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GRAIN YIELD AND HECTOLITRE WEIGHT OF SOME WHEAT CULTIVARS IN ORGANIC AND CONVENTIONAL PRODUCTION SYSTEMS

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ABSTRACT

For organic agriculture, wheat cultivars with good and stable grain yield across years are needed. Grain yield and hectolitre weight of 10 cultivars were estimated in field trials for three years at conventionally and organically production systems under the central part of Oltenia, Romania conditions. Our research evidentiated that cultivar influenced significant only hectolitre weight; production system influenced significant the both grain yield and hectolitre weight, and interaction between cultivars x production system was non-significant for the both traits. On average for the study period, the grain yield from the organic production system was by 35% lower than that achieved from the conventional production system. Hectolitre weight was also, affected by production system showing in the organic system values by 2% lower than in the conventional system. The cultivar Miranda was more stable than the other studied cultivars in both conventional and organic production system. On average most cultivars fulfilled the requirements for Grades 2 and 3, but the percentage of cases below the 72 kg/hl limit (non bakery value) varied from 0 to 66.7% in both production systems.

Keywords: conventional and organic production system, cultivars, grades of quality, stability of yield.

INTRODUCTION

Organic agriculture is a production system that sustains the health of soils, ecosystems and people (INFOAM, 2008). The total area under organic farming in the European Union in 2019 covered almost 13.8 million hectares of agricultural land. The majority this area was located in Spain (2.35 million hectares), France (2.24 million hectares), Italy (1.99 million hectares) and Germany (1.29 million hectares) (EUROSTAT, 2021).

In Romania, according to the statistical data in 2021, the area of utilized agricultural area with organic production was 468.887 ha and in the national structure of utilized agricultural area, cereal cultivation accounted for 28.6% of total utilized agricultural area in organic ones (MADR, 2021).

Wheat (*Triticum aestivum* L.) is the most important and cultivated crop in the world alongside maize, rice and soybean (FAOSTAT, 2019). It is used for human consumption and for animal feed. Through its processing is obtained flour, groats, pasta, cereal and bakery products (Bîlteanu, 1991).

In recent years, organic wheat production has increased significantly because of increased demand by consumers. Global consumption of wheat was over 759 million metric tons consumed in 2020/2021 marketing year (Shahbandeh, 2021).

Organic farming represents a viable option to reduce the use of non-renewable resources and the environmental degradation, while maintaining productivity and profitability (Wheeler, 2008). Organic farmers have fewer tools at their disposal than conventional farmers to influence the growing environment and achieve good yields. Also, in Oltenia area, drought and heat are becoming major environmental constraint on crop production (Bonea, 2020; Bonea and Urechean, 2020). Therefore, organic agriculture needs cultivars that can cope with varying levels of abiotic and biotic stress and have good and stable grain yield across years. Successful wheat

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cultivars for organic conditions should have a high average yield combined with a low degree of fluctuation when grown in different environments.

Many studies have shown that grain yield of wheat produced under organic conditions are often 14% to 40% lower than those achieved under conventional conditions (Mader et al., 2007; Seufert et al., 2012; Iannuci and Codianni, 2016).

Thus, trials conducted across a range of environments within different farming systems and over multiple years will be needed to identification of tolerant cultivars that have the characteristics of adaptability and stability under such low-input conditions, in terms of both seed yield and grain quality (Iannucci and Codianni, 2016).

Grain yield and test weight are considered the two most important traits in the selection of wheat varieties because yield is an excellent indicator that can be used as an appropriate measurement of genotypic response to system-specific conditions and hectolitre weight is a good overall quality characteristic (Murphy et al., 2007).

Therefore, the main aims of this study was to compare the performances of ten cultivars under two different production systems in order to identify cultivars suitable for organic and conventional production systems in the central part of Oltenia, and to estimate the frequency of achieving the required limits for grading according to hectolitre weight.

MATERIAL AND METHODS

A bifactorial trial was organized in the experimental field of the ARDS Şimnic - Craiova (the central part of Oltenia, Romania), over three consecutive growing seasons (2018-2019, 2019-2020 and 2020-2021) using a split-plot design in 10 x 2 factorial arrangements with three replications, on a reddish preluvosoil (pH 5.08-5.33, humus 2.2-2.7%).

The experimental factors were: factor A represented by ten Romanian cultivars (Glosa, Izvor, Miranda, Pajura, Pitar, Ursita, Şimnic 60, Adelina, Otilia and Bezostaia) and factor B represented by two production system: conventional (typical practices applied to a wheat crop in Oltenia area) and organic (no-chemical input system). The grain yield was reported at 14% standard moisture. The hectolitre weight (kg/hl) was analyzed by specific apparatus.

The stability of cultivars was estimated by combining the use of coefficient of variation (CV%) and average yield (Francis and Kannenberg, 1978).

Analyses of variance were performed using Microsoft Excel. The main effects - cultivar, production system and their interactions were tested for significance by two-factors ANOVA. Significance between averages was determined by Fisher's least significant difference (LSD) at $P \leq 0.05$ (Săulescu and Săulescu, 1967).

Weather conditions during the experiment are summarized in Figures 1 and 2. Precipitation from growing season totaled 437.9 mm in 2018-2019, 451.4 mm in 2019-2020 and 557.6 mm in 2020-2021 with 127.8, 104.3 and 8.1 mm below multiannual average, respectively. Temperatures were over multiannual average in all growing seasons (+1.5°C, +2.3°C and +1.6°C, respectively).

In 2018-2019 growing season, in October and November during the sowing and seedling periods, precipitation were completely absent or very lower which led to a reduction in the density of plants in all plots.

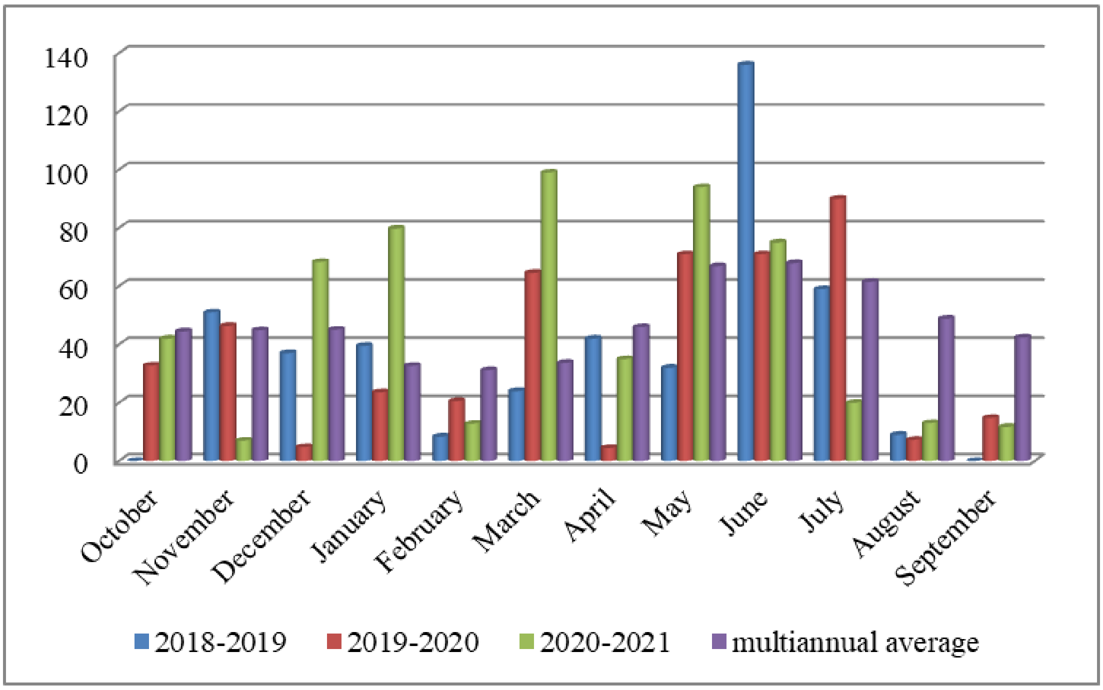

Figure 1. Monthly precipitation (mm) during October - September at ARDS Şimnic (2018-2021)

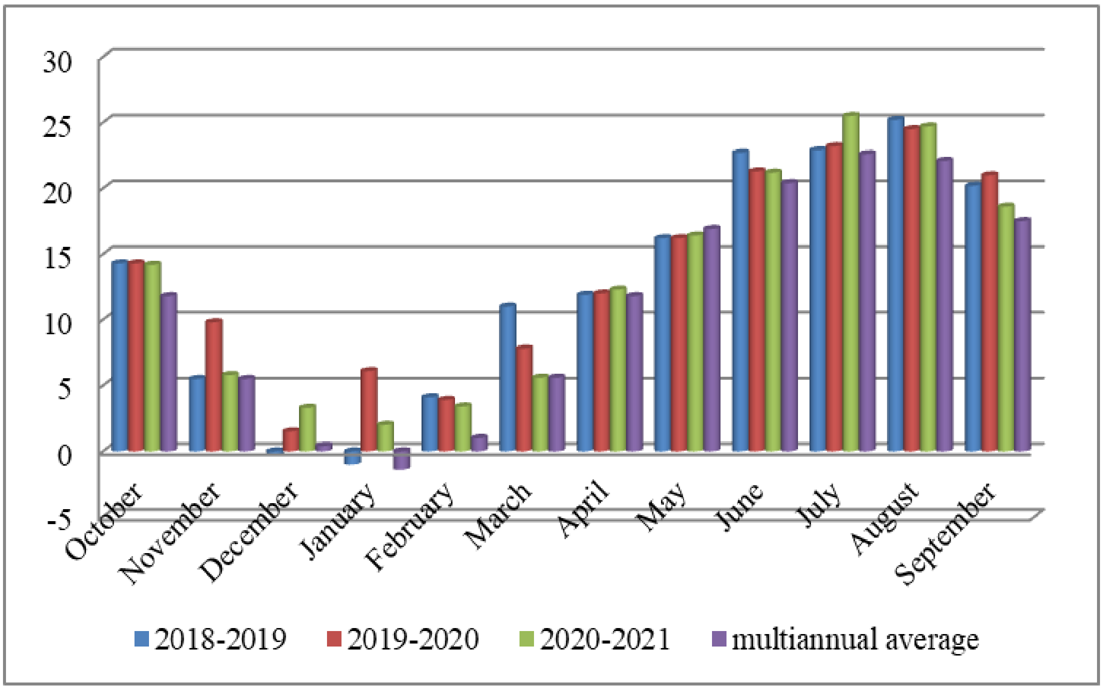

Figure 2. Average temperatures (°C) registered during October - September at ARDS Şimnic (2018-2021)

RESULTS AND DISCUSSION

The production system (S) had a significant effect on grain yield, on average for three years of study, while the effects of cultivar (C) and of C x S interaction were non-significant (Table 1). Our results suggest that cultivars not differed in grain yield, and the interaction C x S cannot always change the response of the cultivars regarding grain yield.

Hildermann et al. (2009) reported that yield of wheat was significantly affected by cultivars and by production systems, but C x S interaction was non-significant.

Table 1. ANOVA for grain yield (GY)

Source of variation	2019		2020		2021		Average over years (2019-2021)	
	F value	P value	F value	P value	F value	P value	F value	P value
Cultivar (C)	1.865 ns	0.086	1.307 ns	0.263	0.419 ns	0.916	1.242 ns	0.298
Production system (S)	1.561 ns	0.218	130.582*	3.599	121.485*	1.088	173.601*	3.899
C x S interaction	0.551 ns	0.828	0.850 ns	0.576	0.763 ns	0.650	0.855 ns	0.572 ns

*: Significant at 0.05 probability levels; ns: not significant.

ANOVA for the hectolitre weight revealed different effects of cultivar (C), production system (S) and their interaction (Table 2). Influence of cultivar was significant for hectolitre weight in all three studied years. Production system (S) had a significant effect on hectoliter weight in 2019 and in 2020, while in 2021 influence was non-significant. The C x S interaction was significant in 2019, but non-significant in 2020 and 2021.

The combined analysis of variance of the trials over 3 years showed significant effects of cultivars and production systems, but the C x S interaction was non-significant (Table 2).

Marinciu et al. (2021) showed that cultivars had a very significant effect on hectolitre weight, while management's systems influence was non-significant and interactions of cultivars and managements were also non-significant.

Table 2. ANOVA for hectolitre weight (HLW)

Source of variation	2019		2020		2021		Average over years (2019-2021)	
	F value	P value	F value	P value	F value	P value	F value	P value
Cultivar (C)	8.263*	8.111	7.547*	2.333	5.702*	4.588	10.770*	2.922
Production system (S)	4.423*	0.042	135.803*	1.966	3.248 ns	0.079	43.728*	6.522
C x S	7.645*	2.011	1.815 ns	0.096	0.276 ns	0.978	1.872 ns	0.084

*: Significant at 0.05 probability levels; ns: not significant.

Our data show that the major differences in grain yield among the years (Table 3) were associated with the rainfall distribution (monthly quantity) and with the temperatures during the vegetation period. In conventional systems, the yields were greater than in the organic systems by approximately 45% and 43% for 2020 and 2021, respectively.

This finding agrees with Cox et al. (2019), who showed that in years with high precipitation during the grain-filling period, organic compared with conventional grain yields are much lower because of increased weed infestation in organic production system. Therefore, ability to manage weeds is a very important part of organic production system.

In contrast, in the year 2019, the grain yield from the conventional production system was lower, but non-significant, compared to the organic production system (-6%). These results are probably due to the lack or insufficiency of precipitation during the sowing and seedling periods that resulted in a lower density of plants in the plots and implicit a lower yield. On the other hand, Nawaz et al. (2012) observed that in conventional system, the early drought stress significantly reduced the nitrogen (N) uptake by 38%. Also, under severe drought conditions, the better water holding capacity of organically managed soils is a likely mechanism for better yields under these conditions (Lotter et al., 2003).

Averaged across the 3 years of the study the conventional production system produced a grain yield of 6150 kg/ha compared with 4015 kg/ha for the organic production system (-35%). Previous studies have shown that grain yield of wheat produced under organic conditions are often 34% to 60% lower than those achieved under conventional conditions, due to site, year and management systems used (Murphy et al., 2007; Ingver et al., 2008; Iannuci and Codianni, 2016; Anastasi et al., 2019).

Table 3. Average values of grain yield (kg/ha) under organic (ORG) and conventional (CONV) production systems at ARDS Şimnic, Craiova

Cultivar (C)	Production systems (S)											
	2019			2020			2021			Average 2019-2021		
	ORG	CONV	Average per cultivar	ORG	CONV	Average per cultivar	ORG	CONV	Average per cultivar	ORG	CONV	Average per cultivar
Glosa	4259	3548	3904	4290	7254	5772	4573	7396	5985	4374	6066	5220
Izvor	3900	3210	3555	2349	6994	4672	4205	7805	6005	3485	6003	4744
Miranda	4146	3850	3998	4179	7245	5712	4227	8409	6318	4184	6501	5343
Pajura	3895	3527	3711	3738	8166	5952	4515	8111	6313	4049	6601	5325
Pitar	3479	3363	3421	4267	7325	5796	4235	8929	6582	3994	6539	5266
Ursita	3665	3195	3430	4547	7387	5967	4649	7827	6238	4287	6136	5212
Şimnic 60	3344	3599	3472	3911	7636	5774	4365	8036	6201	3873	6424	5148
Adelina	2972	3289	3131	4003	7404	5704	4831	8236	6534	3935	6309	5122
Otilia	3579	3684	3632	4663	7000	5832	4182	6898	5540	4141	5861	5001
Bezostaia	2852	2858	2855	3535	5577	4556	5093	6738	5916	3827	5058	4442
Average per system	3609	3412	3511	3948	7199	5574	4488	7838	6163	4015	6150	5082
LSD 5% for factor C	711			1285			1374			731		
LSD 5% for factor S	317			576			614			327		
LSD 5% for C x S	1004			1818			1941			1034		

The hectoliter weight (or test weight) affects the productivity and efficiency of flour milling and therefore is a good indicator of interest to both farmers and the milling industry (Marinciu et al., 2019).

As shown in Table 4, hectolitre weight in the conventional production systems was greater than in the organic production systems by approximately 6% for year 2020 and by 2% for year 2021. In contrast, in 2019 in the conventional production system, hectolitre weight was lower than in organic conventional system by approximately 1%.

Table 4. Average values of hectolitre weight (kg/hl) under organic (ORG) and conventional (CONV) production systems at ARDS Şimnic, Craiova

Cultivar (C)	Production systems (S)											
	2019			2020			2021			Average 2019-2021		
	ORG	CONV	Average per cultivar	ORG	CONV	Average per cultivar	ORG	CONV	Average per cultivar	ORG	CONV	Average per cultivar
Glosa	73.3	74.1	73.7	72.2	75.1	73.7	70.2	74.3	72.3	71.9	74.5	73.2
Izvor	74.5	71.5	73.0	69.4	74.2	71.8	71.3	71.6	71.4	71.7	72.4	72.1
Miranda	71.2	72.2	71.7	68.6	74.9	71.8	70.7	71.0	79.8	70.2	72.7	71.4
Pajura	73.7	74.0	73.9	72.7	76.8	74.8	72.7	74.0	73.3	73.0	74.9	74.0
Pitar	72.0	74.7	73.3	73.1	77.1	75.1	76.6	78.0	77.3	73.9	76.6	75.2
Ursita	73.9	73.7	73.8	72.3	73.4	72.9	77.1	77.4	77.3	74.4	74.8	74.6
Şimnic 60	71.7	73.0	72.3	71.0	74.8	72.9	74.2	75.5	74.9	72.3	74.4	73.4
Adelina	72.8	66.8	69.8	66.3	72.8	69.6	76.6	77.3	76.9	71.9	72.3	72.1
Otilia	72.3	67.4	69.9	70.4	74.5	72.5	74.4	75.7	75.1	72.3	72.5	72.4
Bezostaia	72.1	73.2	72.7	70.4	75.5	73.0	76.5	77.5	77.0	73.0	75.4	74.2
Average per system	72.7	72.0	72.4	70.6	74.9	72.8	74.0	75.2	74.6	72.5	74.1	73.3
LSD 5% for factor C	1.51			1.65			3.00			1.09		
LSD 5% for factor S	0.67			0.75			1.35			0.48		
LSD 5% for C x S	2.14			2.32			4.26			1.53		

On average for 3 years of the study, in organic system Pitar and Ursita cultivars showed the highest hectolitre weight (73.9 and 74.4 kg/hl, respectively), while the lowest was found in Miranda (70.2 kg/hl). In conventional system the highest hectolitre weight was found in Pitar and Bezostaia cultivars (76.6 and 75.4 kg/hl, respectively) and the lowest value in Miranda, Otilia, Izvor and Adelina (72.7, 72.5, 72.4 and 72.3 kg/hl, respectively). Regarding production systems, in the conventional production system, hectolitre weight (74.1 kg/hl) was higher (+2%) compared with the organic production system (72.5 kg/hl).

In contrast to our findings, other studies have shown non-significant differences for hectolitre weight between conventional and organic production systems (Mason et al., 2007; Annicchiarico et al., 2010). Also, Bilsborrow et al. (2013) found that organic management system produced a higher and significant hectolitre weight than the conventional system (71.6 kg/hl vs. 71.0 kg/hl).

Regarding coefficient of variation for grain yield in conventional system all cultivars had registered very large variability (>30%), but in organic system Miranda, Pitar and Ursita cultivars had registered medium variability (<20%); Glosa, Pajura, Şimnic 60, Otilia and Bezostaia cultivars had registered high variability (<30%) and Izvor and Adelina very large variability (>30%) (Table 5).

The coefficients of variation for hectolitre weight were small (<10%), ranging between 0.9% and 5.4% under the organic system and between 2.3% and 6.6% under the conventional system (Table 5).

We tested the hypothesis developed by Palaniappan and Sivaraman (1996) that the absence of genotype x system interaction suggests that selection in one production system can lead to identification of suitable and stable cultivars that are optimal across a range of production systems.

Genotype stability for yield has been categorized by Francis and Kannenberg (1978) into four groups: group I with high yield and small variation; group II with high yield and large variation; group III with low yield and small variation and group IV with low yield and large variation. Only group I can be considered as stable.

Table 5. Coefficient of variation (CV%) for grain yield (GY) and hectolitre weight (HLW), and group of stability under organic (ORG) and conventional (CONV) system, as average of 3 years

Cultivar	GY (CV%)				HLW (CV%)			
	ORG	Group of stability	CONV	Group of stability	ORG	Group of stability	CONV	Group of stability
Glosa	20.9	I	33.6	III	1.5	III	4.8	II
Izvor	30.5	IV	36.5	III	4.0	IV	4.6	IV
Miranda	19.7	I	34.5	I	2.6	IV	3.2	III
Pajura	26.5	II	37.2	I	1.2	I	3.2	I
Pitar	19.0	III	40.0	II	0.9	I	2.3	I
Ursita	16.0	I	40.9	IV	1.6	I	3.1	I
Şimnic 60	21.7	III	35.2	I	1.4	III	2.3	I
Adelina	30.7	IV	38.9	II	5.4	IV	6.6	IV
Otilia	20.9	I	35.3	III	2.2	III	5.5	IV
Bezostaia	28.7	IV	39.9	IV	2.3	I	3.3	I
Average	23.5		37.2		2.3		3.9	

Our data showed that, for grain yield, Glosa, Miranda, Ursita and Otilia cultivars (placed in group I) were stable in organic production system, and Pajura, Miranda and Şimnic 60 cultivars were stable in conventional system.

The stable cultivars for hectolitre weight were Pajura, Pitar, Ursita and Bezostaia in organic system and also, Pajura, Pitar, Ursita, Şimnic 60 and Bezostaia in conventional system (Table 5).

Therefore, we could identify that Miranda cultivar performed the highest and stable yields in both conventional and organic systems. Thus, the tested hypothesis can be corroborated with our results. Miti (2007) reported that when G x E interaction effect is non-significant, the genotypes are stable across the environments and a significant G x E indicates that selections from one environment may often perform differently in another and the genotype is not stable across the environments.

The Romanian Grading Manual (CNGSC, 2017) which governs the buying and selling operations for wheat (grading of quality), sets a minimum value of 78 kg/hl for Grade 1, while Grades 2 and 3 must exceed 75 and 72 kg/hl, respectively. Lower grades result in a substantial economic loss for farmers.

In our study, the most cultivars fulfilled the requirements for Grade 2 and 3, and the percentage of cases below the 72 kg/hl limit varied from 0 to 66.7% (Table 6). In organic system, the most cases with values below the limit of 72 kg/hl (with non bakery value) were registered for Izvor and Şimnic 60 (66.7%). Only the Miranda cultivar had all cases (100%) with values in non bakery grade (below the Grade 3). The Pajura was the only cultivar with all cases in Grade 3.

In conventional system only the Izvor cultivar had the most cases below the Grade 3 (66.7%) with non bakery values, and Pitar was the only variety with 33.3% of cases in the first degree of quality (≥78 kg/hl).

In another study conducted at NARDI Fundulea, Marinciu et al. (2021) reported higher values of this indicator for most hybrids studied by us, probably due to site with high natural fertility. In contrast to our results, they also showed and that Izvor cultivar had highest average and lowest frequency of lower grades in different management system.

Table 6. Hectolitre weight (HLW) - frequency of grades, under organic (ORG) and conventional (CONV) system

Cultivar	ORG				CONV			
	% cases belonging to:				% cases belonging to:			
	Grade 1 (≥78 kg/hl)	Grade 2 (≥75, <78 kg/hl)	Grade 3 (≥72, <75 kg/hl)	Non bakery value (<72 kg/hl)	Grade 1 (≥78 kg/hl)	Grade 2 (≥75, <78 kg/hl)	Grade 3 (≥72, <75 kg/hl)	Non bakery value (<72 kg/hl)
Glosa	0	0	66.7	33.3	0	33.3	66.7	0
Izvor	0	0	33.3	66.7	0	0	33.3	66.7
Miranda	0	0	0	100	0	0	66.7	33.3
Pajura	0	0	100	0	0	33.3	66.7	0
Pitar	0	33.3	66.7	0	33.3	33.3	33.3	0
Ursita	0	33.3	66.7	0	0	33.3	66.7	0
Şimnic 60	0	0	33.3	66.7	0	33.3	66.7	0
Adelina	0	33.3	33.3	33.3	0	33.3	33.3	33.3
Otilia	0	0	66.7	33.3	0	33.3	33.3	33.3
Bezostaia	0	33.3	33.3	33.3	0	66.7	33.3	0

CONCLUSIONS

On average for the study period, the grain yield of wheat in the organic production system was by 35% lower than that achieved in the conventional production system. Hectolitre weight was also, affected by production system showing in the organic system values by 2% lower than in the conventional system.

Grain yield and hectolitre weight differences between the production systems were especially large in 2020 and 2021 due to higher precipitation from these years.

Based on the yield stability, Glosa, Miranda, Ursita and Otilia were most stable cultivars in organic production system from the central part of Oltenia area, while the cultivars Miranda, Pajura and Şimnic 60 were well adapted for best seed yield in conventional system. Thus, the cultivar Miranda was more stable than the other studied cultivars under these two production systems.

On average most cultivars fulfilled the requirements for Grades 2 and 3, but the percentage of cases below the 72 kg/hl (non bakery value) limit varied from 0 to 66.7% in both production systems. Only Miranda cultivar had all cases with non bakery values (below the Grade 3) in organic system.

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