Agronomic and Quality Traits of Winter Barley Varieties (*Hordeum vulgare* L.) under Growing Conditions in Croatia

Alojzije LALIĆ [1(✉)], Josip KOVAČEVIĆ [1], Dario NOVOSELOVIĆ [1], Gordana ŠIMIĆ [1], Ivan ABIČIĆ [1], Vlado GUBERAC [2]

Summary

This paper presents an investigation of the agronomic and quality traits of the barley varieties, their stability and adaptability and specific reactions towards growing conditions in the Republic of Croatia. During four year trials on localities in Tovarnik, Nova Gradiska, Pozega and Osijek we researched 14 winter barley varieties. Interaction effect variety*environment has been explored together with estimation of significant parameters of stability towards grain yield, hectoliter weight, protein and starch content. With usage of cluster analysis it was possible to group varieties considering genotype x environment interaction (GEI).

Impact of year, location and variety on grain yield, hectoliter grain weight, protein and starch content has been estimated by analysis of variance. There was no significant difference between two different sowing rates (300 and 450 grains/m^2) for grain yield, hectoliter weight and protein content. There also was no significant interaction of variety*sowing rate for all researched parameters.

Parameters of stability and achieved grain yield show that under favorable growing conditions one can expect better results of varieties 'Trenk' and 'Princ' with lower stability and variety Barun with higher stability of grain yield. Stability parameters point out varieties 'Vanessa', 'Plaisant', 'Favorit' and 'Zlatko' to have auspicious reaction to grain yield under extensive cultivation conditions but with significantly different levels of grain yield achieved.

Cluster analysis for grain yield of the highest clustering similarity level displays five variety groups and variety Princ that does not show tendency to group with none of the other varieties. The first group is made by varieties 'Barun', 'Zlatko' and 'Rex'. The second one consists of varieties 'Prometej' and 'Gvozd' with 'Bingo' and 'Sladoran'. 'Tiffany' and 'Vanessa' make special, somewhat detached group of varieties that tend to group together with varieties 'Favorit', 'Trenk', 'Plaisant' and 'Lord' but on the lower grouping level.

Key words

barley, variety, grain yield, grain quality, stability parameters, cluster analysis

[1] Agricultural Institute Osijek, Juzno predgradje 17, HR-31000 Osijek, Croatia
✉ e-mail: alojzije.lalic@poljinos.hr
[2] University J. J. Strossmayer in Osijek, Faculty of Agriculture,
Trg Svetog Trojstva 3, HR-31000 Osijek, Croatia

Received: March 23, 2009 | Accepted: June 4, 2009

ACKNOWLEDGEMENTS
This work was supported by the Ministry of Science, Educations and Sports of the Republic of Croatia.

Introduction

Estimate of interaction effect between genotype and environment has significant role in stating differences between varieties considering stability and adaptability, with characterization of varieties towards growing conditions. Analysis of interaction influence between genotype and environment can serve as selective criteria through breeding process and also as basis for recommendation of certain varieties in commercial production. Breeding towards specific adaptability with goal set to increase grain yield and grain quality for different sub-regions within a region is an important strategy of using positive genotype*environment interaction (Ceccarelli, 1998; Annicchiarico, 2002).

Costa and Boller (2001) pointed out that based on greater environment influence, especially year, it is justified to conduct selection through longer time period and it is not recommendable to increase the number of locations as an alternative solution towards shortening the breeding process.

Protein content in the barley grain is one of the most important factors on which the quality and value of barley as raw material in brewing industry depends, and also its value as fodder. To produce quality barley for brewing industry in Republic of Croatia one must consider problems with increased amount of grain protein. It is well known that grain protein content is, together with variety factor, well affected by climate and agronomic production factors such are: soil type and fertility, weather conditions during vegetation, total vegetation duration, pre-sowed crop and fertilization (Eagles et al., 1995; Kovačević et al., 1994).

Starch, above all other grain components, has the highest specific mass and it is considered that barley with higher hectoliter weight also is richer in starch that leads to conclusion that that kind of barley will have higher extract output (Štefanić and Marić, 1990). However, the hectoliter weight is considered as less liable indicator of malting quality than 1000 grain mass, because hectoliter weight is influenced by shape and form of grain with dependence of actions like harvesting, spicule removal, moist content, etc..

With breeding and selection one tries to create barley varieties of high grain yield, high hectoliter grain weight, low (malting barley) protein or high (barley for fodder) protein content and high starch content that will also be less affected by environment and to variation of these attributes (Bertholdsson, 1999).

Material and methods

Material and field experiments

Field trials were conducted from season of 2003/2004 to season of 2006/2007 in locations in Tovarnik, Nova Gradiska, Pozega and Osijek with 14 varieties of winter barley, of which 10 are from Agricultural Institute Osijek ('Sladoran', 'Rex', 'Zlatko', 'Gvozd', 'Prometej', 'Barun', 'Trenk', 'Bingo', 'Lord' and 'Princ'). 'Tiffany' and 'Vanessa' originate from Germany, variety 'Plaisant' from France and 'Favorit' belongs to BC institute in Zagreb. Varieties 'Lord', 'Princ', 'Favorit' and 'Plaisan't have 6-row spike form.

Every location distinguishes itself with its own type of soil. Selection field of Agricultural Institute Osijek has brown lesive soil: pH (KCl) =6.25, humus =2.20 %. Location Tovarnik has mould soil type: pH (KCl) =7.42, humus =2.96 %. Location Nova Gradiska has alluvial soil type: pH (KCl) =7.63, humus =1.83 % and location in Pozega has pseudogley soil type: pH (KCl) =4.46, humus =1.80 %.

Experiment was set in three replications with two sowing rates (300 and 450 grains/m^2). Average dimension of basic parcel was 7.56 m^2. Sowing was done using a Hege 80 seeder in seven rows with 13.5 cm distance between rows.

Barley grain protein and starch content (%) was determined with Infratec 1241 Grain Analyzer (Foss Tecator AB, Sweden).

Data analysis

Acquired data has been analyzed with SAS 9.1 software using procedures PROC GLM and PROC MEANS (SAS Institute Inc, 2007). Differences between varieties and environments were tested with LSD-test and Duncan`s Multiple Range test.

Regression coefficient (bi) (Finlay and Wilkinson, 1963), ecovalence (Wi) (Wricke, 1962) and variance of regression aberration (Sdi^2) (Eberhart and Russell, 1969) were used to estimate the reaction and stability of explored parameters of winter barley varieties. Parameters of grain yield stability, protein content, starch content and hectoliter weight were estimated based on of 32 trials (four years, four localities, two sowing rates).

Based on cluster analysis (Everitt, 1980) dendrograms were formed to estimate and display the levels of grouping between varieties for grain yield, protein and starch content and hectoliter grain weight. Method of "Hierarchic tree clustering" was used to graphically point out different groups (clusters) via dendrograms. Ward`s method of approach to variance analysis was used to estimate the distance between clusters. Software IRRISTAT 5.0 (Irristat for Windows ©, 2005) was used for cluster analysis and dendrogram forming.

Weather characteristics

Climate data considering average monthly temperatures and total precipitation for period 2003/04 to 2006/07 in locations Osijek, Tovarnik, Nova Gradiska and Pozega, as well as average data (from 1981 to 2006) were aquired from Croatian Meteorological and Hydrological Service.

Table 1. shows average air temperatures and total precipitation during winter barley vegetation period (October-June) by year and locations. During three vegetation seasons (2003/04, 2004/05 and 2005/06) the average monthly temperature was lower than the multiple year average, in vegetation season 2006/07 air temperature was well above the multiannual average. Vegetation season 2006/07 was extremely dry, and 2003/04 extremely moist comparing to the multiple year average. During 2004/05 above average amount of precipitation was measured in locations in Osijek and Tovarnik, while

Table 1. Long-term (1981-2006) average air temperature and total precipitation, average air temperatures and total precipitations in the investigated years 2003-2007, and 9-month (October-June) average air temperatures and 9-month (October-June) total precipitations for the period 2003-2007 in the locations of Osijek, Pozega, Nova Gradiska and Tovarnik

Year	Average air temperature, °C				Total rainfall, mm			
	Osijek	Pozega	Nova Gradiska	Tovarnik	Osijek	Pozega	Nova Gradiska	Tovarnik
2003	11.3	11.6	11.1	11.9	516.5	562.4	612.6	477.1
2004	11.0	11.1	10.8	11.6	865.4	898.6	898.6	848.2
2005	10.4	10.5	10.1	10.8	973.7	754.0	797.0	868.0
2006	11.5	11.1	10.8	12.0	632.1	697.5	788.1	619.7
2007	12.4	12.2	11.7	12.9	620.9	678.0	828.6	766.1
Average, 1981/2006	11.1	11.1	10.9	11.5	679.7	783.3	781.0	674.2
The growing season	Air temperatures during winter barley vegetation period (October-June), °C				Precipitation during winter barley vegetation period (October-June), mm			
2003/04	7.8	8.1	7.7	8.6	626.1	737.8	699.8	639.2
2004/05	7.8	8.0	7.6	8.3	622.7	453.2	544.3	573.5
2005/06	8.0	7.7	7.5	8.3	496.1	479.6	581.7	486.8
2006/07	10.9	10.7	10.4	11.6	336.1	355.5	470.1	371.0
Average, 1981/2006	8.2	8.3	8.0	8.7	490.9	534.0	563.9	481.8

in locations in Pozega and Nova Gradiska the amount of precipitation was well below multiple year average. Vegetation season 2005/06 was within the average values, with minor aberrations in different localities, but only in Nova Gradiska the lower amount of precipitation was measured concerning multiple year average.

Results and discussion

Estimate with ANOVA analysis of variance shows significant (F=***) effects of year, location and variety for grain yield, hectoliter weight, protein and starch content. There was no significant difference between sowing rates (300 and 450 grains/m^2) for grain yield, hectoliter weight, protein and starch content. Also no significance in interaction of variety*sowing rate for all attributes was established. Significant (F=**; ***) interaction year*sowing rate for attributes like grain yield, protein and starch content was established. Significant (F=***) interactions were shown in locality*sowing rate (L*D), year*location *sowing rate (Y*L*D), year*variety (Y*G), variety*location (G*L) and year*variety*location (Y*G*L) for grain yield, hectoliter weight, protein and starch content (Table 2).

Sowing rate of 450 grains/m^2 achieved grain yield of 6.793 t/ha while 300 grains/m^2 gave 6.796 t/ha. Highest grain yield was achieved by varieties 'Bingo' (7.357 t/ha), 'Barun' (7.336 t/ha), 'Gvozd' (7.281 t/ha) and 'Zlatko' (7.214 t/ha) (Table 3).

The highest hectoliter weight had varieties 'Zlatko' (67.76 kg) and 'Bingo' (67.34 kg), and the highest starch content had 'Barun' (60.89 %), 'Zlatko' (60.85 %), 'Trenk' (60.77 %) and 'Lord' (60.77 %) (Table 2.). The highest protein content had varieties 'Vanessa' (13.06 %) and 'Prometej' (12.94%), and the lowest varieties 'Barun' (12.14%) and 'Princ' (12.29%).

Table 2. ANOVA for grain yield and grain quality parameters for 14 winter barley varieties in four locations during four growing seasons

Source of variability	n-1	Sum of squares			
		Grain yield, tha^{-1}	Hectoliter weight, kg	Protein content, %	Starch content, %
Replication	2	0.09	3.40	7.05	2.47
Year (Y)	3	1335.32 ***	5470.06 ***	853.36 ***	319.43 ***
Sowing rate (D)	1	0.01	1.27	0.32	1.18 *
Y*D	9	7.25 **	15.15	18.91 ***	9.45 ***
Location (L)	1	944.75 ***	1783.78 ***	266.36 ***	58.16 ***
Y*L	3	221.29 ***	1089.45 ***	458.63 ***	301.20 ***
L*D	3	21.29 ***	40.81 **	15.98 ***	6.43 ***
Y*L*D	9	23.57 ***	68.56 **	41.09 ***	7.67 ***
Variety (G)	13	326.79 ***	8706.11 ***	91.20 ***	157.97 ***
Y*G	39	179.40 ***	784.18 ***	58.75 ***	57.99 ***
G*D	39	3.98	10.72	6.24	2.70
Y*G*D	117	14.15	59.28	12.65	9.70
G*L	13	142.25 ***	445.11 ***	60.99 ***	45.59 ***
Y*G*L	39	238.45 ***	1272.85 ***	61.80 *	93.14 ***
G*L*D	39	8.46	32.81	7.91	7.84
Y*D*L*G	117	39.39	190.12	40.52	30.31
Error	894	498.79	2111.07	381.90	258.99
Total	1343	4005.22	22084.72	2383.66	1370.23

F-test significance level: * P≤0,05; ** P≤0.01; *** P≤0.001

Table 3. Means for grain yield, hectoliter weight, protein and starch content for 14 winter barley varieties in four locations during four growing seasons

Variety/Year/Location/Sowing rate	Grain yield, tha^{-1}	Hectoliter weight, kg	Protein content, %	Starch content, %
Sladoran	6.892 cd	64.19 d	12.69 cd	60.50 d
Rex	7.055 bc	66.55 b	12.53 de	60.71 bc
Zlatko	7.214 ab	67.76 a	12.47 ef	60.85 ab
Barun	7.336 a	65.73 c	12.14 g	60.89 a
Trenk	6.847 cd	66.36 b	12.35 ef	60.77 abc
Gvozd	7.281 a	66.24 b	12.84 bc	60.19 e
Prometej	7.147 ab	66.50 b	12.94 ab	60.22 e
Bingo	7.357 a	67.34 a	12.48 e	60.69 c
Tiffany	5.561 g	62.61 f	12.83 bc	60.03 f
Vanessa	6.198 f	62.81 f	13.06 a	60.40 d
Plaisant	6.429 e	63.36 e	12.42 ef	60.42 d
Lord	6.509 e	63.90 d	12.35 ef	60.77 abc
Princ	6.796 d	59.81 g	12.29 fg	60.22 e
Favorit	6.502 e	59.44 g	12.69 cd	59.67 g
LSD p=95 %	0.211	0.43	0.18	0.15
2004	6.348 c	63.49 c	13.59 a	60.35 c
2005	5.386 d	61.73 d	13.10 b	59.81 d
2006	7.534 b	66.98 a	11.63 d	61.18 a
2007	7.910 a	65.69 b	11.99 c	60.47 b
LSD p=95 %	0.113	0.23	0.10	0.08
Osijek	8.231 a	66.30 a	12.93 a	60.41 b
Nova Gradiška	6.351 b	64.45 b	11.81 c	60.67 a
Pozega	6.125 c	64.41 b	12.53 b	60.13 c
Tovarnik	6.471 b	63.15 c	13.02 a	60.59 b
LSD p=95 %	0.113	0.23	0.10	0.08
300 seed	6.796	64.50	12.56	60.48 a
450 seed	6.793	64.44	12.59	60.42 b
LSD p=95 %	ns	ns	ns	0.05
Average	6.795	64.47	12.58	60.45

"a...d" - Duncan's Multiple Range Test at $P \leq 0,05$

All in all, every single variety had over the average high in grain proteins (11.5 %) that was dependent on year of production. More favorable years for malting barley production were 2005/06 and 2006/07 (Table 3). However, with the amount of grain proteins the quality is also determined by the ability to dissolve proteins during malting process (Narziss, 1976). Parameters of stability (Table 4) and achieved grain yield (Table 3) display to us the fact that under amiable (intensive) production conditions one can expect better results in grain yield by varieties 'Trenk' and 'Princ' with lesser stability and variety 'Barun' with higher stability. Regression coefficients (bi) show that varieties 'Vanessa', 'Plaisant', 'Favorit' and 'Zlatko' have better reaction towards grain yield under extensive production conditions, but with significant differences considering grain yield. Regression coefficients for grain yield point out the smallest reactions in production intensity changes by varieties 'Bingo' and 'Gvozd' with some leveling towards higher grain yield, and by variety Tiffany with lower grain yield. Varieties 'Zlatko', 'Barun' and 'Lord' on the ground of ecovalence (Wi) and variance of regression aberration (Sdi^2) for hectoliter weight show the least change after environment alteration.

Becker and Leon (1988) stated that ecovalence (Wi) shows the level of genotype contribution to genotype*environment interaction. Genotype stability is greater as its ecovalence value (Wi) is smaller. Environment stability shown with variance of regression aberration (Sdi2) tells us how great can one single attribute become after environment changes (cultivation conditions) (Ferreira et al., 2006). However, while estimating stability with this method it can be possible that genotypes which have been estimated with great yield stability can have, in fact, low grain yield. This method of estimating stability is useful because it can point out to some disease resistances or stress tolerance.

Regression coefficients (bi) show to us that in case of more intensive cultivation conditions the protein content will be greatly increased with varieties 'Vanessa' (bi=1.26), 'Tiffany' (bi=1.28) and 'Plaisant' (bi=1.23), and these cognitions also can be useful while organizing production and fertilization of malting barley crops.

Varieties 'Barun' and 'Zlatko' considering ecovalence (Wi) and variance of regression aberration (Sdi2) show the highest stability of protein content, and the regression coefficient (bi) shows that variety 'Barun' (bi=0.82) achieves higher amounts of protein under extensive cultivation conditions. Varieties 'Vanessa' and 'Tiffany' together with variety Rex show the highest instability (Wi and Sdi^2 values are high) in protein content considering cultivation conditions. Variety Zlatko with results regarding ecovalence (Wi) and variance of regression aberration (Sdi^2) had the least reaction in protein content considering cultivation conditions.

Environment conditions during plant growing period will influence some cultivars to increase starch content and

Table 4. Stability parameters for grain yield, hectoliter weight, protein and starch content for 14 winter barley varieties in four locations during four growing seasons

Variety	Grain yield			Protein content			Hectoliter weight			Starch content		
	b_i	W_i	S_{di}^2	b_i	W_i	S_{di}^2	b_i	W_i	S_{di}^2	b_i	W_i	S_{di}^2
Sladoran	0.96	11.85	0.65	0.90	3.31	0.16	0.96	34.18	1.88	1.14	10.51	0.57
Rex	1.02	4.47	0.25	0.98	6.09	0.34	0.93	37.62	2.04	1.07	4.09	0.22
Zlatko	0.91	4.72	0.23	0.97	2.08	0.11	1.00	25.27	1.40	1.23	3.98	0.17
Barun	1.14	7.69	0.36	0.82	2.34	0.06	1.03	15.29	0.84	1.10	2.68	0.14
Trenk	1.11	9.75	0.50	0.90	3.18	0.16	1.00	53.05	2.95	1.08	3.11	0.17
Gvozd	0.99	7.53	0.42	0.94	3.26	0.17	0.94	25.53	1.38	0.90	3.00	0.16
Prometej	0.96	9.27	0.51	0.93	1.95	0.10	0.83	32.64	1.48	0.90	1.84	0.09
Bingo	1.02	9.88	0.55	0.80	3.57	0.11	0.84	14.95	0.54	0.89	3.10	0.16
Tiffany	1.03	38.49	2.13	1.28	9.06	0.34	1.34	126.57	5.73	1.13	11.80	0.64
Vanessa	0.88	6.55	0.31	1.26	7.87	0.29	1.13	73.01	3.86	1.15	3.51	0.18
Plaisant	0.86	7.31	0.34	1.23	6.35	0.24	0.97	16.90	0.93	0.91	3.21	0.17
Lord	1.00	7.81	0.43	1.12	5.03	0.25	1.15	20.54	0.89	1.03	3.22	0.18
Princ	1.21	11.63	0.50	0.80	4.70	0.17	1.07	72.89	9.55	0.58	4.96	0.11
Favorit	0.91	16.41	0.88	1.07	4.10	0.22	0.79	74.92	3.67	0.91	8.50	0.46

significant reaction, considering regression coefficient, will be shown by varieties 'Zlatko' (bi=1.23), 'Vanessa' (bi=1.15), 'Tiffany' (bi=1.13), 'Sladora' (bi=1.14) and 'Barun' (bi=1.10). Instability towards starch content attribute considering environment conditions is shown by varieties 'Sladoran' (Wi=10.51, Sdi^2=0.57), 'Tiffany' (Wi=11.80, Sdi^2=0.64) and 'Favorit' (Wi=8.50, Sdi^2=0.46).

Classification methods are characterized with irregularities between data so some of the similar entities are being grouped into clusters. Cluster and discriminant analysis also belong within this group of methods, which are very useful to compress and sort data. Cluster analysis is a technique which is being used to group different variables or samples so that these, dependent on measured characteristics, are spread to maximum longitude between groups. This analysis is different to other methods of classification because the number and characteristics of different groups are not familiar before analysis itself, instead they become extrapolated directly from data available (Brown, 1998).

Variety groups are structured by hierarchy, and the process of structuring starts with grouping on the highest level of clustering (grouping), and then grouping goes down towards lower levels. Groups realized in these explorations display some level of similarities when varieties respond under different cultivation conditions. Appliance of cluster analysis in breeding process is very useful because it reveals groups of varieties with similar reactions to environment. Parallel analysis based on homogenous groups points out similarities that may be useful while recommending new varieties, because it is possible to determine similarities and also divergence from standardized and confirmed varieties, and in addition it is possible to assume reactions of these new varieties to production and cultivation conditions.

One can see five groups of varieties on cluster dendrogram for grain yield trait on the highest level of clustering (Figure 1), with variety Princ that has no tendency to group at all. Varieties 'Barun', 'Zlatko' and 'Rex' make the first group; 'Prometej' and 'Gvozd' make the second, where 'Bingo' and 'Sladoran' join these two on the same level of grouping. 'Tiffany' and 'Vanessa' make one special group, and also show the same trend of grouping on the highest level considering all of the examined attributes (Figure 1-4). Cluster dendrogram (Figure 2) on the first level of grouping for protein content shows varieties in five groups. The first one consists of 'Plaisant' and 'Lord' (both 6-row spike type). The second one is compiled with 'Barun' and 'Princ', and the third with 'Zlatko' and 'Bingo'. 'Favorit', 'Rex' and 'Trenk' make one group on this level. Varieties 'Sladoran', 'Gvozd' and 'Prometej' make one distinct group. Varieties 'Plaisant' and 'Lord' make one group considering grain yield, but they also form one single group determined by traits like protein content and hectoliter mass of grain.

'Trenk' (2-row type) and 'Favorit (6-row type) make one separate group regarding grain yield and they also show connection considering protein content. However, variety Favorit especially shows specific reaction considering starch content trait but shows no linkage or grouping towards other groups of barley varieties or cultivars for that matter.

The highest level dendrograms (Figure 1-4) point out that grouping process of varieties 'Sladoran' (2-row) and 'Princ' (6-row) is being done with different varieties dependent on examined trait. Grain yield dendrogram, on lower grouping level, shows two large variety groups that can be characterized on basis of spike formation (either 2-rowed or 6-rowed), vegetation duration, plant height, lodging resistance and genetic ancestry of varieties examined (Lalić et al., 2003). It has been proven through various explorations that genotypes of later spike forming, with longer vegetation duration (like 'Tiffany', 'Vanessa' and 'Favorit') achieve significantly lower grain yield (Table 3, Figure 1-4) considering varieties that ripe early (like 'Bingo', 'Barun', 'Prometej', 'Gvozd' and 'Zlatko'). Difference between varieties that form spikes early and those which form spikes later is from six to twelve days, dependent on year and variety (Lalić et al., 2003; Lalić et al., 2006). Reaction of va-

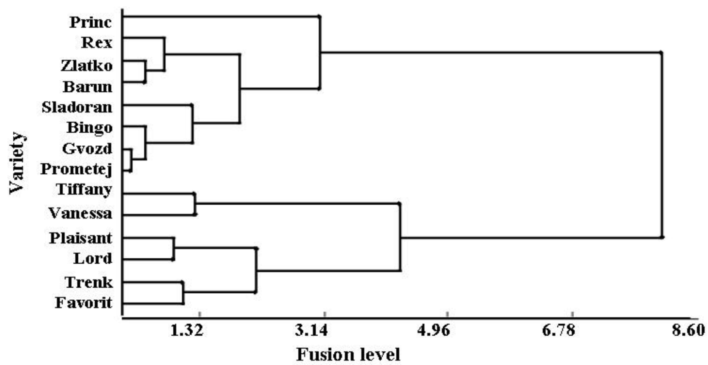

Figure 1. Cluster dendogram varieties for grain yield

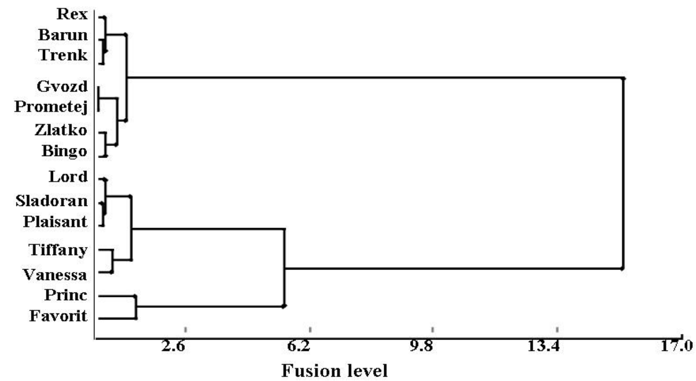

Figure 3. Cluster dendogram varieties for hectolitre weight

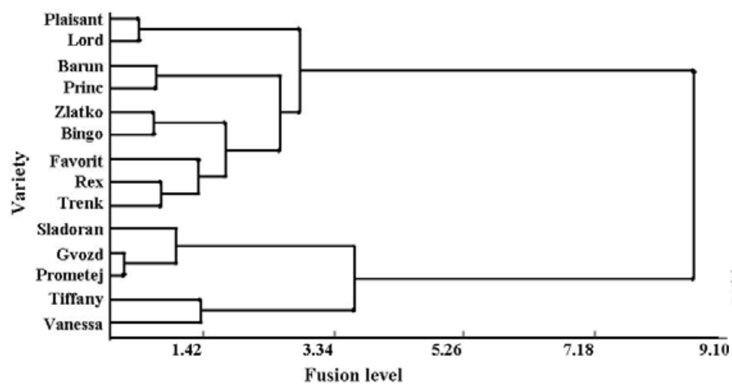

Figure 2. Cluster dendogram varieties for protein content

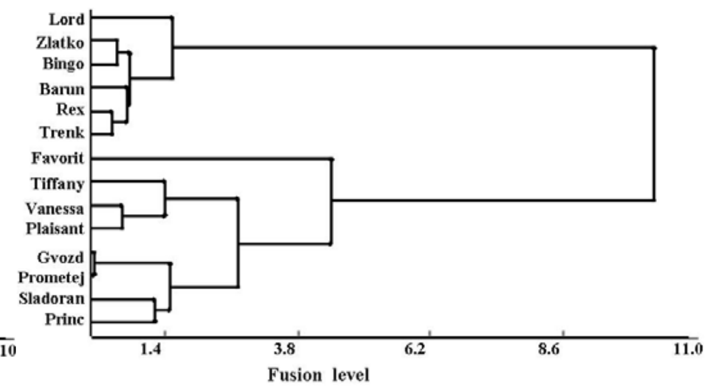

Figure 4. Cluster dendogram varieties for starch content

rieties that ripen later is connected with interaction of spike forming date and grain filling period length, together with dry production conditions (drought stress), which are usual in the Republic of Croatia and Southeastern Europe. Shaktah et al. (2001) confirmed that length of grain filling period under conditions of adequate moisture has positive effect towards grain yield and quality, but under drought genotypes with longer vegetation achieve significantly lower grain yield.

When selecting for the best variety for production in specific area it is imperative to explore varieties under different production conditions, different locations, sowing rates and years as well (Lalić et al., 2003). This selection strategy imposes itself in "sustainable agriculture" to maximize usefulness potential of different sub-regions with appropriate genotype. Conducted research shows differences regarding adaptability and expression of varieties towards cultivation conditions (location and year), different reactions to abiotic and biotic stress factors, and also points out superior varieties cultivated under conditions in Republic of Croatia.

Conclusion

Significant effects of factors: year, locality and variety for traits as grain yield, hectoliter grain weight, protein and starch content have been estimated with analysis of variance. Clear affirmation of no significant difference for grain yield, hectoliter grain weight and protein content considering sowing rate between 300 and 450 grains/m^2 has been confirmed. Also, there was no significant interaction of variety*sowing rate for all researched parameters. Significant interactions location*sowing rate (L*D), year*location*sowing rate (Y*L*D), year*variety (Y*G), variety*locytion (G*L) and year*variety*location (Y*G*L) have been estimated for grain yield, hectoliter grain weight, protein and starch content. Significant interaction year*sowing rate (Y*D) has been determined for grain yield, protein and starch content.

Estimated stability parameters and achieved grain yield point out the fact that under more intensive production conditions one can expect better results with varieties Trenk and Princ together with lower stability, and with variety Barun but with increased stability. Stability parameters also indicate that varieties 'Vanessa', 'Plaisant', 'Favorit' and 'Zlatko' have fair reaction to extensive production conditions in traits regarding grain yield, but with various oscillations in grain yield achieved.

Cluster analysis on highest grouping level for grain yield shows five variety groups, with variety Princ that has no tendency to group at all. Varieties Barun, Zlatko and Rex make the first group on the highest grouping level; Prometej and

Gvozd make the second where Bingo and Sladoran join these two on the same level of grouping. Tiffany and Vanessa make one special group that is pretty detached from others, and this group is well connected with another group consisted of 'Favorit' and 'Trenk', and 'Plaisant' and 'Lord'.

References

Annicchiarico P. (2002). Genotype x environment interactions–Challenges and opportunities for plant, plant breeding and cultivar recommendations. Food and agriculture.

Becker H.C., Leon J. (1988). Stability analysis in plant breeding. Plant Breed. 101:1-23.

Bertholdsson N. O. (1999). Characterization of malting barley cultivars with more or less stable grain protein content under varying environmental conditions. European Journal of Agronomy, 10: 1-8.

Brown C.E. (1998). Applied Multivariate statistics in geohydrology and related sciences. Springer-Verlag, 248.

Ceccarelli S., Grando S., Impiglia A. (1998). Choice for selection strategy in breeding barley for stress environments. Euphitica, 103(3), 307-318.

Costa J.M., Boller G.A. (2001). Stability analysis of grain yield in barley (Hordeum vulgare) in the US mid-Atlantic region. Annals of Applied Biology. 139(1), 137-143.

Eagles H.A., Bedggod A.G., Panozzo J.F., Martin P.J. (1995). Cultivar and enviromental effects on malting quality in barley. Australian Journal of Agr. Research, 46,831-844.

Eberhart S. A., Russell W. A. (1966). Stability parameters for comparing varieties. Crop Sci., 6, 36-40.

Everitt B. (1980). Cluster analysis. London, Heinemann educational books.

Ferreira F.D., Demetrio S.G.B., Manly B.F.J., Machado A.A., Vencovsky R., (2006). Statistical models in agriculture: Biometrical methods for evaluating pfenotypic stability in plant breeeding. Cerne, 4:373-388.

Finlay K. W., Wilkinson G. N. (1963). The analyses of adaptation in a plant-breeding programme. J. Agric. 14,742-754.

Irristat for Windows © 2005, Version 5.0. International Rice Research Institute DAPO Box 7777, Metro Manilla, Phillipines.

Kovačević J., Lalić A., Martinčić J., Šimić I., Horvat J., Juzbašić M., Kelečenji Z., Kuti I., Lešić L., Marjanović I., Mužar Z., Nikolić B. (1994). Mogućnosti proizvodnje ječma i slada u Republici Hrvatskoj, Poljoprivredne aktualnosti, 30, 457-469.

Lalić A., Kovačević J., Novoselović D., Babić D., Gunjača J. (2003). Ostvarena dobit i učinak uvjeta uzgoja na urod zrna sorti ozimog i jarog ječma // Priopćenja - 38. Znanstveni skup hrvatskih agronoma, p.93-96.

Lalić A., Kovačević J., Drezner G., Novoselović D., Babić D., Dvojković K.; Šimić,Gordana (2006). Response of Winter Barley Genotypes to Croatian Environments-Yield, Quality and Nutritional Value. Cereal Research Communications. 34, 1; 433-436.

Narziss L. (1976). Technologie der Malzbereitung, 6th ed., f.-Enke-Verlag, Stutgart.

SAS Institute Inc., 2007. SAS/STAT User's Guide . SAS Institute Inc., Cary, NC.

Shakhatreh Y., Kaffavin O., Ceccarelli S., Saoub H. (2001). Selection of barley lines for drought tolerance in low-rainfall areas. Journal of Agronomy. 186(2), 119-127.

Štefanić K., Marić V. (1990). Pivarski priručnik. V. Marić (ur.), Jugoslavensko udruženje pivovara, Beograd.

Wricke G. (1962). Uber eine methode zur erfassung der okologishen streubreite in feldversuchen. Z. Pflanzencuhtg., 47, 92-96.

acs74_50