farming conditions is necessary and suitable for this type of production. Modest requirements regarding climatic and soil factors and agrotechnical resources are prerequisites for spelt wheat production in ecological cultivation systems, among which organic farming has a particular significance (Grobelnik-Mlakar *et al*., 2014).

Spelt (*Triticum aestivum* ssp. *spelta* L.) successfully grows without any special climatic and soil demands, and it is suitable for cultivation in low input systems in marginal regions (Sugár *et al*., 2019). On the other hand, spelt wheat is resistant to pests and diseases but less tolerant of abiotic stress from drought (Wang *et al*., 2021). The disadvantages of spelt cultivation also include its sensitivity to lodging and the fact that it is not adjusted to mechanised harvesting since its production requires an additional step of grain peeling. Nevertheless, owing to its nutritional composition and modest requirements regarding soil conditions and agrotechnique, spelt wheat production has been gaining increasing interest in the last 20 years. This interest is predicted to rise at the rate of 5% a year (Wang *et al*., 2021). The results of research conducted in Europe show that in organic or other ecologically friendly production systems, spelt wheat yields of: 3.0 t ha^{-1} in Croatia (Rapčan *et al*., 2020), 3.09 t ha^{-1} in southern Italy (Troccoli and Codianni, 2005), 4.07 to 4.45 t ha^{-1} in Poland (Andruszczak *et al*., 2011), 3.44 to 5.26 t ha^{-1} in Lithuania (Jablonskytė-Raščė, 2013) 3.9 to 5.3 t ha^{-1} in Serbia (Roljević Nikolić *et al*., 2018) and 5.84 t ha^{-1} in Slovakia (Lacko-Bartošová *et al*., 2010). Yield differences result from the different genetic potentials of cultivars and applied cultivation methods that have to be adapted to the complexity and specificities of agro-ecological conditions in organic farming systems.

The starting hypothesis of the present study was that yield and profitability of organic spelt wheat production differed between treatments in the three regions. Therefore, the first goal of this study was to examine the impact of different fertiliser treatments and soil conditioners on yield and assess the economic effects of these treatments. The second goal was to determine the relationship between the analysed production and economic indicators to understand better the cost of production, which is an essential element for improving the competitiveness of organic production.

Materials and methods

Site description

The research was carried out from 2015 to 2017 and included three one-factor field experiments conducted in the following regions: plain (44°45′21.18″ N, 20°34′43.27″ E; 130 m a.m.s.l.), hilly (44°19′0.6″ N, 19°57′12.6″ E; 300 m a.m.s.l.), and mountainous (43°23′52″ N, 19°52′33″ E; 1065 m a.m.s.l.). Soil characteristics are presented in Table 1.

The weather conditions during the two years displayed certain deviations from the typical characteristics of the climate in the production regions (Figure 1). According to the data of the Republic Hydrometeorological Service of Serbia, the average long-term (2071-2000) air temperatures and the amount of precipitation are as follows: the plain region –10.9°C, 650 mm; hilly region – 10.0°C and 800 mm; mountainous region –6.0°C, 1000 mm. The analysed period was significantly warmer than the long-term average for all three regions (13.6°C, 12.6°C, 8.8°C). On the other hand, although the precipitation was not evenly distributed, the total amount of precipitation was in the long-term average range for all three regions (627.6 mm, 841.7 mm, 1055.6 mm). The mountainous region is characterised by lower average air temperatures and a greater total amount of precipitation than the other two regions. These agro-ecological factors are favourable for spelt growth. This region recorded slightly higher precipitation in June (103.8 mm), which is the period of the BBCH 51-69 phases at that altitude. Frequent and extended precipitation hinders pollination and the formation of grains in the spike. The hilly region is between the plain and mountain region according to its climatic features. No substantial deviations from the average monthly temperatures were recorded, while precipitation in March (103.7 mm) and May (109.0 mm) was higher than in other months. In the plains, rainfall was uniformly distributed during the observed period, which, along with the favourable temperatures, enabled the understanding growth and development of spelt wheat in this region.

Experimental design, treatments, and crop management

The experiment was established as three one-factor field experiments with a randomised complete block design with three replications in each region. The winter spelt cultivar Nirvana was bred at the Institute of Field and Vegetable Crops in Novi Sad, and the same cultivar was grown in all three regions. Nirvana is a cultivar of late maturity. Its test weight amounts to 74-77 kg, and the grain has a protein content of 14-16.0% and a high essential amino acid content. The optimal sowing density was determined at 550 seeds per m^2.

The cultivation technology of spelt in this study was adjusted to the specifics of soil and climatic conditions in the plain, hilly and mountainous regions. The adjustments were primarily related to the proper depth of soil tillage, sowing norm, selection, and combination of organic fertiliser, microbiological fertilisers, and soil conditioners. The adjustments were made to maintain and increase soil fertility and provide adequate conditions for fulfilling

Table 1. Chemical characteristics of the soils in plain, hilly, and mountain regions.

Region/municipality/village	Soil type	pH (KCl)	N (%)	P_2O_5 (mg 100 g^{-1})	K_2O (mg 100 g^{-1})	Soil organic carbon (%)
Plain (Grocka, Radmilovac)	Leached chernozem	7.08	0.273	22.18	19.10	14.2
Hilly (Valjevo, Jasenica)	Eutric cambisol	4.38	0.238	2.5	35.0	26.2
Mountain (Nova Varoš, Radijevići)	Pseudogley	4.07	0.220	0.9	11.4	25.5

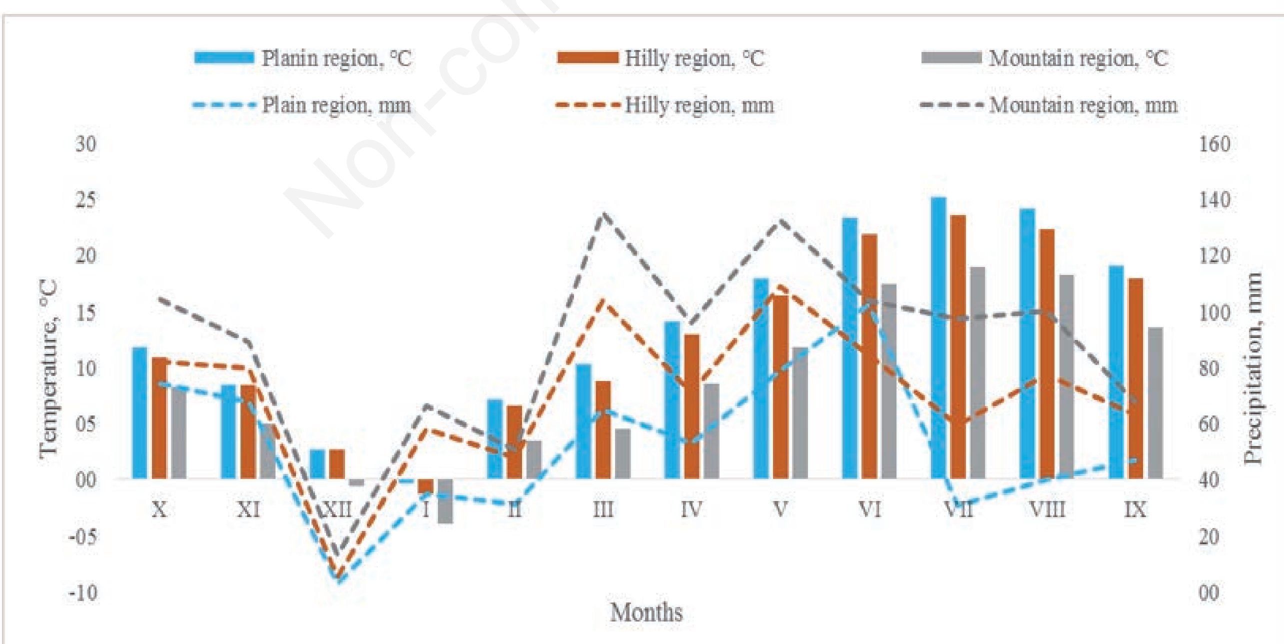

Figure 1. Average monthly air temperatures and the sum of precipitation in the plain, hilly, and mountain regions over the period 2015/16-2016/17.

the genetic potential of the wheat cultivar. In all three regions, the pre-crop was spring beans, which were ploughed into the soil in autumn to supply the soil with the necessary nitrogen and contribute to weed control. Sowing was done manually.

Plain region

The elementary plot area was 12 m^2. Tillage was performed by a moldboard plough at 25 cm depth, while the presowing preparation was performed using a disc harrow and spike-tooth harrow. The sowing was done on 21st October 2015, and on 7th October 2016, with a seed density of 500 germinating seeds per m^2. The following treatments were examined: i) T1 - microbiological fertiliser 'Slavol' (5.0 l ha^{-1}); ii) T2 - biohumus (3000 kg ha^{-1}) + microbiological fertiliser 'Slavol' (5.0 l ha^{-1}); iii) T3 - control, without the use of fertilisers.

The harvest was performed with a combine harvester during the BBCH 89 phenophase (5th July 2016 and 30th June 2017). Immediately after the harvest, the grain yield per plot was measured and calculated at 14% moisture content.

Hilly region

The elementary plot area was 12 m^2. Tillage was performed by a moldboard plough at 25 cm depth, while the presowing preparation was carried out using a disc harrow and spike-tooth harrow. The sowing was done on 15th October 2015 and 5th October 5 2016, with a seed density of 550 germinating seeds m^{-2}. The following treatments were examined: i) T1 - biohumus (3000 kg ha^{-1}); ii) T2 - zeolite (2670 kg ha^{-1}); iii) T3 - biohumus (3000 kg ha^{-1}) + zeolite (2670 kg ha^{-1}); iv) T4 - control.

During the BBCH 31-33 phenophase, the foliar microbiological fertiliser ('Slavol') was applied in all treatments (T1-T4) in the quantity of 5.0 l ha^{-1} to ensure faster initial growth of crops and stress resistance of plants. The harvest was performed with a combine harvester during the BBCH 89 phenophase (10th July 2016 and 4th July 4 2017). Immediately after the harvest, the grain yield was measured and calculated at 14% moisture content.

Mountain region

The elementary plot area was 12 m^2. A moldboard plough performed tillage at 15 cm depth while the presowing preparation was carried out using a disc harrow and spike-tooth harrow. The sowing was done on 1st November 2015, and on 20th October 2016, with a seed density of 600 germinating seeds m^{-2}. The following treatments were examined: i) T1 - zeolite (2670 kg ha^{-1}); ii) T2 - microbiological fertiliser 'Unliker' (10 L ha^{-1}); iii) T3 - microbiological fertiliser 'Unliker' (10 L ha^{-1}) + zeolite (2670 kg ha^{-1}); iv) T4 - microbiological fertiliser 'Unliker' (10 L ha^{-1}) + hydrogel (20 kg ha^{-1}); v) T5 - control.

During the BBCH 31-33 phenophase, the foliar microbiological fertiliser ('Slavol') was applied in all treatments (T1-T5) in the quantity of 5.0 L ha^{-1} to ensure faster initial growth of crops and stress resistance of plants. The harvest was performed with a combine harvester during the BBCH 89 phenophase (15th August 2016 and 7th August 2017). Immediately after the harvest, the grain yield was measured and calculated at 14% moisture content.

Materials used in the study

Biohumus ('Biohumus Royal offert' 'Altamed' Serbia) - certified organic fertiliser, ploughed in the autumn. The properties of biohumus: pH 8.63, N 2.2%; P_2O_5 4.8%, and K_2O 2.8%.

'Slavol' ('Agrounik' Serbia) - liquid foliar microbiological fertiliser containing: *Bacillus megaterium* 10^{-6} cm^3, *Bacillus licheniformis* 10^{-6} cm^3, *Bacillus suptilis* 10^{-6} cm^3, *Azotobacter chroococcum* 10^{-6} cm^3, *Azotobacter vinelandii* 10^{-6} cm^3, Derxia sp. 10^{-6} cm^3. In all three regions, it was applied during the BBCH 31-33 phenophase.

Uniker ('Agrounik' Serbia) - liquid microbiological fertiliser applied in soil with the tillage soil, contains efficient proteolytic and cellulolytic bacteria strains: min 10^{-6} cm^3 *Bacillus megaterium*, *Bacillus licheniformis* and *Bacillus pumilis*.

Zeolite ('Aqua Vita di Natura', Serbia) - was evenly dispersed and ploughed in autumn.

Hydrogel ('Aqua Vita di Natura', Serbia) - was evenly dispersed on the soil surface after sowing in autumn.

Estimation of economic effects of spelt wheat production

Costs are most commonly classified into fixed and variable costs. There were no fixed costs in this case since the land is the property of the farms included in the research, and no rent was paid. The only costs were variable costs, which were considered to represent total costs. Therefore, the gross margin equals profit (Adamtey *et al*., 2016). The variable costs included: grain, fertilisers, soil conditioners, and services related to the agricultural machinery and the hired workforce. The values of all means of production were calculated per hectare. The prices of machinery services are standardised according to the Pricelist of Machinery Services for the year 2021, issued by the Cooperative Union of Vojvodina, and they are valid for Serbia. The prices of intermediate goods were obtained by market research. Incentives intended for organic farming, which significantly increase the value of goods and other relevant indicators, were considered while doing calculations. The economic output included the yield of the hull-less grain.

The analytical calculation based on the variable costs was conducted using the following formula (Subić *et al*., 2019):

$$GM = TR - VC, \text{ while } TR = (v \times p) + s \quad (1)$$

where the analytical elements represent: GM, gross margin; TR, total revenue; VC, gained variable costs; v, the volume of product per unit of measure; p, the price of the product per unit measure; s, subsidies per unit of production area.

Economic efficiency is calculated as:

$$\text{Benefit-Cost ratio} = \text{Gross margin} / \text{Total costs} \quad (2)$$

Statistical analysis

Data on grain yield and gross margin were analysed using the one-way analysis of variance (ANOVA) in the statistical software SPSS 19.0. The comparisons among treatments were made with the least significant differences (LSD) test. Correlation analysis was performed to examine the relationship between parameters of economic efficiency. Significances were declared at the probability level of $P<0.05$.

Results and discussion

Spelt grain yield in different regions

The organic spelt production treatments resulted in significant differences in grain yield in the plain and hilly regions but not in the mountainous region (Table 2). The highest hulled grain average yield of 4954 kg ha^{-1} was achieved in the treatments in the plain, on the leached chernozem soil type, with good physical and chemical properties. The most significant grain yield of 5601 kg ha^{-1} was achieved in the biohumus + biofertiliser treatment, which was significantly higher than the biofertiliser treatment (11.6%) and control (28.0%) (Table 2). A three-year- study by Roljević Nikolić *et al*. (2018) on the leached chernozem soil type showed that a significantly higher spelt grain yield could be obtained in treatments with organic and microbiological fertilisers (5289 kg ha^{-1}) than the microbiological fertilisers (19.7%) and control (35.1%). Wang *et al*. (2021) obtained similar results, stating that spelt wheat production with organic fertilisers resulted in a 15% higher grain yield than NPK mineral fertiliser-based production. Furthermore, the application of organic fertilisers increased soil organic matter in the tilled layer (Borrelli and Pecetti, 2019), enhanced the soil rhizosphere's physicochemical properties, and increased the biomass and activity of microorganisms, thus raising the yield of the cultivated plants (Tobiašová, 2011).

The average hulled spelt grain yield of 3093 kg ha^{-1} was obtained on the treatments in the hilly region on the eutric cambisol soil type, which is acidic (pH 4.38) and has a low content of available phosphorus (2.5 mg). Aside from the unfavourable agrochemical qualities of the soil, uneven distribution of precipitation was also recorded in this region, reaching maximum in May (heading and the flowering of wheat). In the treatment with organic fertiliser (3138.67 kg ha^{-1}) and zeolite (2925.00 kg ha^{-1}), the grain yield was significantly higher than the control (13.9% and 6.1%), but thanks to the increase in the content and efficiency of nutrients their combined application had a much better effect (28.8%). Studying a soya cultivar, Haniati *et al*. (2020) also noticed a significant impact of the combined application of organic fertilisers and zeolite.

In the mountainous region, at the height of more than 1.000 m a.m.s.l, the average hulled grain yield in the treatments was 2241 kg ha^{-1}. The yield of spelt in this region was lower than those in the plains and hilly regions. Prior research also showed that lower spelt yield was typical for marginal, mountainous regions (Ruegger and Winzeler, 1993; Troccoli and Codianni, 2005). Similarly, studies conducted in Poland have shown that crop production productivity can be 74% lower in the mountainous regions than other more favourable areas for crop production (Jankowska-Huflejt *et al*., 2011; Klima *et al*., 2020). The differences in grain yield between treatments in this study in the mountainous region were insignificant. The highest hulled grain yield was obtained in the treatment of zeolite and microbiological fertiliser (2303 kg ha^{-1}), which was slightly higher than the control (2216 kg ha^{-1}). Treatment with hydrogel and microbiological fertiliser produced a similar result (2301 kg ha^{-1}). On the other hand, the microbiological fertiliser (2190 kg ha^{-1}) and zeolite (2193 kg ha^{-1}) did not increase the spelt grain yield than the control. Although no additional testing has been performed, we speculate that the low grain yield in this region may have been due to the chemical characteristics of pseudogley, having a very low phosphorus content, which plays a key role in fertility. Phosphorus represents a soil element of low mobility. In pseudogley, there is an additional problem in chemical mobilisation due to high acidity. Sembiring *et al*. (2020) indicate that high content of Al and Fe in the soil reduces the availability of P to plants and can cause low soil pH, thus inhibiting plant growth. Janković *et al*. (2013) highlight that the highest spelt yield can be achieved on the chernozem soil type, but due to its modest requirements regarding agrotechnique, spelt wheat is mainly grown in marginal regions with severe agro-ecological conditions.

Economic efficiency of spelt organic production in different regions

Total costs, production value, and financial results of agricultural production were determined by individual factors, primarily the input prices and market price of the products (Winnicki and Żuk-Gołaszewska, 2018). The cost analysis shows that to set up the organic production of cereals with different fertilisation treatments in the regions, it was necessary to invest between 1076.43 and 3569.71 € ha^{-1}

Table 2. Average spelt grain yield on treatments in the plain, hilly, and mountain regions.

Treatments	Grain yield (kg ha^{-1}) Average±SE	df	One way ANOVA F	Sig.	Treatments	LSD Mean difference	Sig.
Plain region							
T1	4882.85±215.9	2	13.174	0.006	T1/T2	–718.5*	0.024
T2	5601.36±199.1	6			T2/T3	1224.8*	0.002
T3	4376.55±186.2	8					
Average	4953.59±196.9						
Hilly region							
T1	3138.67±62.8	3	16.451	0.001	T1/T3	–411.0*	0.009
T2	2925.00±54.3	8			T2/T3	–624.7*	0.001
T3	3549.70±109.3	11			T3/T4	794.0*	0.000
T4	2755.67±258.7				T4/T1	383.0*	0.013
Average	3092.25±334.3						
Mountain region							
T1	2193.33±85.5	4	0.788	0.559			
T2	2190.20±175.6	10					
T3	2303.00±65.3	14					
T4	2301.00±67.6						
T5	2216.00±120.2						
Average	2240.73±107.4						

ANOVA, analysis of variance; LSD, least significant difference; SE, standard error; df, degree of freedom. *Significant at P<0.05 level.

(Table 3). The direct costs (raw materials) had the largest share in total production costs in all three regions, accounting for 78.3% (mountainous) to 93.6% (hilly) of total costs. Within direct costs, the costs of certified organic fertiliser dominated, with 76.1% and 95.8% in the hilly and the plain region, respectively. Due to the modest agrotechnical demands of spelt, the average cost of cultivation, harvesting, transport, and labour, accounted for 6.4% and 21.7% of the total costs in the hilly and mountainous regions, respectively (Table 3). The analysis of the profitability of spelt production under organic farming conditions has shown that a positive coverage margin can be expected in all three regions despite the high share of external inputs. Although better production (3467.8 kg ha^{-1}) and economic results (GM=3189.65 € ha^{-1}) were obtained in the plains, the lowest production costs (0.32 € ha^{-1}) and largest benefit-cost ratio (2.1) were achieved in the mountainous region (Table 4). On the other hand, high production costs (3569.71 € ha^{-1}) and low yield of the hull-less spelt grain (2165.1 kg ha^{-1}) resulted in very low economic efficiency (0.1) in the hilly region.

However, after analysing the variance of economic effects of different treatments on spelt production, the application of expensive fertilisers in the plain region was not economically justified

Table 3. Economic efficiency of organic spelt production in the plain, hilly, and mountain regions.

Specification	Units	Quantity			Value (€)		
		Plain region	Hilly region	Mountain region	Plain region	Hilly region	Mountain region
Direct costs - raw materials							
Seeds	kg	240.0	260.0	300.0	101.69	110.17	126.00
Biohumus	kg	3000.0	3000.0		2542.37	2542.37	
Microb. fertiliser 'Slavol'	l	5.0	5.0	5.0	10.47	10.47	10.47
Microb. fertiliser 'Uniker'	l			10.0			21.19
Hydrogel	kg			20.0			6.44
Zeolite	kg		2670.0	2670.0		678.81	678.81
Total (A)	€ ha^{-1}				2654.53	3341.82	842.91
Indirect costs - farm machinery operation with labour force							
Appl. of biohumus	ha	1	1	1	11.86	11.86	
Appl. of zeolite	ha	1	1	1		11.86	11.86
Appl. of microb. fertiliser 'Uniker'	ha	1	1	1			22.54
Ploughing (up to 25, 20, 15 cm)	ha	1	1	1	48.14	42.88	33.9
Discing	ha	1	1	1	12.71	12.71	11.86
Harrowing	ha	1	1	1	7.63	7.63	7.63
Sowing	ha	1	1	1	13.14	13.14	13.14
Appl. of hydrogel	ha	1	1	1			11.86
Foliar appl. of microb. fertiliser 'Slavol'	ha	1	1	1	22.54	22.54	22.54
Combine harvester	ha	1	1	1	68.98	68.98	68.98
Grain transport	ha	1	1	1	10.59	10.59	10.59
Baling straw	kg	1733.9	1082.3	784.4	41.14	25.69	18.61
Total (B)	€ ha^{-1}				236.74	227.89	233.53
Total costs (A+B)	**€ ha^{-1}**				**2891.27**	**3569.71**	**1076.43**
Subsidies for organic farming	€ ha^{-1}				220.34	220.34	220.34
Yield of hull-less grain*	kg ha^{-1}	3467.8	2165.1	1568.7			
Price of hull-less grain	€ kg^{-1}	1.69	1.69	1.69			
Total revenue	€ ha^{-1}				6080.92	3879.36	2871.44
Gross margin	€ ha^{-1}				3189.65	309.65	1795.01

Table 4. Indicators of economic efficiency of organic spelt production in different regions.

Indicator	Region		
	Plain	Hilly	Mountain
Total revenue, € ha^{-1}	6080.92	3879.36	2892.34
Total costs, € ha^{-1}	2891.27	3569.71	1076.43
Gross margin, € ha^{-1}	3189.65	309.64	1795.01
Gross margin rate, %	52.4	7.98	62.23
Unit production cost, € kg^{-1}	0.47	0.92	0.32
Benefit-COST RATIO	1.1	0.1	2.1

(Table 5). Namely, no significant difference in the gross margin was found between the treatment with organic fertilizer (3955.05 € ha^{-1}) and the control (5094.31 € ha^{-1}). Additionally, a significantly higher gross margin was observed in the treatment with the microbiological fertiliser in comparison to the organic fertiliser treatment (5659.90 *vs* 3955.05 € ha^{-1}). This result indicates that in favourable soil and climatic conditions, high investment through direct costs will not significantly increase the profitability of organic grain production, especially investment in expensive fertilisers, despite the increase in grain yield. Furthermore, significant differences between treatments were also observed in the hilly region, where a significantly lower gross value of production was found in treatments with expensive organic fertilisers (T1 1104.75 and T3 629.94 € ha^{-1}) than the (1833.85 € ha^{-1}). We can conclude that increasing grain yield by applying expensive fertilisers is not always economically justified.

Similarly, other authors point out that fertilisers are not necessary for the production of cereals (Wilson *et al*., 2008; Zielinski *et al*., 2008). Studying the economic efficiency of the organic cultivation of old wheat types (*Triticum monococcum* L., *Triticum dicoccum* Sch. and *Triticum spelta* L.), Atanasov *et al*. (2020) found that high prices of fertilisers certified for organic production did not guarantee economic efficiency, and that better results were achieved without their application. Other authors also highlight the high production costs and lower profitability of spelt wheat in organic farming systems (Vukoje *et al*., 2011; Winnicki and Żuk-Gołaszewska, 2018).

The differences in gross margin between treatments were also significant in the mountainous region, where the increase in direct production costs was not justified and significantly reduced gross income. None of the examined treatments significantly affected gross income with respect to the control. In the zeolite treatment (T1), in addition to the fact that there were no increases in grain yield, a significantly lower coverage margin (1579.93 € ha^{-1}) was determined compared to the control (2297.81 € ha^{-1}) (Table 5). From the perspective of the sustainability of production in marginal areas is reliant upon direct payments through subsidies (Di Mola *et al*., 2021).

Additional analysis of the production and economic indicators determined a strong negative correlation between the total costs and economic efficiency of production (r= –0.91**) (Table 6). The economic efficiency of production is also negatively correlated with the unit production cost (r= –0.49), although this correlation is not statistically significant. When it comes to the relationship of the gross margin with other analysed indicators, a strong positive

Table 5. Analysis of gross margin on treatments in the plain, hilly, and mountain regions.

Treatments	Gross margin (€ ha^{-1}) Average±SE	One way ANOVA df	F	Sig.	Treatments	LSD Mean difference	Sig.
Plain region							
T1	5659.90±372.39	2	6.693	0.030	T1/T2	1704.8*	0.011
T2	3955.05±326.20	6					
T3	5094.31±304.84	8					
Average	4903.09±301.67						
Hilly region							
T1	1104.75±50.00	3	77.893	0.000	T1/T2	–1560.4*	0.000
T2	2665.15±123.55	8			T2/T3	2035.2*	0.000
T3	629.94±33.49	11			T3/T1	–474.8*	0.031
T4	2935.55±218.24				T4/T1 T4/T3	1830.8* 2305.6*	0.000 0.000
Average	1833.85±302.22						
Mountain region							
T1	1579.93±94.11	4	3.905	0.037	T1/T5	–717.9*	0.021
T2	2223.32±167.43	10			T2/T1	643.4*	0.034
T3	1665.80±102.19	14			T3/T4	–670.5*	0.029
T4	2336.33±281.75				T4/T1	756.4*	0.016
T5	2297.81±213.04				T5/T3	632.0*	0.037
Average	2020.64±112.24						

ANOVA, analysis of variance; LSD, least significant difference; SE, standard error; df, degree of freedom. *Significant at P<0.05 level.

Table 6. Correlation analysis of the production and economic indicators.

	Yield	Total cost	Gross margin	Unit production cost	Benefit-cost ratio
Yield	1				
Total cost	0.54	1			
Gross margin	0.66*	–0.28	1		
Unit production cost	0.06	0.57	–0.43	1	
Benefit-cost ratio	–0.22	–0.91**	0.57	–0.49	1

*Correlation is significant at the 0.05 level (1-tailed); **correlation is significant at the 0.01 level (2-tailed).

correlation was observed only with grain yield (r=0.66*). A positive correlation was also determined for the benefit-cost ratio (r=0.57), but it was insignificant. As expected, a negative correlation was determined between the gross margin and production costs (r= –0.28; r= –0.43).

Conclusions

This study showed that spelt cultivation in the organic farming systems is profitable, but with significant differences between the regions with specific soil and climatic characteristics (309.64 to 3189.65 € ha^{-1}). The most significant average yield was recorded in treatments in the plain region under favourable climate conditions on the leached chernozem soil type with good chemical properties. It was followed by the yield on treatments in the hilly region, where the plants were grown in acidic soil and with a very uneven distribution of precipitation during vegetation. The lowest average yield was observed in the mountainous region at 1.000 m a.m.s.l. with extreme soil and climatic conditions. Appropriately balanced formulations of fertilisers and soil conditioners generally provided the greatest benefit to spelt wheat grain yield; however, expensive certified organic fertilisers were not economically justified. The most remarkable difference between the observed treatments was determined in the hilly region, where the application of biohumus and zeolite increased grain yield by 28.8% in comparison to control conditions. However, despite the increase in grain yield, the applied commercial organic fertiliser did not ensure the economic efficiency of production in this region (0.1).

On the other hand, the most significant economic efficiency of the spelt wheat organic production was registered in the mountain region (2.1), where no expensive fertilisers were applied. The obtained results lead to the conclusion that the economic efficiency of spelt wheat cultivation in organic farming systems is directly correlated to the total costs (r=–0.91**). The results of the study may be of interest in other countries and regions with similar soil and agro-ecological conditions, as they indicate that organic spelt production may be economically relevant if it is adapted to the specifics of local conditions and directed towards ensuring the independence of cultivation from expensive external inputs, such as commercial organic fertilisers.

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