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Research Article

Assessment of common wheat (*Triticum aestivum* L.) yield and quality under organic farming in the southwest of Romania

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Abstract

Taking into account the rising demand for organic wheat and the need to guarantee both high productivity and quality of the crops, the choice of cultivar plays a crucial role. These intended objectives may solely be attained by employing the most appropriate cultivars for organic agriculture. The aim of this study was to evaluate the suitability of 15 wheat cultivars for cultivation in organic farming according to three important parameters for organic farmers and processors, namely grain yield, test weight and protein content. The field experiment took place over two consecutive growing seasons, in the center of the Oltenia region (southwest of Romania) under organic farming conditions. The results showed significant effects of the climatic conditions in the year of study, but also of the cultivar on all studied parameters. The effect of genotype-environment interactions was significant only for test weight and protein content. On average, over the two years of study, the grain yield was 3899 kg ha^{-1}, the test weight was 70.8 kg hl^{-1}, and the protein content was 10.1%. The recently released cultivar 'Voinic' obtained the maximum grain yield (4755 kg ha^{-1}) and also a maximum test weight and protein content (73.9 kg hl^{-1}, respectively 10.7%). In conclusion, it follows that by using cultivars suitable for organic farming, good and quality yields can be obtained that can be a suitable raw material for baking industry.

Keywords: cultivars; grading wheat; grain yield; protein content; test weight

Introduction

Common wheat (*Triticum aestivum* L.) is a popular crop in both conventional and organic farms because it has an important role in global agri-food systems and in ensuring food security. In the last decade organic food and agriculture have grown both at the EU level and in Romania. In 2020, the area used in organic production in the EU reached 14.7 million ha, with an increase of 56% compared to 2012, and in Romania it reached 468,887 ha, with an increase of 62.7% (EUROSTAT, 2020).

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The interest in organic agriculture is stimulated not only by the increase in consumer awareness of food safety, but also by the concern for reducing environmental pollution. The main objectives of the European Green Deal strategy (associated Common Agricultural Policy) for 2030 envisage reducing the use of pesticides by 50%, of fertilizers by at least 20%, as well as increasing the area dedicated to organic agriculture to 25% of agricultural land in each European Union member country (Mitura *et al*., 2023). Organic farming relies more on ecosystem management than the use of synthetic inputs (Bux *et al*., 2022). Interest in agronomic research for organic farming systems and crop breeding is growing in many parts of the world, both in Europe and in Canada and the USA (Marinciu *et al*., 2022a).

However, in organic farming, wheat yield and quality are limited especially by the relatively low availability of nitrogen, in addition, these parameters are significantly influenced by genotype and environmental conditions (Cesevičienė *et al*., 2009). Also, for organic production to be competitive, wheat grains intended for consumption must meet certain quality standards (test weight, protein content, etc.), standards that organic farmers have a harder time achieving, although they are remunerated with a higher price for organic wheat. The yield and quality of the wheat grains allow determining the direction of use: e.g., processing in the milling industry, bakery (bread, biscuits), production of pasta and groats or animal feed (Sobolewska and Stankowski, 2017). Some studies show that the quality and destination of the raw material are significantly influenced by the genotype, environment and applied technology (Voinea, 2021).

Therefore, choosing the most suitable cultivar for organic farming is a key element for agricultural practice because it can have a greater effect on the economics/profitability of a wheat crop than in conventional farming (Revilla *et al*., 2008).Cereal varieties suitable for organic farming should have resistance to diseases and pests and good capacity to suppress weeds and absorb nutrients (Feledyn-Szewczyk *et al*., 2014; 2020).It is estimated that more than 95% of organic production is based on the use of varieties obtained for conventional agriculture (Löschenberger *et al*., 2008). Many studies have shown that some modern varieties obtained for conventional agriculture with high inputs, obtained good yields with superior quality in organic agriculture as well (Carr *et al*., 2006, Marinciu *et al*., 2022b). According to Marinciu *et al.* (2022b), the genetic progress for wheat yield obtained in conventional agriculture is also reflected in the performance of varieties grown in organic agriculture. Other studies have shown that old varieties are more suitable for organic agriculture than modern varieties (Carranza-Gallego *et al*., 2018).

The individual responses of wheat cultivars to applied agricultural practices are not the same. That is why, in the context of current climate changes, it is important to evaluate the performance of cereal varieties in organic farming conditions and select productive cultivars with a quality corresponding to European quality standards. Test weight and protein content are considered the two most important quality traits for both farmers and the milling industry. The test weight affects the productivity and efficiency of flour milling, and the protein content influences the elasticity of the dough and the formation of good bread (Sobolewska and Stankowski, 2017; Dunăreanu and Bonea, 2022).

The aim of this study was to determine the effect of the organic farming system on the grain yield and quality of 15 common wheat cultivars, in order to select suitable cultivars that would obtain good yields with quality parameters that would meet the requirements of commercialization and processing.

Materials and Methods

The field experiment was carried out during two growing seasons of 2020-2021 and 2021-2022 at the Agricultural Development Research Station (ARDS) Șimnic located in the center of Oltenia region, Romania (44°19' N and 23°48' E, and 182 m altitude), in organic farming on a reddish preluvosoil with a low humus content (1.8), medium supplied with NPK and a pH=5.7-5.9. This area is characterized with the semi-arid conditions.

The experiment was set up according to the randomized blocks method in three replications, with a harvest plot area of 7.5 m^2 and included 15 cultivars of winter wheat: twelve cultivars obtained at NARDI Fundulea, Romania ('Glosa', 'Litera', 'FDL Miranda', 'Izvor', 'Otilia', 'Pitar', 'Semnal', 'Pajura', 'Ursita', 'Voinic', 'FDL Abund' and 'Zamfira'), two cultivars created by ARDS Şimnic, Romania ('Adelina', 'Șimnic 60') and one cultivar created at KNIISH Krasnodar, Russia ('Bezostaia 1').

The weather parameters (temperature and precipitations) during growing seasons 2020-2021 and 2021-2022 are presented in Table 1. The 2020-2021 growing season was relatively favorable to the wheat crop, with rainfall and temperatures closer to the multi-year average (2006-2022). The 2021-2022 growing season was dry, with total precipitations of 504.9 mm, 149.6 less than the multi-year average. Most months had rainfall deficits, but the biggest deficits were in June (grain-filling period). Also, most months were warmer.

Table 1. Weather parameters at ARDS Şimnic

Month	Total of precipitation (mm)			Average temperature (°C)		
	2020-2021	2021-2022	Multi-year average (2006-2022)	2020-2021	2021-2022	Multi-year average (2006-2022)
IX	81.0	3.0	60.2	14.2	10.6	12.4
X	28.0	61.0	52.7	5.8	8.0	7.0
XI	84.0	50.0	38.9	3.3	2.6	1.3
XII	79.8	12.0	38.3	2.0	2.1	-0.3
I	12.8	7.4	34.6	3.4	5.1	2.2
II	99.0	7.5	56.9	5.6	4.9	6.9
III	35.0	70.0	48.6	12.3	11.5	12.8
IV	94.0	78.0	79.2	16.4	17.7	17.4
V	75.0	9.0	81.0	21.2	22.8	21.9
VI	20.0	54.0	69.2	25.5	24.7	24.0
VII	13.0	51.0	42.1	24.7	25.1	24.3
VIII	5.5	102.0	52.7	12.6	17.4	18.8
Sum	**627.1**	**504.9**	**654.5**			
Average				**12.1**	**13.2**	**12.4**

Agricultural practices

Pea was the preceding crop in both years of the study. Sowing was carried out on October 30th, 2020, respectively on November 5th, 2021, and harvesting was carried out on July 14th, 2021, respectively on July 8th, 2022. The wheat cultivars were cultivated with organic management practices according to the rules of organic farming (CR, 2007).

Data collected

The main data collected included grain yield, test weight and protein content. The grain yield per hectare was calculated by harvesting each plot, weighing and converting to hectare then adjusting to 14% moisture. Test weight (bulk density, or the weight of wheat grain per unit of volume) and protein content were determined on the grain samples by automatic instrument Infratec Grain Analyzer 1225.Grading of common wheat was performed according to CNGSC (2017).

Statistical analyses

The data was processed with the help of Minitab 21.4.0 statistical software (Minitab, State College, Pennsylvania, USA) using analysis of variance (ANOVA: Two-Factor with Replications) and *post-hoc* Tukey test ($p < 0.05$). Means were used to compare grain yield and quality between cultivars and years.

Results

The results across two growing seasons showed that there were significant differences between cultivars and between years for grain yield, test weight and protein content. The cultivar × year interaction was significant only for test weight and protein content. The proportion of the explained mean of squares showed that the contribution of the climatic conditions in the years of study to the achievement of these traits was dominant (91%, 97% and 98%, respectively) (Table 2).

Table 2. Analysis of variance (ANOVA) of grain yield of 15 wheat cultivars

Source of variation	df	Grain yield (kg ha^{-1})		Test weight (kg hl^{-1})		Protein content (%)	
		Mean squares	Share of factors (%)	Mean squares	Share of factors (%)	Mean squares	Share of factors (%)
Cultivar	14	965706.5*	5	10.4*	1	0.9*	1
Year	1	19737440*	91	1369.7*	97	85.3*	98
C × Y interaction	14	526707.4 n.s.	2	22.8*	2	0.7*	1
Error	60	499169.6	2	2.5	0	0.2	0

*Significant at $p < 0.05$; n.s. = non-significant

Grain yield

In organic farming, the grain yield in 2021 was significantly higher than in 2022. The average yield for the cultivars tested was 4367 kg ha^{-1} in 2021 and 3431 kg ha^{-1} in 2022. In 2021, the cultivar 'Voinic' (5437 kg ha^{-1}) followed by 'Bezostaia 1' (5093 kg ha^{-1}) recorded significantly higher yields compared to other cultivars. In 2022, although the yield between cultivars varied between 2956 and 4074 kg ha^{-1}, there was non-significant difference between cultivars. On average, over the two years of study, 'Voinic' (4755 kg ha^{-1}) recorded a significantly higher grain yield, and 'Litera' (2973 kg ha^{-1}) a significantly lower grain yield compared to other cultivars. The rest of the cultivars were at the same level of significance as 'Voinic' (Figure 1).

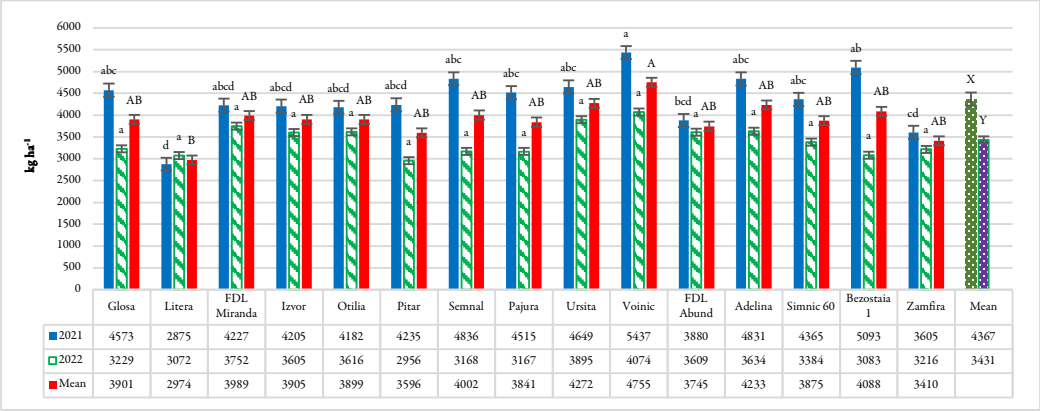
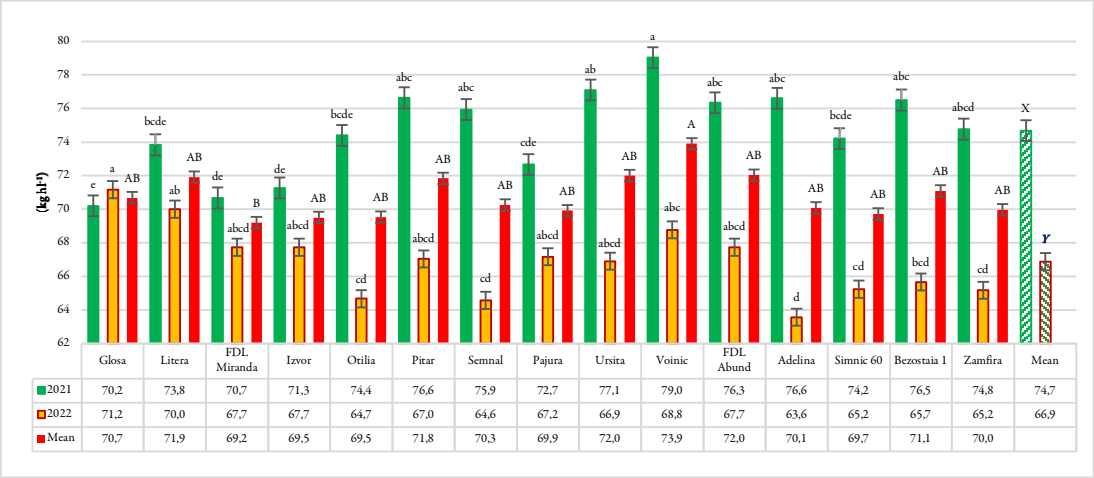


Figure 1. Grain yield of 15 wheat cultivars in 2021-2022 under organic farming
Differences between any two variants followed by a common letter are not significant, according to Tukey's post hoc test ($p < 0.05$). Vertical lines represent the standard error of the mean (±SEM).

Test weight

The test weight of the wheat cultivars tested in the organic farming system varied significantly in the period 2021-2022, from 63.6 kg hl^{-1} to 79 kg hl^{-1}. The average test weight in 2021 (74.7 kg hl^{-1}) was significantly higher compared to 2022 (66.9 kg hl^{-1}). The cultivar 'Voinic' recorded a significantly higher test weight in both 2021 (79 kg hl^{-1}) and as an average over the two years of study (73.9 kg hl^{-1}), compared to other cultivars. In

2022, 'Glosa' recorded a significantly higher test weight (71.2 kg hl^{-1}) followed by 'Litera' (70 kg hl^{-1}), while 'Adelina' recorded a significantly lower test weight (63.6 kg hl^{-1}). The lowest test weight, on average over the two years of the study, was recorded at the cultivar 'FDL Miranda' (69.2 kg hl^{-1}). The rest of the cultivars were at the same level of significance as 'Voinic' (Figure 2).

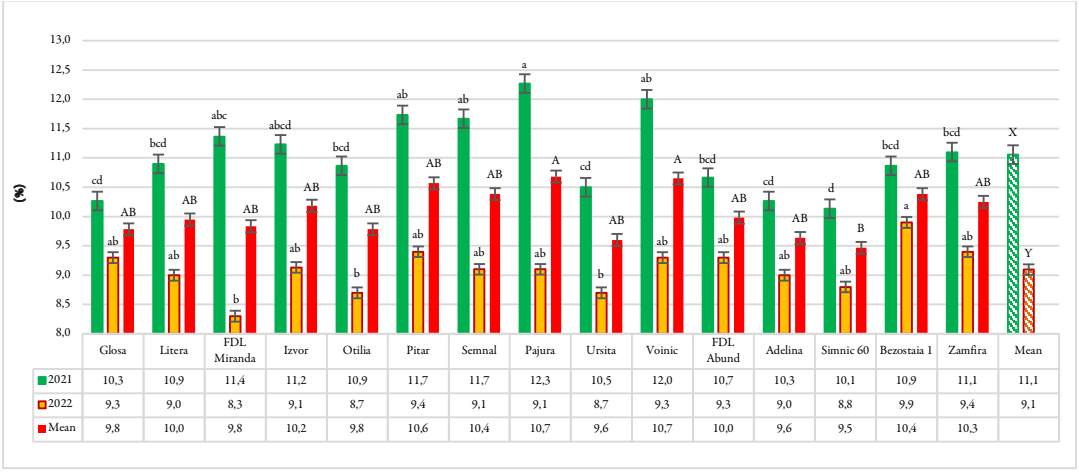


	Glosa	Litera	FDL Miranda	Izvor	Otilia	Pitar	Semnal	Pajura	Ursita	Voinic	FDL Abund	Adelina	Simnic 60	Bezostaia 1	Zamfira	Mean
2021	70,2	73,8	70,7	71,3	74,4	76,6	75,9	72,7	77,1	79,0	76,3	76,6	74,2	76,5	74,8	74,7
2022	71,2	70,0	67,7	67,7	64,7	67,0	64,6	67,2	66,9	68,8	67,7	63,6	65,2	65,7	65,2	66,9
Mean	70,7	71,9	69,2	69,5	69,5	71,8	70,3	69,9	72,0	73,9	72,0	70,1	69,7	71,1	70,0	

Figure 2. Test weight of 15 wheat cultivars in 2021-2022 under organic farming
Differences between any two variants followed by a common letter are not significant, according to Tukey's post hoc test ($p < 0.05$). Vertical lines represent the standard error of the mean (±SEM).

Protein content

The average protein content for the cultivars tested was 11.1% in 2021 and 9.1% in 2022. In 2021, 'Pajura' (12.3%) recorded significantly higher protein content followed by 'Voinic' (12%), 'Semnal' (11.7%) and 'Pitar' (11.7%), while 'Şimnic 60' (10.1%) recorded a significantly lower protein content compared to other cultivars. In 2022, the highest and most significant protein content was recorded in 'Bezostaia 1' (9.9%), and the lowest protein content in 'Otilia' (8.7%), 'Ursita' (8.7%) and 'FDL Miranda' (8.3%). On average over the two years of study, 'Pajura' and 'Voinic' stood out (10.7%), while 'Şimnic 60' recorded the lowest protein content (9.5%). The rest of the cultivars were at the same level of significance as 'Pajura' and 'Voinic' (Figure 3).



	Glosa	Litera	FDL Miranda	Izvor	Otilia	Pitar	Semnal	Pajura	Ursita	Voinic	FDL Abund	Adelina	Simnic 60	Bezostaia 1	Zamfira	Mean
2021	10,3	10,9	11,4	11,2	10,9	11,7	11,7	12,3	10,5	12,0	10,7	10,3	10,1	10,9	11,1	11,1
2022	9,3	9,0	8,3	9,1	8,7	9,4	9,1	9,1	8,7	9,3	9,3	9,0	8,8	9,9	9,4	9,1
Mean	9,8	10,0	9,8	10,2	9,8	10,6	10,4	10,7	9,6	10,7	10,0	9,6	9,5	10,4	10,3	

Figure 3. Protein content of 15 wheat cultivars in 2021-2022 under organic farming
Differences between any two variants followed by a common letter are not significant; according to Tukey's post hoc test ($p < 0.05$). Vertical lines represent the standard error of the mean (±SEM).

Grading of wheat grains

In Romania, common wheat (*Triticum aestivum* L.) for baking industry is classified by Quality Grade according to several parameters (CNGSC, 2017). Based on test weight, common wheat is classified into: Grade 1 (TW ≥ 77 kg hl^{-1}), Grade 2 (TW ≥ 75 kg hl^{-1}) or Grade 3 (TW ≥ 72 kg hl^{-1}), with the highest remuneration for Grade 1.

The data in Table 3 showed that in 2021, only two cultivars ('Ursita' and 'Voinic') were classified in Grade 1, six cultivars were classified in Grade 2 ('Litera', 'Pitar', 'Semnal', 'FDL Abund', 'Adelina' and 'Bezostaia 1'), four cultivars were classified in Grade 3 ('Otilia', 'Pajura', 'Şimnic 60' and 'Zamfira'), and three cultivars ('Glosa', 'FDL Miranda' and 'Izvor') could not be graded (without consumption value). In 2022, no cultivar reached the optimal grading value. As an average over the two years of study, only the cultivars 'Ursita', 'Voinic' and 'FDL Abund' were classified in Grade 3.

Table 3. Grading of test weight for wheat cultivars tested in organic farming

Cultivar	2021	2022	Average 2021-2022
'Glosa'	Without grading	Without grading	Without grading
'Litera'	Grade 2	Without grading	Without grading
'FDL Miranda'	Without grading	Without grading	Without grading
'Izvor'	Without grading	Without grading	Without grading
'Otilia'	Grade 3	Without grading	Without grading
'Pitar'	Grade 2	Without grading	Without grading
'Semnal'	Grade 2	Without grading	Without grading
'Pajura'	Grade 3	Without grading	Without grading
'Ursita'	Grade 1	Without grading	Grade 3
'Voinic'	Grade 1	Without grading	Grade 3
'FDL Abund'	Grade 2	Without grading	Grade 3
'Adelina'	Grade 2	Without grading	Without grading
'Şimnic 60'	Grade 3	Without grading	Without grading
'Bezostaia 1'	Grade 2	Without grading	Without grading
'Zamfira'	Grade 3	Without grading	Without grading

Without grading is for TW < 72 kg hl^{-1} according CNGSC (2017)

According to CNGSC (2017), the classification of common wheat for baking industry based on protein content is done in: Grade 1 (PC ≥ 12%), Grade 2 (PC ≥ 11%) or Grade 3 (not regulated), with the highest remuneration for Grade 1. From the data presented in Table 4, it can be seen that in 2021 only two cultivars were classified in Grade 1 ('Pajura' and 'Voinic'), five cultivars were classified in Grade 2 ('FDL Abund', 'Izvor', 'Pitar', 'Semnal' and 'Zamfira') and the rest were classified in Grade 3. Both in 2022, and in the average over the two years of study, all cultivars tested were classified in Grade 3.

Table 4. Grading of protein content for wheat cultivars tested in organic farming (according to CNGSC, 2017)

Cultivar	2021/ Grade	2022/ Grade	Average 2021-2022 / Grade
'Glosa'	3	3	3
'Litera'	3	3	3
'FDL Miranda'	2	3	3
'Izvor'	2	3	3
'Otilia'	3	3	3
'Pitar'	2	3	3
'Semnal'	2	3	3
'Pajura'	1	3	3
'Ursita'	3	3	3
'Voinic'	1	3	3
'FDL Abund'	3	3	3
'Adelina'	3	3	3
'Şimnic 60'	3	3	3
'Bezostaia 1'	3	3	3
'Zamfira'	2	3	3

Discussion

Many studies carried out in the Oltenia region show that drought and heat are frequent phenomena in this area of Romania, leading to substantial losses of grain yields in many agricultural crops (Urechean and Bonea, 2012; 2017; Bonea, 2020; Borleanu and Bonea, 2020; Dunăreanu *et al*., 2021).

In the present study, the climatic conditions in the two growing seasons varied a lot in terms of average temperatures, total precipitation and their distribution throughout the vegetation periods. The drought and higher temperatures in June 2022 (when the plants were in the period of grain-filling towards physiological maturity) affected the level of grain yields and quality, thus confirming the results of other studies (Hossain, 2012; Bonea and Urechean, 2020; Stupar *et al*., 2021) who showed that the climatic conditions, especially in the critical stages of plant development, significantly influence grain yield and quality of grains. Analysis of variance showed that the strongest influence for all studied parameters had climatic conditions of the year of study (91%, 97% and 98%, respectively). Therefore, the effects of environments cannot be ignored when breeding wheat for organic farming. This strong influence of climatic conditions on yield, test weight and protein content are in agreement with Kaya and Akcura (2014).

Our results regarding grain yield did not confirm any significant interaction between cultivar and year, but for test weight and protein content the cultivar x year interaction was significant. However, in other studies the cultivar x year interaction was significant for yield (Marinciu *et al*., 2022b; Petcu *et al*., 2011). The presence of cultivar x year interaction effect on these parameters of quality indicated the inconsistency of some cultivars in expressing these traits across growing seasons, complicating the selection of superior cultivars. Marinciu *et al*. (2022a) reported similar results for yield and test weight in organic farming over the two years of study (2020-2021) at NARDI Fundulea, Romania.

The yield level of the 15 wheat cultivars tested (3899 kg ha^{-1}) was close to that reported in the study of other authors (Feledyn-Szewczyk *et al*., 2020) from Europe (Poland) who obtained 3.76 t ha^{-1} of wheat in organic system and higher than that reported by Marinciu *et al*. (2022b) in Romania who obtained 3176 kg ha^{-1}, which demonstrates the favorability of the study area for organic farming.

Among the cultivars tested, the recently released cultivar 'Voinic' (released in 2020) stood out both in terms of grain yield (4755 kg ha^{-1}) and grain quality (73.9 kg hl^{-1} test weight and 10.7% protein content), being

in accordance with those reported by Marinciu *et al.* (2022a; 2022b), where this cultivar 'Voinic', according to grain yield and test weight, was considered one of the most suitable cultivars for organic farming. The oldest cultivar 'Bezostaia 1' (released in 1961) obtained lower, but statistically insignificant levels for all studied parameters compared to this recently/modern cultivar. Data from the literature show different results regarding the suitability of modern or old varieties for organic farming. Some authors consider that old varieties are more suitable for organic farming because they have higher plant height and test weight (Migliorini *et al*., 2016) and can increase the sustainability of agro-systems by improving soil quality, reducing the need for chemical products, without significant decreases in yield (Carranza-Gallego *et al*., 2018). On the other hand, other authors have shown that modern varieties obtain significantly higher yields, often with better quality than old varieties, including in organic farming, having a high efficiency of nitrogen use (Guarda *et al*., 2004; Zhao *et al*., 2009; Løes *et al*., 2020).

Wheat grain yield and quality are some of the most important parameters considered by farmers and processors when comparing organic and conventional farming systems. In order to make a proper comparison, we used the results obtained by the same cultivars in conventional farming at ARDS Şimnic. The comparative data regarding the results obtained by the 15 wheat cultivars tested in the conventional system according to Dunăreanu (2021; 2022) and the organic system showed a reduction by 47.7% of the grain yield, by 5.2% of the test weight and by 27.3% of the protein content in organic farming, confirming the results reported in other studies that showed lower yields by 40%-45% (Feledyn-Szewczyk *et al*., 2014; Ianuci and Codianni, 2016), lower tests weight by 3.2-3.3 kg/hl (Hilderman, 2010; Draghici *et al*., 2011) as well as lower protein contents by 14.7-23.3% (Draghici *et al*., 2011; Sobolewska and Stankowski, 2017) in organic farming. These differences are due to several unfavorable conditions that differentiate organic agriculture from conventional agriculture (lack of chemical fertilization, lack of chemical weed control, etc.). Also, a low yield and low quality in organic farming could be the consequence of the conditions during the grain-filling period and the lower supply of nutrients (Mikó *et al*., 2014).

Regarding the grading of wheat by quality Grades, our results showed that the drought and higher temperatures of 2022 led to a reduction in test weight so that no cultivar reached the minimum level of 72 kg hl^{-1} required for to be graded. On average over the two years of study, only the cultivars 'Voinic', 'Ursita' and 'FDL Abund' could be classified in Grade 3. The influence of climatic conditions on the test weight in wheat was also shown by Švancárková and Žák (2015).

In general, it is known that drought and higher temperatures can reduce the carbohydrate content of grains (Balla *et al*., 2011) and increase the protein content (Flagella *et al*., 2010). However, our results showed that all tested cultivars had lower protein content in the dry year 2022 than in 2021, corresponding to the lowest quality Grade (Grade 3). This suggests that in organic agriculture the effects of drought depend to a large extent on the intensity and timing of the drought, on the genotype, as well as on the interactions with other environmental stresses.

Conclusions

This research is in line with the objectives of the European Green Deal Strategy that aim for sustainable agricultural production. Our results indicate that by using cultivars suitable for organic farming, good and quality yields can be obtained that can be a suitable raw material for baking industry. Also, the study showed that the evaluated cultivars responded differently to the climatic conditions of the study years, therefore it is very important to test and select the most suitable cultivars for each crop area. Among the 15 wheat cultivars tested, the cultivar 'Voinic' obtained the highest grain yield (4755 kg ha^{-1}), the highest test weight (73.9 kg hl^{-1}) and the highest protein content (10.7%). Also, 'Pajura' stood out for its high protein content (10.7%).

Therefore, the cultivar 'Voinic' can be recommended to organic farmers for expansion in cultivation for the region of Oltenia, Romania

Authors' Contributions

Conceptualization: ICD and DB; Organized the data and performed the statistical analysis: MB and DB; Conducting the field experiment and measurements: ICD and GLP; Writing – original draft: DB; Writing - review and editing: DB and MB; Supervision and translate: MB. All authors read and approved the final manuscript.

Ethical approval (for researches involving animals or humans)

Not applicable.

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Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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