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Research Article

Evaluation of the performance of some Romanian barley genotypes under organic agriculture conditions in South-West Romania

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Abstract

The purpose of this research was to assess certain agronomic traits (grain yield, test weight and protein content) of ten Romanian barley genotypes in order to identify the most suitable genotypes for organic agricultural system. Field experiments were performed for three years under organic culture conditions at Agricultural Research and Development Station (SCDA) Șimnic, Craiova, Dolj County. ANOVA results have showed significant effects of genotype and experimental year on all studied traits and also significant effects of genotype x year interaction on test weight and protein content. On average, the 'Gabriela' variety registered the highest grain yield (4.68 t ha^{-1}), this variety being the most stable (CV 19.87%). The 'DH 375-4' line had the highest test weight (65.63 kg hl^{-1}), and the 'DH 424-1' line had the highest protein content (10.51%). The plant breeders may use these genotypes depending on the referred direction by means of the breeding program (malt or feed).

Keywords: grain yield; *Hordeum vulgare*; malt; protein content; test weight

Introduction

The organic agriculture is a production system combining tradition, innovation and science to the benefit of humans and environment, based on cultivating genotypes adapted to the local pedo-climatic conditions and whose products are required on the market (Voica and Lazăr, 2021). This type of agriculture is encouraged by the consumers whose behaviour has changed during the last years, as they have become more aware of what they are consuming and have redirected their attention to healthier products that offer them a balanced diet. Also, the farmers have realized the opportunity to obtain better prices on the market place with organic products.

At the European Union level, the area meant for the organic agriculture have reached 14.7 million hectares in 2020 and the countries with the highest share of organic land are France, Spain, Italy and Germany

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(EUROSTAT, 2020). In Romania, although the area registered in organic agriculture represents only 3% of the total agricultural area, we see annual increases, reaching approximately 469 thousand ha in 2020. In Dolj County, the area cultivated with organic agriculture was 4.8 thousand hectares (MARD, 2020).

Cereals are crop plants that play an important role in ensuring global food security, therefore, the transition to sustainable agriculture by reducing chemical inputs is a challenge (Le Campion *et al.*, 2020).

Barley (*Hordeum vulgare* L.) is one of the important cereals for agriculture, being the fourth cereal worldwide after wheat, corn and rice, with 5.1 million hectares cultivated, and in Romania ranks third among cereals, with an area of 445 thousand hectares (FAOSTAT, 2020). Barley grains are mainly used as feed and as a malt source in beer industry. Because of their richness in functional ingredients, barley grains and the malt have gained renewed attention worldwide, being used more and more in obtaining processed foods (bread, pearl barley, soups, coffee substitutes, etc.). Barley grains contain soluble and insoluble dietary fiber, proteins, phenolic compounds, minerals, vitamin E, B-complex vitamins, providing a balanced diet (Madhujith *et al.*, 2006; Badea and Wijekoon, 2021). On the other hand, the content of beta-glucans and arabinoxylans (major components of barley fibre) has benefits on decreasing the risk of type II diabetes, cancer or coronary heart diseases (Gangopadhyay *et al.*, 2015; Martinez-Subira *et al.*, 2021; La geng *et al.*, 2022).

Organic agriculture system is fundamentally different from the conventional agriculture system, having greater requirements on production; this is why the variety idiotype is different. Thus, in order to obtain high and stable yields, the varieties suitable to the organic crop system should have the following traits: a better developed root system, an efficient use of the soil nutrients, competitiveness against weeds and tolerance for biotic and abiotic factors (Lammerts van Bueren *et al.*, 2002). Besides to assure high and stable yield, barley should also meet certain quality criteria. In order to satisfy the requirements suitable to malt industry, barley grains should have low protein content (between 9.5% and 11.5%), but for feed or food, they should have high protein content (Roman *et al.*, 2015). The test weight or hectolitre weight is another quality indicator, depending on which the quality groups are established both for malt barley and for feed barley (CNGSC, 2017). Since the relation between yield and quality is generally negative (Kizilgeci *et al.*, 2018), researchers recommend having moderate balance between these traits.

Dolj is an agricultural area placed in South-West Romania belonging to the temperate climate zone with Mediterranean influences, characterised by the variability of climatic conditions. Previous studies show that drought and heat are the main abiotic stress factors in this area that lower the yield of agricultural crops (Urechean *et al.*, 2019; Bonea and Urechean, 2020). In order to increase the barley productivity in this area, the barley varieties meant for ecological agriculture should bear both the unfavourable crop conditions (lack of fertilizers, of pesticides) and the hydric and thermic stress.

Assessing the performances of the current autochthonous varieties of winter barley in an organic crop system, within the climatic changes, allows the identification of some productive genotypes able to provide the accomplishment of a raw material equivalent to the European quality standards according to the Grading Manual for Consumer Seeds (CNGSC, 2017).

The destination and the technological quality of the final product (malt or feed) are decisively influenced by the variety, the environment and the applied technology (Voinea, 2021). The study of the G x E interaction makes possible the differential classification of the genotype between environments (Yan *et al.*, 2000). There is very little research regarding the barley performance in the organic crop system, especially in Romania. Therefore, the purpose of this research was to compare certain agronomical traits of Romanian barley genotypes concerning their performance to organic agriculture and to identify the genotypes the most suitable to this agriculture system.

Materials and Methods

Experimental procedures

Field experiments were achieved during 2019-2021 at Agricultural Research and Development Station (SCDA) Şimnic within an organic crop system. The tested biologic material consisted of ten Romanian genotypes of winter barley: three varieties obtained from different germplasm combinations by pedigree method ('Andreea', 'Artemis') and by *bulbosum* method ('Gabriela') (Vasilescu *et al.*, 2022) and seven breeding lines ('DH 424-1', 'DH 409-13', 'DH 375-4', 'DH 425-4', 'F 8-106-10', 'DH 315-10' and 'DH 386-1') created and owned by the National Agricultural Research and Development Institute (INCDA) Fundulea, Romania (Table 1).

These genotypes were placed in a comparative culture according to the randomized blocks method in three repetitions, on reddish preluvosoil, with the pH in water of 5.7-6.9 and with a humus content of 1.8%. The previous crop was peas for all experimental years. Sowing was performed on 18.10.2018, on 21.10.2019 and on 30.10.2020, and the harvesting was performed on 28.06.2019, on 29.06.2020 and on 14.07.2021. According to the rules of organic agriculture, no fertilizers or synthesis pesticides were used (CR, 2007).

Table 1. Description of tested varieties and breeding lines

Name of variety	Year of registration	Row type	Breeding method	Genealogy
'Andreea'	1994	2	pedigree	(Egmond x Griviţa)
'Artemis'	2012	2	pedigree	(Obruk 86 x Andra)
'Gabriela'	2017	2	*bulbosum*	[NS 525 x (Azuga x Fundulea 1328-69)]
'DH 424-1'	-	6	double haploid line	under testing at INCDA Fundulea
'DH 409-13'	-	6	double haploid line	under testing at INCDA Fundulea
'DH 375-4'	-	2	double haploid line	under testing at INCDA Fundulea
'DH 425-4'	-	2	double haploid line	under testing at INCDA Fundulea
'F 8-106-10'	-	2	line	under testing at INCDA Fundulea
'DH 315-10'	-	6	double haploid line	under testing at INCDA Fundulea
'DH 386-1'	-	2	double haploid line	under testing at INCDA Fundulea

Experimental measurements

The following agronomical traits were determined: grain yield, test weight and protein content. The grain yield per hectare was determined by harvesting every plot, weighing and converting to hectare in tones, then by adjusting to 14% humidity. The test weight (or hectolitre weight) and the protein content were determined using the NIR System Infratec 1225 Grain Analyzer.

Climatic conditions

The precipitation and temperature data were collected from Weather Station Craiova.The climatic conditions during the experimental years 2018-2021 highlighted differences from one year to another both regarding the amount and the distribution of monthly rainfall and the monthly average temperatures (Figures 1 and 2).The rainfall was below the multiannual average with -137.8 mm in the agricultural year 2018-2019, with -114.3 mm in the agricultural year 2019-2020 and with -8 mm in the agricultural year 2020-2021. The agricultural year 2018-2019 was the most droughty year, as the highest deficits of rainfall were registered in October (-44.5 mm), February (-22.8 mm), May (-34.9 mm), August (-39.9 mm) and September (-42.4 mm). In the agricultural year 2019-2020, the highest deficits of rainfall were registered in December (-40.3 mm), April (-41.5 mm), August (-41.6 mm) and September (-27.6 mm), and in 2020-2021, there were high deficits in November (-37.9 mm), February (-18.4 mm), July (-41.5 mm), August (-35.9 mm) and September (-30.7 mm).The average monthly temperatures in the experimental years (2018-2021) were over the multiannual average with +1.83°C in the agricultural year 2018-2019, with +0.6°C in 2019-2020 and with +1.4°C in 2020-2021. During all the experimenting years, we noticed a tendency of warming since autumn, as the average monthly temperatures overcame the multiannual average, except for the months of November and May in the agricultural year 2018-2020, the month of May in the year 2019-2020, and the months of March and May in the year 2020-2021.

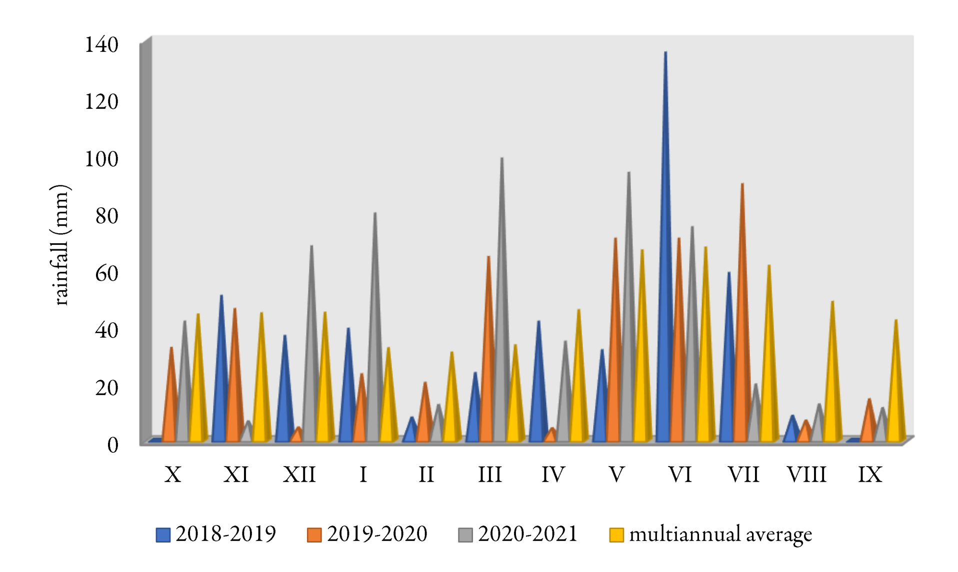

Figure 1. Monthly rainfall (mm) registered at ARDS Şimnic (2018-2021)

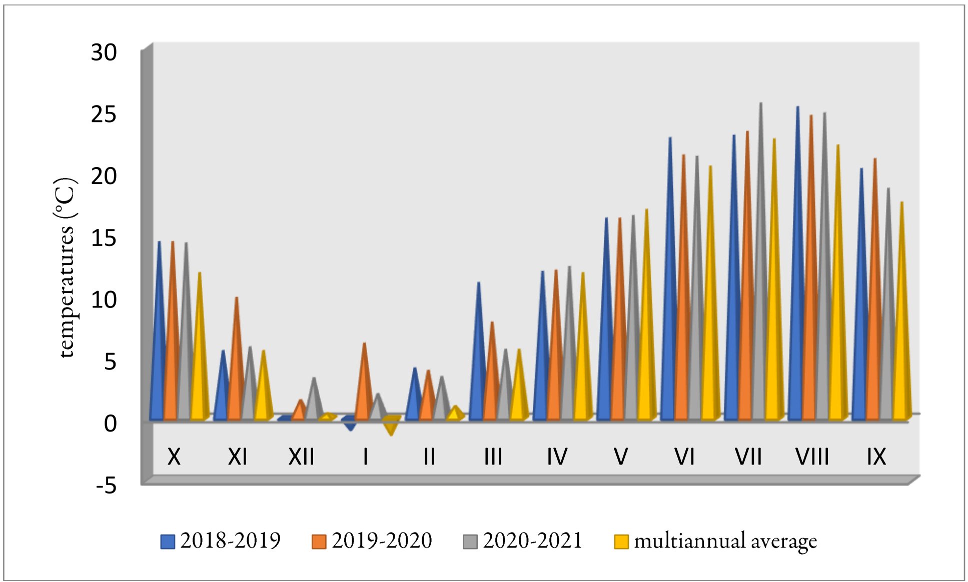

Figure 2. The average monthly temperatures (°C) registered at ARDS Şimnic (2018-2021)

Statistical analyses

The obtained experimental data were processed by the analysis of variance (two-way ANOVA) by using Excel Data Analysis. The following descriptive statistics were used: average, maximum, minimum, standard deviation and variation coefficient. The CV% estimates were categorized as very high (CV≥21%), high (15%≤CV≤21%), moderate (10%<CV≤15%) and low (CV<10%) according to Gomes (2009). The statistical data were expressed in tables and figures.

The differences between genotypes, years and their interactions were separated and the comparison was accomplished by using the Duncan Multiple Range Test at $p \leq 0.05$, and the association between the studied traits was estimated by the simple correlation method according to Botu and Botu (2003).

Results

The analysis of variance for the grain yield, test weight and protein content traits showed that the experimental factors and their interaction had different influences on these traits (Table 2). Thus, three studied traits were significantly influenced by experimental factors genotype and year but only test weight and protein content were significantly influenced by the genotype x year interaction.

Table 2. Sum squares of ANOVA for studied traits

Source of variation	Sum of squares		
	Grain yield (t ha^{-1})	Test weight (kg hl^{-1})	Protein content (%)
Genotype (G)	54.72*	446.27*	7.29*
Year (Y)	66.23*	1121.54*	78.49*
Interaction (GxY)	8.82^{ns}	130.76*	16.96*
Error	18.88	218.83	11.16

* - significant at 0.05% level; ns - non-significant

Grain yield

Fluctuations in the individual values of barley genotypes tested during the three experimental years, together with variability indicators (average, maximum, minimum and variation coefficient) are presented in Table 3 (for grain yield), Table 4 (for test weight) and in table 5 (for protein content). The different climatic conditions during the experimental years led to getting different yields, so that the grain yield in 2020 was significantly higher than in 2019 and 2021. The yield average of the tested genotypes in 2020 (4.64 t ha^{-1}) was significantly higher compared to 2019 (3.20 t ha^{-1}) and 2021 (2.60 t ha^{-1}). Among the tested genotypes, 'Gabriela' variety registered the highest grain yield (4.68 t ha^{-1}) which was at par with 'Artemis' variety (4.14 t ha^{-1}). The lowest yield within the organic system was obtained by the 'DH 375-4' line (1.51t ha^{-1}). Also, the 'Gabriela' variety recorded the highest yields every year

The variability of the grain yields across the years was high and very high, as the variation coefficients varied between 19.87% ('Gabriela') and 48.15% ('DH 409-13') (Table 3).

Table 3. Grain yield (t ha^{-1}) of barley genotypes and indicators of variability

Genotype (G)	Year (Y)			Average factor G	Maximum	Minimum	CV (%)
	2019	2020	2021				
'DH 424-1'	3.20 ^{b}	3.92 ^{d}	2.27 ^{d}	3.13 c	3.92	2.27	26.52
'DH 409-13'	3.67 ^{ab}	4.53 ^{cd}	1.51 e	3.24 c	4.53	1.51	48.15
'Andreea'	3.30 ^{b}	4.72 ^{bc}	2.53 ^{cd}	3.52 bc	4.72	2.53	31.53
'Artemis'	3.69 ^{ab}	5.34 ^{ab}	3.39 ^{b}	4.14 ab	5.34	3.39	25.36
'Gabriela'	4.16 ^{a}	5.75 ^{a}	4.13 ^{a}	4.68 a	5.75	4.13	19.87
'DH 375-4'	1.46 ^{c}	2.10 ^{e}	0.98 ^{e}	1.51 d	2.10	0.98	37.75
'DH 425-4'	2.95 ^{b}	4.71 ^{bc}	3.07 ^{bc}	3.58 bc	4.71	2.95	27.37
'F 8-106-10'	3.38 ^{b}	5.26 ^{abc}	2.87 ^{bcd}	3.84 bc	5.26	2.87	32.81
'DH 315-10'	3.15 ^{b}	5.04 ^{abc}	2.50 ^{cd}	3.56 bc	5.04	2.50	37.08
'DH 386-1'	3.01 ^{b}	5.06 ^{abc}	2.75 ^{bcd}	3.61 bc	5.06	2.75	35.18
Average factor Y	3.20 B	4.64 A	2.60 B	3.48	4.64	2.60	32.26

Averages followed by different letters under the same factor or in interactions differ significantly ($p \leq 0.05$); CV% = Coefficient of variation

The proportion of the explained sum of squares showed that the variability of the grain yield was induced, in the first place, by the effect of the year (44%), then by the effect of the genotype (37%) and in the end by the effect of the GxY interaction (13%) (Figure 3).

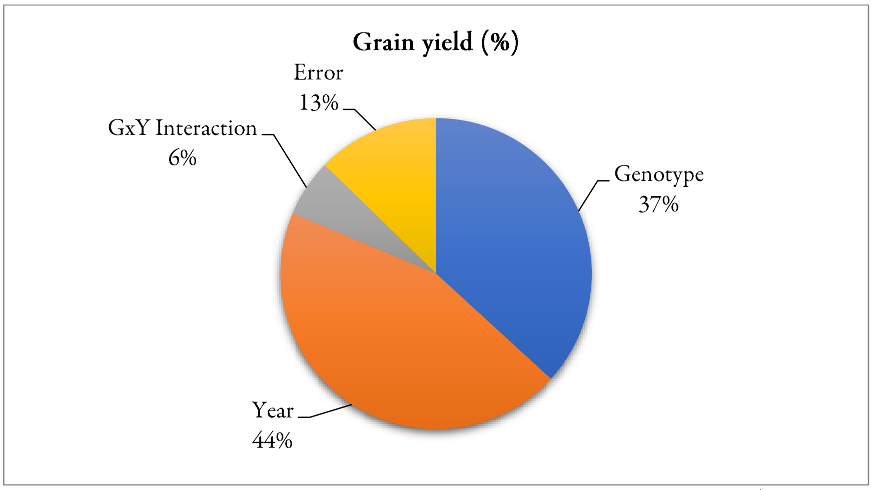

Figure 3. Share of genotype, year and their interaction in the variation of grain yield (according to Anova: Two-Factor with Replication calculation)

Test weight

The test weight in 2021 (64.12 kg hl^{-1}) was significantly higher than in 2020 (60.85 kg hl^{-1}) and 2019 (55.55 kg hl^{-1}). Among the tested genotypes, the 'DH 375-4' line registered the highest test weight (65.63 kg hl^{-1}), followed by 'DH 315-10' (61.1 kg hl^{-1}), 'DH 386-1' (61.08 kg hl^{-1}) and 'Andreea' (60.89 kg hl^{-1}), while the lowest test weight was obtained by the 'DH 424-1' line (56.84 kg hl^{-1}). Every year, the highest values of test weight were obtained by the 'DH 375-4' line (67.17 kg hl^{-1} in 2020; 66.17 kg hl^{-1} in 2021 and 63.57 kg hl^{-1} in 2019). The variability of the test weight over the years was low, as the variation coefficients was between 2.83% ('DH 375-4') and 9.99% ('Gabriela') (Table 4).

The proportion of the explained sum of squares showed that the variation of the test weight was mainly determined by the year effect (59%) followed by the genotype effect (23%) and then by the effect of the GxY interaction (7%) (Figure 4).

Table 4. Test weight (kg hl^{-1}) of barley genotypes and indicators of variability

Genotype (G)	Year (Y)			Average factor G	Maximum	Minimum	CV (%)
	2019	2020	2021				
'DH 424-1'	51.60 ^{d}	58.15 ^{d}	60.77 ^{c}	56.84 d	60.77	51.60	8.30
'DH 409-13'	52.63 ^{cd}	58.30 ^{d}	63.87 ^{ab}	58.27 cd	63.87	52.63	9.64
'Andreea'	56.80 ^{b}	61.17 ^{bc}	64.70 ^{a}	60.89 b	64.70	56.80	6.50
'Artemis'	54.67 ^{bc}	60.20 ^{bcd}	65.43 ^{a}	60.10 bc	65.43	54.67	8.95
'Gabriela'	53.13 ^{cd}	61.50 ^{bc}	64.70 ^{a}	59.78 bc	64.70	53.13	9.99
'DH 375-4'	63.57 ^{a}	67.17 ^{a}	66.17 ^{a}	65.63 a	67.17	63.57	2.83
'DH 425-4'	53.40 ^{cd}	59.43 ^{cd}	64.47 ^{a}	59.10 bcd	64.47	53.40	9.37
'F 8-106-10'	56.10 ^{b}	59.03 ^{cd}	61.70 ^{bc}	58.94 bcd	61.70	56.10	4.75
'DH 315-10'	56.83 ^{b}	62.40 ^{b}	64.07 ^{a}	61.10 b	64.07	56.83	6.20
'DH 386-1'	56.77 ^{b}	61.17 ^{bc}	65.30 ^{a}	61.08 b	65.30	56.77	6.99
Average factor Y	55.55 C	60.85 B	64.12 A	60.17	64.12	55.55	7.35

Averages followed by different letters under the same factor or in interactions differ significantly ($p \le 0.05$); CV% = Coefficient of variation

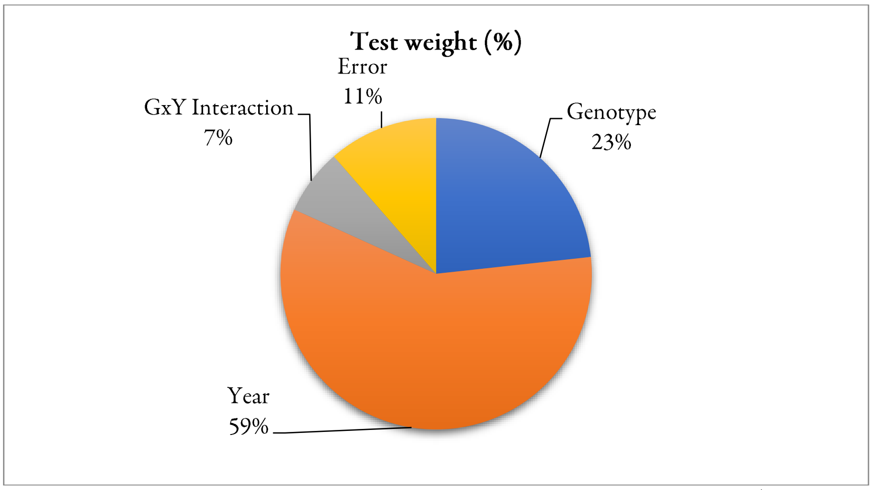

Figure 4. Share of genotype, year and their interaction in the variation of test weight (according to Anova: Two-Factor with Replication calculation)

Protein content

The protein content in barley grains was significantly higher in 2021 (11.11%) compared to 2019 (10.24%) and 2020 (8.84%). Among the studied genotypes, the 'DH 424-1' line (10.51 %) had the highest protein content, which was at par with 'DH 386-1' line (10.46%),'DH 375-4' (10.18%), 'Artemis' (10.12%), 'F 8-106-10' (10.10%), 'DH 315-10' (10.08%) and 'DH 409-13' (10.01%). The 'Andreea' variety (9.48%) had the lowest protein content. In 2021, the highest protein content was recorded by the 'DH 375-4' line (12.27%); in 2020 by the 'DH 386-1' line (9.20%) and the 'DH 4254' line (9.17%); in 2019 by the 'DH 424-1' line (11.13%).

For the protein content there was a variability from low to high, as the variation coefficients was between 7.15% ('Gabriela') and 17.9% ('DH 375-4') (Table 5).

The proportion of the explained sum of squares showed that this trait was mainly determined by the year which represented 69% of the content variation, while the GxY interaction and the genotype represented 15%, respectively 6% of the variation (Figure 5).

Table 5. Protein content (%) of barley genotypes and indicators of variability

Genotype (G)	Year (Y)			Average factor G	Maximum	Minimum	CV (%)
	2019	2020	2021				
'DH 424-1'	11.13 a	8.77 abc	11.63 b	10.51 a	11.63	8.77	15.08
'DH 409-13'	10.57 bc	8.57 bc	10.90 c	10.01 abcd	10.90	8.57	12.58
'Andreea'	10.07 cd	8.50 c	9.87 d	9.48 d	10.07	8.50	8.97
'Artemis'	10.90 ab	8.67 abc	10.80 c	10.12 abc	10.90	8.67	12.40
'Gabriela'	9.70 de	9.13 ab	10.53 c	9.79 cd	10.53	9.13	7.15
'DH 375-4'	9.23 e	9.03 abc	12.27 a	10.18 abc	12.27	9.03	17.9
'DH 425-4'	9.70 de	9.17 a	10.93 c	9.93 bcd	10.93	9.17	9.06
'F 8-106-10'	10.13 cd	8.57 bc	11.60 b	10.10 abc	11.60	8.57	15.04
'DH 315-10'	10.53 bc	8.83 abc	10.87 c	10.08 abc	10.87	8.83	10.80
'DH 386-1'	10.47 bc	9.20 a	11.70 b	10.46 ab	11.70	9.20	10.60
Average factor Y	10.24 B	8.84 C	11.11 A	10.06	11.11	8.84	11.40

Averages followed by different letters under the same factor or in interactions differ significantly ($p \leq 0.05$); CV% = Coefficient of variation

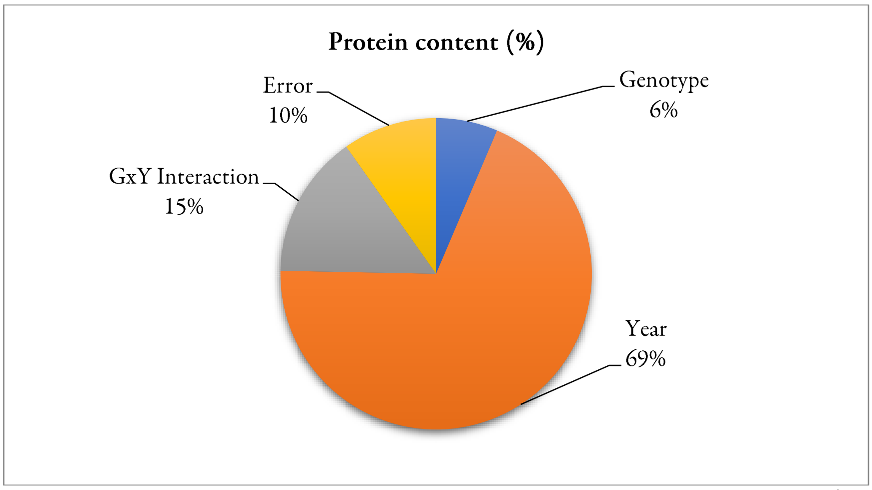

Figure 5. Share of genotype, year and their interaction in the variation of protein content (according to Anova: Two-Factor with Replication calculation)

Interrelationship among evaluated traits

Table 6 presents the correlation coefficients among the studied traits. There was only one significant, but negative correlation (r=-0.465**) between grain yield and test weight. The correlation between yield and protein content was negative but insignificant.

Table 6. Coefficients of correlation between grain yield and quality traits (n = 90)

Trait	Grain yield	Test weight	Protein content
Grain yield	1		
Test weight	-0.465**	1	
Protein content	-0.108^{ns}	0.097^{ns}	1

** Significant at the 0.01 level; ns – non-significant

Discussion

The recommendation of the most suitable varieties for the organic agriculture should be based on the evaluation of these varieties especially concerning the traits that are important for the organic farmers and processors (Przystalski *et al.*, 2008). Plant breeders make many efforts in order to bring to the market new barley varieties adapted for the less favourable conditions of organic agriculture, which should combine high yields with better grain quality. For this purpose, we need barley varieties which withstand the pressure of weeds, pests and the nutrient deficiency (Shelton and Tracy, 2016), and this is why many breeders (Przystalski *et al.*, 2008; Wolfe *et al.*, 2008) recommend the direct selection in organic conditions.

Our results regarding the proportion of the explained sum of squares (Figures 3, 4 and 5) showed that the experimental year was the determining factor of the variability of the yield (44%), the test weight (59%) and the protein content (69%). Therefore, the adaptation of barley genotypes and agronomic management to the variability of climatic conditions, as well as their impact on yield and yield quality are very important for barley breeding (Cammarano *et al.*, 2021).

According to Hossain *et al.* (2012) and Stupar *et al.* (2021), yield and quality traits are influenced by the weather conditions in critical stages, especially during flowering and the grain filling stage. Grain filling is influenced by the environment, leading to a difficult definition of the quality of a genotype and the duration of grain filling is poorly correlated to the grain weight and size (Coventry *et al.*, 2003). These findings are also confirmed by our results showing that the climatic variations from one year to another, the quantity and the uneven distribution of rainfall during the growing season led to significant variations of yields. Thus, the lack or insufficiency of rainfall during the germination-emergence stage in the agricultural years 2018-2019 and 2020-2021 (October, November) or during the flowering stage in 2019 (May) affected the number of emerged plants, the number of tillers plant and the number of grains, which has led to a decrease in plant density and, finally, a decrease in yields in these years. On the contrary, according to Koziara *et al.* (2008), the genetic conditions influence the achievement of some satisfying yields more than the habitat conditions and the applied agrotechnics; this is why it is very important to identify the varieties suitable for the organic agriculture for every crop area. In other studies (Dunăreanu *et al.*, 2021; Vasilescu *et al.*, 2020), different results were reported on the performance of barley genotypes, these differences being determined by genotype, applied technology, soil type and climatic conditions.

Thus, in the present study within the conditions of the organic system and on a reddish preluvosoil, the average of the obtained yields was 3.48 t ha^{-1}with -20.7%-54.9% smaller than the average of the Romanian genotypes obtained in conventional system in different locations. For example: in another study conducted in the same location but in a conventional system, Dunăreanu *et al.* (2021) reported an average of 5.40 t ha^{-1} for an assortment of six Romanian barley varieties; Vasilescu *et al.* (2020) reported an average yield of 5.37 t ha^{-1} on a cambic chernozem, 'Gabriela' and 'Artemis' varieties obtaining yields close to or higher than this average (5.85 t ha^{-1}, respectively 5.25 t ha^{-1}; and Voinea (2021) reported an average yield of 7.73 t ha^{-1} on a loamy vermic chernozem, 'Gabriela' and 'Artemis' varieties exceeding this average (7.87 t ha^{-1}, respectively 7.83 t ha^{-1}). On the other hand, the results obtained by Voica and Lazăr (2021) with eight Romanian barley genotypes in an organic system on luvosoil showed an average yield of 1.01 t ha^{-1}, with -70.9% lower than the average yield obtained in present study (3.84 t ha^{-1}), which indicates that the Dolj area is favourable for the organic barley crop.

Compared to the yields of some foreign barley genotypes in organic system, the results of previous studies (Legzdina *et al.*, 2013; Leistrumaite *et al.*, 2009) showed that the average of their yields (2.90 t ha^{-1}, respectively 3.35 t ha^{-1}) was lower than the yields average of the Romanian barley genotypes in present study (3.84 t ha^{-1}).

Barley is especially used for the industry of malt and for feed (Badea and Wijekoon, 2021; Roman *et al.*, 2015). The quality requirements that the grains should meet in order to be accepted for malt make the difference between the barley meant for malt and fodder (Hoyle *et al.*, 2020), as the price paid to the farmers for feed barley is smaller than the price for malt. According to the National Commission for Grading the Seeds for Consumption in Romania (CNGSC, 2017), these quality requirements include: organoleptic traits, test weight and impurity levels (broken grains, damaged grains, sprouted grains and other impurities). In order to be used for obtaining malt, the barley grains should have a test weight of minimum 63 kg hl^{-1}, respectively: group 1 (≥67 kg hl^{-1}), group 2 (≥65and<67 kg hl^{-1}) and group 3 (≥63 and <65 kg hl^{-1}). Therefore, the test weights from 2021 (except for the 'DH 424-1' and 'F 8-106-10' lines) and the test weights from 2019 and 2020 for the 'DH 375-4' line were higher than 63 kg hl^{-1}, these can be directed to the malt industry.

Also, for use as feed, barley grains are classified into two quality groups: group 1 (≥ 62 kg hl^{-1}) and group 2 (≥60 and<62 kg hl^{-1}), therefore only the test weight achieved in 2020 of five barley genotypes ('Andreea', 'Artemis', 'Gabriela', 'DH 315-10'and 'DH 386-1') and in 2021 by two genotypes ('DH 424-1' and 'F 8-106-10') fall within these limits.

The highest test weights were accomplished in 2021 when the plants benefited in June (grain-filling stage) from rainfall and temperatures more favourable than in 2019 or 2020 when the temperatures were higher. According to Loffler *et al.* (1985), during the grain filling stage, about 93% of the nitrogen supplies change into grains. The drought and especially the thermic stress during the grain filling stage determine the plant senescence, the diminution of the grain filling stage (Samarah *et al.*, 2009), the diminution of the starch synthesis and, implicitly, the decrease of the grain size (Martinez-Subira *et al.*, 2021).

The results obtained in this study at SCDA Şimnic were compared with those in the literature for the conventional system, where Dunăreanu *et al.* (2021) reported an average test weight of 58.16 kg hl^{-1} for six

Romanian barley genotypes cultivated at the same location. Also, Voinea (2021) reported an average test weight of 54.8 kg hl^{-1} for eleven Romanian barley genotypes cultivated at SCDA Mărculești, which means that this trait is more stable, being less influenced by the crop system and pedo-climatic conditions.

The presence of a high GxY interaction in determining the test weight makes the selection of the genotypes with the desired quality (malt or feed) more complicated, as a genotype has a high-test weight in a year and a low-test weight in a different year. However, the 'DH 375-4' line had the highest (>63 kg hl^{-1}) and the most stable test weight (CV = 2.83%) over the three years.

The protein content is a quality indicator on which the malt production depends. For malt barley, the European standard stipulates low protein content, between 9.5-11.5% (Vasilescu *et al.*, 2019). A protein content lower than 9.5% may compromise the enzyme levels and a protein content higher than 13% may lead to a mild change of the endosperm and, thus, to a reduced level of malt extract (Izydorczyk and Edney, 2017). In order to be used as feed or for food, the protein content should be as high as possible (Roman *et al.*, 2015). The results of the present study showed that the values of the protein content were lower than 9.5% in 2020 for all tested genotypes, as well in 2019 for the 'DH 375-4' line. In 2021, some of the lines ('DH 424-1', 'F 8-106-10' and 'DH 386-1') reached protein content over 11.5%, therefore these genotypes are recommended for obtaining feed or food. It has been observed that the presence of a high GxY interaction in determining the protein content makes the genotype selection with the desired quality (malt or feed) more complicated.

Regarding the influence of the climatic conditions, it was observed that there was a higher average protein content in 2021 than in 2019 and 2020. It is interesting that the protein content was not negatively influenced by the high temperatures in grain filling stage in 2019 and 2020, as it was mentioned in literature (Passarela *et al.*, 2002), and the difference between the protein content in these two years is probably given by the abundant rainfall from June 2019. According to Wang *et al.* (2007), the abundant rainfall in the grain filling stage may extend the life of the leaves, favouring thus the assimilation and translocation of carbohydrates to the detriment of proteins. According to Chen *et al.* (2006), the protein content in barley grains is affected by the rate, the applying time of the nitrogen fertilizers and also by the nitrogen available in the soil.

Identifying the correlations between the agronomic traits is very important for the breeding activity, in order to facilitate the selection process and the shortening of the time for obtaining new varieties (Boanta *et al.*, 2020). The results of this study showed a strongly negative correlation between the grain yield and the test weight. In the literature we did not find results regarding the relationship between these traits under the organic system, but under the conventional system, Kizilgeci (2018) and Ozturk (2020) reported significant positive correlations between yield and test weight.

Conclusions

The major variation of yield, test weight and protein content in barley grains was caused by the environment across the different field trials of growing seasons, showing that the temperatures, the quantity and the distribution of rainfall have great influence on the barley crop in the organic system. The genotype with the highest and the most stable yield in the organic system was the 'Gabriela' variety. The 'DH 375-4' line had the highest test weight, and the 'DH 424-1' line had the highest protein content. The only genotype with a test weight acceptable for the malt industry in all experimental years was the 'DH 375-4' line, but this genotype had the lowest yield. The plant breeders may use these genotypes depending on the direction they want to follow: malt (high test weight and low protein content) or feed, food (high yield). The correlations between yield and the quality traits (test weight and protein content) were negative, thus the improvement of the barley genotypes for higher yield and quality in the organic system need a moderate balance between these traits.

Authors' Contributions

Conceptualization: FC and DB; Organized the data and performed the statistical analysis: MB, DB and FC; Conducting the field experiment and measurements: ICD and FC; Writing – original draft: FC and DB; Writing - review and editing: MC; Supervision: 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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