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Correlation between qualitative-technological traits and grain yield in two-row barley varieties

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Abstract. *The aim of this paper was to determine the correlation between qualitative-technological traits and grain yield, as well as, the variability of these properties in two-row barley varieties. The experiment was conducted during the period of 2012/2013 and 2013/2014 on the research fields of the Faculty of Agriculture, in two different locations in the Republic of Macedonia, Ovche Pole and Strumica. The total numbers of 21 genotypes were used as research material, of which 5 were Macedonian, 2 were Croatian, 2 were Serbian and 12 genotypes originate from Bulgaria. The following qualitative-technological traits were analyzed: protein content, uniformity of I class grains, weight of 1 000 grains, hectoliter mass, water sensitivity and soaking degree. In both experimental years, the average values for grain yield for tested genotypes in Strumica location were higher, compared with genotypes examined in Ovche Pole location. In both locations significant and positive correlation was established between the grain yield and weight of 1 000 grains. Using the principle component analysis, it was determined that as far as qualitative traits and grain yield were concerned, two main components with cumulative percent of variation of 69.63% were identified for genotypes analyzed in Ovche Pole. Also for tested genotypes grown in Strumica were obtained two main components with cumulative percent of variation of 59.75%. The most suitable for growing in Ovche Pole location were the genotypes: Perun, Lardeya, Asparuh, Sajra and Odisej and for Strumica location genotypes: Hit, Line 1, Lardeya, Kuber, Sajra and Devinija.*

Keywords: barley genotypes, grain yield, grain quality, correlation

Introduction

Barley (*Hordeum vulgare* L.) is one of the oldest crops which has significant role in development of agriculture (Hosin Babaiy et al., 2011; Ullrich, 2011). It was considered among four most significant cereals, right after wheat, rice and corn (Kanbar, 2011; Zaefizadeh et al., 2011; Biel and Jacyno, 2013). This crop has wide distribution area, foremost by its adaptability and possibility to be cultivated in different ecological and weather conditions (Lalevic and Biberdzic, 2012; Khajavi et al., 2014). Primarily, barley is used in production of malt and beer, but is main component in animal feed as well.

Increasing the yield is main goal of every cultivated crop and yield's importance is related to the economic benefit the producer expects. The yield is a function of genetic potential of the variety, external conditions in which the crop is grown, applied technology and the interaction of all these factors (Alam et al., 2007; Abad et al., 2013). Increasing the yield is a basic task of breeding program of barley and aim in improving the existing genetic potential through creating more favorable conditions for optimum realization of existing potential or creation of new varieties whose yield will be higher than the yield of the existing varieties (Johnson and Aksel, 1959; Yau and Hamblin, 1994; Mersinkov, 2000).

Another main task in selection process, not just the yield itself, is to obtain high quality of the grain too. The following are the main qualitative-technological traits of barley which influence the grain quality meant for production of beer: hectoliter mass, grains uniformity, protein and carbohydrates content (Valcheva, 2000; Hayesa et al., 2004; Valcheva et al., 2011). High quality barley cultivars used in beer industry contain: 10 – 11% of protein, 63-65% of carbohydrates, grains uniformity over 85%, 1 000 grains weight of 40 – 46 g at grain moisture of 13 – 14%, soaking degree 42 – 47% and low water sensitivity (Manchev, 1975).

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Many papers were published containing research on determination of correlation coefficients among grain yield and its components (Akhtar et al., 2011; Dyulgerova, 2012; Markova Ruzdik et al., 2015). Also in many papers was presented the correlation between grain yield and certain qualitative-technological barley traits. No matter obtained results are not unanimous, still determination of correlation links between indicated properties have great significance in barley's selection program since they provide possibility to predict the influence of one trait over another. In Valcheva and Vulchev's (2012) research, high positive significant correlation was determined between grains uniformity I class and 1 000 grains weight. On the other side, grain yield was in negative correlation with protein content (Mersinkov et al., 1985; Stošović et al., 2010; Valcheva and Vulchev 2012).

One of the most frequent in use analysis which provides an overlook on the variation of tested traits in relation to the overall variation is principle component analysis (PCA). This analysis was applied for determination of the variability of barley's quantitative and qualitative-technological properties too. Valcheva and Vulchev's (2012) research, through the use of this analysis, contributed to obtain two main components with eigenvalue higher than 1.

This paper's aim was to determine the correlation between qualitative-technological traits and grain yield, as well as the variability of these properties using principle component analysis on two-row winter barley varieties.

Material and methods

Field trials were set up during 2012/2013 and 2013/2014 on Goce Delchev University's, Faculty of Agriculture trial fields, in two locations. The first one was Ovche Pole with altitude between 200 – 400 m, longitude 41°49'21.9" and latitude 21°59'03.9". The other locality was Strumica with 280 m altitude, longitude 41°26'32.0" and latitude 22°39'54.5". The total number of 21 genotypes were used as research material, of which 5 genotypes were from Macedonia (*Hit, Izvor, Egej, Line 1* and *Line* 2), 2 genotypes were from Croatia (*Zlatko* and *Rex*), 2 genotypes were from Serbia (*NS 525* and *NS 565)* and 12 genotypes were with Bulgarian origin (*Obzor, Perun, Emon, Lardeya, Orfej, Imeon, Zagorec, Asparuh, Kuber, Sajra, Devinija* and *Odisej*). The trials were set up in accordance to the random block system, in three repetitions for each of the genotypes and location. Plot size was 1 m^2, for each of the repetition. On each plot there were 500 seeds/m^2 planted into the seedbed. Sowing was performed by hand, on the same day for both locations. Field trials were realized by using standard barley soil/seed preparation. Pre-sowing soil preparation was conducted in suitable timing, in both testing years and in accordance with weather and soil conditions for both locations.

According to the classification of Filipovski et al. (1996), the both locations on which the trials were set up were under continental and sub-Mediterranean weather type. Figures 1 and 2 presented the weather characteristics of Ovche Pole and Strumica for the period in which testing were conducted, as well as long-term data for period of 2001 – 2011. The average monthly temperature values for Ovche Pole and Strumica locations didn't differ significantly, during the period of study. In both locations, the average temperatures were higher compared with the average temperatures from the long term period. On the other hand, Ovche Pole location was characterized by lower monthly precipitations, compared to Strumica in the period of study. According to weather conditions, Strumica location had better climate characteristics for growing the barley genotypes.

After harvest of each plot was finished, the grain yield of each genotype was calculated. Part of the qualitative properties were analyzed in the Laboratory for plant and environment protection of the Faculty of Agriculture, at "Goce Delchev" University in Shtip, Republic of Macedonia, while another part were analyzed at malt-technological laboratory in the Institute of Agriculture in Karnobat, Bulgaria. The following qualitative-technological barley traits were determined: protein content (%), grains uniformity of I class (%), weight of 1 000 grains (g), hectoliter mass (kg/hl), water sensitivity (%) and soaking degree (%). Protein content was determined by using the Kjeldahl (1883) method, as the rest of the qualitative and technological traits were determined in accordance to the EU convention for beer production (European Brewery Convention, 2003).

Obtained results were statistically analyzed by using statistical software (Stat Soft, 8.0). The correlation between qualitative-technological properties and grain yield was determined by using linear correlation (Singh and Chaudhary, 1985), with SSPS statistical package. In order to determine the variability of tested traits a multi variant analysis, principle component analysis was applied according to Mohammadi and Prasanna (2003).

Results and discussion

Table 1 contains the average values for grain yield and qualitative-technological traits examined in both years (2012/2014 and 2013/2014) in both locations. Average values for grain yield, in both experimental years for period of study were higher for tested genotypes in Strumica, as compared to the analyzed genotypes in Ovche Pole. That was probably consequence to the more favorable weather conditions in Strumica. In both locations, in first testing year, the average values for grain yield were higher compared to second experimental year. The coefficient of variability for this trait was the highest, compared to the other traits, in both locations. Protein content in barley seed is significant qualitative and technological

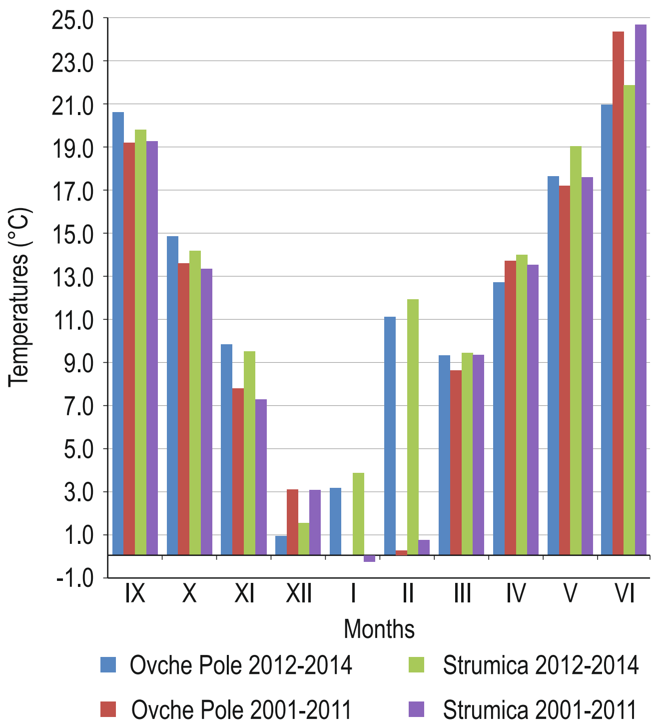

Figure 1. Average monthly temperatures (°C) for period of study and long-term average values in Ovche Pole and Strumica locations

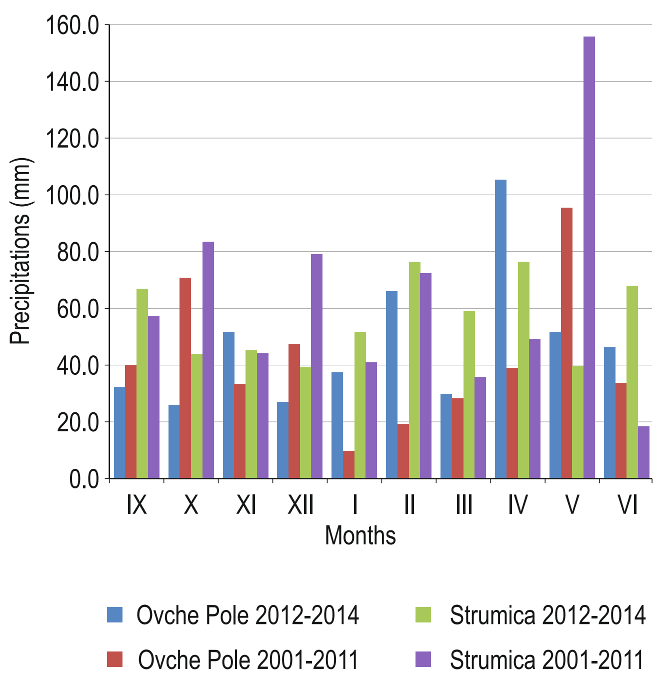

Figure 2. Monthly amount of precipitations (mm) for period of study and long-term period in Ovche Pole and Strumica locations

Table 1. Average values for examined traits for barley varieties in both localities for both years of study

Traits	Ovche Pole									
	2012 – 2013					2013 – 2014				
	Mean	Min.	Max.	$LSC_{0.05}$	CV	Mean	Min.	Max.	$LSC_{0.05}$	CV
Grain yield, kg/ha	5 004	3343	6450	2237.98	27.25	3559	3013	5023	1457.14	24.94
Protein content, %	14.35	12.61	15.91	0.09	0.38	14.58	12.43	18.00	0.61	2.55
Uniformity of I grain class, %	83.31	62.03	95.77	0.48	0.01	88.15	57.50	95.83	0.55	0.38
Weight of 1 000 grains, g	42.58	35.07	47.97	0.45	0.64	47.48	36.50	53.00	0.51	0.65
Hectoliter mass, kg/hl	59.31	54.90	62.60	0.08	0.07	55.76	50.38	60.52	0.09	0.09
Water sensitivity, %	30	8	46	4.34	8.87	68	51	80	6.50	30
Soaking degree, %	45.47	43.14	47.86	0.07	0.10	45.01	43.52	47.19	0.08	0.11
	Strumica									
	2012 – 2013					2013 – 2014				
Grain yield, kg/ha	5869	3797	6972	1738.04	18.05	3857	3018	5096	1498.83	23.68
Protein content, %	13.24	10.44	16.81	0.07	0.30	13.79	12.17	16.67	0.04	0.19
Uniformity of I grain class, %	84.24	62.83	93.50	0.49	0.32	77.62	50.77	90.50	0.47	0.37
Weight of 1 000 grains, g	42.11	35.33	48.33	2.39	3.43	41.93	35.50	46.00	5.59	8.09
Hectoliter mass, kg/hl	59.56	53.98	63.29	0.64	0.65	54.62	50.60	59.27	0.09	0.11
Water sensitivity, %	29	11	52	4.24	8.81	68	29	84	4.04	3.59
Soaking degree, %	45.22	43.22	47.38	0.10	0.14	46.11	44.43	48.12	0.07	0.10

Statistical significance at P<0.05

trait, especially for varieties used in beer industry. In many papers, the content of protein was between 11 – 12% (Manchev, 1975; Maleševic et al., 2010). According to Palmar (1990), varieties used in beer industry were favorable to have lower protein content. Gali and Brown (2000) had determined that protein content in the genotypes for production of beer should be between 8.5 – 12.5%. In our research, at genotypes in both locations, higher average values for protein content than 12% were obtained. The average values for protein content in both experimental years were higher in Ovche Pole location, compared to average values obtained for tested genotypes in Strumica. However, higher protein content in barley makes it suitable for animal feed production (Hunt, 1996). According to Manchev (1975), genotypes meant to be used in beer industry were favorable to have grain uniformity over 85%. This qualitative trait can perform a strong variation and its average values can be from 55.2% to 96.9% (Valcheva and Vulchev, 2005). The results from our research showed that the average values for this trait in both locations were within optimum limits for this characteristic presented by Valcheva and Vulchev (2005).

Weight of 1 000 grains is a property that has strong influence over barley's grain quality and is a function of grain size and its density. According to Manchev (1975), 1 000 grains weight in high-quality barley genotypes was between 40 – 46 g, while according to Maleševic et al. (2010) just around 40 g. According to Valcheva (2000) and Mersinkov (2000), average values for this characteristic can be 34.5 g – 59.5 g. No matter the average values for 1 000 grains weight for the genotypes analyzed in Ovche Pole were a little bit higher than the values obtained from the varieties tested in Strumica, still the average values from both locations were within optimum limits for this characteristic presented by Manchev (1975). Hectoliter mass is a significant grain quality parameter and is related to the size and grains fulfillment. In our research the values for this trait for the genotypes analyzed in Ovche Pole and Strumica were higher in the first experimental year compared to the second. Soaking degree in

Table 2. Linear correlation coefficient between qualitative-technological traits and grain yield in barley genotypes grown in Ovche Pole location

Traits	Protein content	Uniformity of I grains class	Weight of 1 000 grains	Hectoliter mass	Water sensitivity	Soaking degree	Grain yield
Protein content	1	0.461*	0.418	0.404	0.533*	0.003	0.498*
Uniformity of I grains class		1	0.858**	0.527*	0.601**	-0.308	0.653**
Weight of 1 000 grains			1	0.362	0.566**	-0.225	0.692**
Hectoliter mass				1	0.425	-0.351	0.368
Water sensitivity					1	-0.295	0.595**
Soaking degree						1	-0.131
Grain yield							1

*, ** Statistical significance at P<0.05 and P<0.01

genotypes for beer industry, according to Manchev (1975) should be between 42 – 47%. The results from our testing were just within these limits, for both locations. On the other hand, this characteristic had presented the least variability for Strumica location in both years of study.

The correlations between grain yield and qualitative-technological traits for the examined barley varieties in locality Ovche Pole are presented in Table 2. Significant and positive correlation was determined between grain yield and weight of 1 000 grains (r = 0.692) and uniformity of I grains class (r = 0.653), at level of significance 0.01. Also, grain yield made positive correlation with water sensitivity (r = 0.595) and protein content (r = 0.498). Weight of 1 000 grains was in high positive correlation with I class grains uniformity (r = 0,858) at level of significance of 0.01. Positive and significant correlation between 1 000 grains weight and I class grain uniformity was obtained in the research of Valcheva and Vulchev (2012). For water sensitivity, it was obtained positive and significant correlation with I class grains uniformity (r = 0.601) and weight of 1 000 grains (r = 0.566), at level of significance of 0.01. Furthermore, water sensitivity was positive correlated with protein content (r = 0.533), at level of significance 0.05. Significant and positive correlation was determined between uniformity of I grains class and hectoliter mass (r = 0.527) and protein content (r = 0,461), at level of significance of 0.05.

For determined correlation coefficients between qualitative-technological characteristics and grain yield, for genotypes grown in Strumica (Table 3), it was obtained that the grain yield was in positive correlation with weight of 1 000 grains (r = 0.606) and protein content (r = 0.554), at level of significance 0.01. For weight of 1 000 grains it was determined positive correlation with I class grains uniformity (r = 0,544) and negative correlation with soaking degree (r = -0.448) at level of significance 0,05.

Tables 4, 5 and 6 contain results from performed principle component analysis (PCA) for qualitative-technological traits and grain yield in barley. Table 4 clearly presents that for the genotypes grown in Ovche Pole, two main components with eigenvalue higher than 1 were obtained. The first main component participated with 54.25% in the total variation, while the second main component participated with 15.38%. The cumulative percent of the both main components in the total variation was 69.63%. In Strumica locality (Table 4) also two main components with eigenvalue higher than 1 were identified. The first main component participated with 40.17%

Table 3. Linear correlation coefficient between qualitative-technological traits and grain yield in barley genotypes grown in Strumica location

Traits	Protein content	Uniformity of I grains class	Weight of 1 000 grains	Hectoliter mass	Water sensitivity	Soaking degree	Grain yield
Protein content	1	0.124	0.387	0.390	0.175	0.011	0.554**
Uniformity of I grains class		1	0.544*	-0.001	0.028	-0.098	0.366
Weight of 1 000 grains			1	0.428	-0.037	-0.448*	0.606**
Hectoliter mass				1	0.290	-0.141	0.407
Water sensitivity					1	0.098	0.384
Soaking degree						1	-0.393
Grain yield							1

*, ** Statistical significance at P<0.05 and P<0.01

Table 4. Principle component analysis of qualitative-technological traits in Ovche Pole and Strumica location

Main components	Ovche Pole			Strumica		
	Eigenvalue	Percent of variability	Cumulative percentage	Eigenvalue	Percent of variability	Cumulative percentage
PC1	3.80	54.25	54.25	2.81	40.17	40.17
PC2	1.08	15.38	69.63	1.37	19.58	59.75

Table 5. Values of qualitative-technological traits and grain yield to main components of barley genotypes grown in Ovche Pole and Strumica location

Qualitative-technological traits and grain yield	Ovche Pole		Strumica	
	PC1	PC2	PC1	PC2
Protein content	0.40	0.38	0.38	0.30
Uniformity of I grains class	0.46	-0.03	0.30	-0.37
Weight of 1 000 grains	0.43	0.10	0.40	-0.32
Hectoliter mass	0,33	-0.31	0.37	0.33
Water sensitivity	0.41	0.02	0.19	0.60
Soaking degree	-0.12	0.83	-0.27	0.45
Grain yield	0.41	0.24	0.52	0.08

Table 6. Main components values of the analyzed genotypes in Ovche Pole and Strumica location

Genotype	Ovche Pole		Strumica	
	PC1	PC2	PC1	PC2
Hit	-0.96	0.48	0.93	0.49
Izvor	-0.12	0.23	-1.15	-0.39
Egej	-1.75	-1.44	-0.51	1.69
Line 1	1.15	-1.96	0.25	0.52
Line 2	-0.17	-0.55	-0.37	-0.39
Zlatko	-0.17	0.03	-0.48	0.10
Rex	-1.44	1.57	-1.21	0.97
NS 525	1.66	-0.14	1.86	-1.76
NS 565	1.48	-0.87	1.70	-2.56
Obzor	-1.61	0.01	-2.28	-0.16
Perun	1.28	0.52	1.42	-1.33
Emon	0.77	-0.53	-2.18	0.86
Lardeya	0.77	0.39	0.71	0.24
Orfej	-1.49	-0.18	-0.60	1.93

and the second participated with 19.58% in the total variation. The cumulative percentage of both main components was 59.75% of the total variation. Two main components with cumulative percentage of 63,82 % were identified in the research of Valcheva and Vulchev (2012).

Obtained values for the qualitative-technological traits and the grain yield by main components for both locations are presented in Table 5. For Ovche Pole location, it was determined that the first main component was related to the positive values of the following characteristics: uniformity of I grains class, weight of 1 000 grains and grain yield, while second main component was related with positive values for the following properties: soaking degree and protein content.

In Strumica location, first main component was related with the high positive values on the following properties: grain yield and weight of 1 000 grains. The second main component was in correlation with the positive values of the following characteristics: water sensitivity and soaking degree. As well as in our testing, in those of Valcheva and Vulchev (2012), the first main component was in positive correlation with I class grains uniformity, weight of 1 000 grains and grain yield, while the second was related to the protein content. For Ovche Pole location, the genotypes *Perun, Lardeya, Asparuh, Sajra* and *Odisej* presented positive values for both main components, as for Strumica location, genotypes: *Hit*, *Line 1*, *Lardeya, Kuber, Sajra* and *Devinija* had positive values under the both main components (Table 6).

Conclusion

In both experimental years, the average values for grain yield for tested genotypes were higher in Stumica location, compared with genotypes examined in Ovche Pole location. Significant positive correlations between qualitative-technological traits and grain yield, for the genotypes in both locations were obtained between the following traits: grain yield and weight of 1 000 grains, grain yield and protein content and uniformity of I grains class and weight of 1 000 grains. Using principle component analysis for qualitative-technological characteristics and grain yield, for genotypes tested in Ovche Pole, it was obtained two main components with cumulative percent of variation of 69,63 %. In Strumica location, were also identified two main components with cumulative percent of variation of 59,75 %. Genotypes *Perun, Lardeya, Asparuh, Sajra* and *Odisej,* grown in Ovche Pole presented positive values under the two main components and they are suitable for climatic characteristics in Ovche Pole location, while for Strumica locations were the followed genotypes: *Hit*, *Line 1*, *Lardeya*, *Kuber, Sajra* and *Devin*ija.

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Production Systems

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Instruction for authors

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Papers shall be submitted at the editorial office typed on standard typing pages (A4, 30 lines per page, 62 characters per line). The editors recommend up to 15 pages for full research paper (including abstract references, tables, figures and other appendices)

The manuscript should be structured as follows: Title, Names of authors and affiliation address, Abstract, List of keywords, Introduction, Material and methods,Results, Discussion, Conclusion, Acknowledgements (if any), References, Tables, Figures.

The title needs to be as concise and informative about the nature of research. It should be written with small letter /bold, 14/ without any abbreviations.

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Hristova D, 2013. Investigation on genetic diversity in local sheep breeds using DNA markers. Thesis for PhD, Trakia University, Stara Zagora, Bulgaria, (Bg).

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