Agriculture (Poľnohospodárstvo), 58, 2012 (3): 99−112
DOI: 10.2478/v10207-012-0012-9

VARIABILITY OF THE PARAMETERS OF TECHNOLOGICAL QUALITY IN THE SLOVAK SPRING BARLEY GENE POOL

MICHAELA BENKOVÁ*, MICHAELA HAVRLENTOVÁ,
ĽUBOMÍR MENDEL, PAVOL HAUPTVOGEL

Plant Production Research Center Piešťany

BENKOVÁ, M. – HAVRLENTOVÁ, M – MENDEL, Ľ. – HAUPTVOGEL, P.: Variability of the parameters of technological quality in the Slovak spring barley gene pool. Agriculture (Poľnohospodárstvo), vol. *58*, 2012, no. 3, pp. 99–112.

The total 43 Slovak spring barley genotypes with a year of cultivation or registration from 1938 to 2009 were evaluated in terms of selected parameters like protein, starch, and β-glucan contents. Collection of genetic resources consisted of barley malting qualities such as elite – A, standard quality – B, no malting quality – C and five genotypes of unspecified malting quality. Significant ($P < 0.01$) influence of genotype and environmental conditions (years) and also genotype × year interaction on protein, starch, and β-glucan content in the barley grain were detected. The highest average protein content was observed in genotypes from the group with undetermined malting quality. The protein and β-glucan contents in older genotypes were higher in comparison with more recent genotypes. The average starch content in both older and modern genotypes in the studied set was nearly identical, which confirms a high quality of the older malting varieties. According to malting quality groups, the highest average value of β-glucan content was in the group of no malting quality (C) and the lowest in the group of best malting quality (A), which is in correspondence with barley malting quality requirements. In individual years differences in the β-glucan content were found among genotypes. Despite the atypical years, good sources of β-glucan were found out along with modern genotypes such as Cyril and older genotypes such as Orbit and Vladan, but also historically old genotypes were created in the year 1946 such as Diosecký 802 and Slovenský Dunajský trh. Our study has confirmed that these genotypes are donors of not only significant agronomic traits but also qualitative properties, usable in the food industry.

Key words: barley, β-glucan, starch, protein, genotype, environment

Barley (*Hordeum vulgare* L.) is the second mostly represented crop after wheat in Slovakia. Barley covers an area of 136,300 ha (2011). Barley sowing is very important for the national economy; it is grown as a raw material for the food industry, for feeding animals, and for malt production. Currently 57 varieties of spring barley and 24 winter barley varieties are registered in Slovakia; from this 17 varieties are of Slovak origin (List of registered varieties 2011). Although growing of spring barley is connected with brewing, today a renaissance in the use of barley grain as food has been recorded, first of all in developed countries all over the world (Ehrenbergerová 2006). Here barley is used for production of so-called functional foods. Naked barley has a big role in the food industry, with beneficial nutritional and dietary uses. Its disadvantage is its yield that is lower about 15% in comparison with glumose varieties (Candráková *et al.* 2000). Biological and agricultural characters of the currently registered barley varieties fulfil conditions of intensive growing; they are adequately resistant to leaf diseases and have good malting quality and high grain yield (Sleziak 2003). According to the National Biodiversity Strategy of Slovakia, barley genetic resources include not only modern varieties, cultivars, and hybrids used mostly in agriculture but also drawn varieties, old landraces,

Ing. Michaela Benková, PhD., RNDr. Michaela Havrlentová, PhD., Ing. Ľubomír Mendel, PhD., Ing. Pavol Hauptvogel, PhD., Plant Production Research Center, Bratislavská cesta 122, 921 68 Piešťany, Slovak Republic. E-mail: benkova@vurv.sk (*Corresponding author)

ecotypes from widespread plant species. and their natural populations. These so-called historical genetic resources have been used as a store of rare genes. Because the long-time selection of barley was constantly influenced by human needs in terms of nutrition and quality of barley, it causes permanent loss of valuable sources of variability in the germplasm. Typically, many modern varieties of spring barley have relatively narrow genetic basis, and to a certain extent they are similar (Kraic *et al*. 2004; Psota 2009).

Quality of barley grain is a complex character, which is subject to complex genetic conditions, considerably affected by agro-ecological growing conditions and depending on the genotype-environment interaction. Barley grain contains 80–88% of solids and 12–20% of water. The dry matter is composed of nitrogen and nitrogen-free organic compounds and inorganic substances (Sleziak 2003). To carbohydrate components belong starch and non-starch polysaccharides (cellulose, hemicellulose, rubber substances, and lignin). Starch content (%) is decisive for extract formation, and therefore it is a significant parameter of barley quality. In malting barley, starch content in dry matter moves around 63–65%, and it should not be lower than 60% (Prugar & Hraška 1989). Starch content depends not only on protein amount but also on the state of growth and sunshine period during the final phases of vegetation. There is a negative correlation between the content of starch and protein in barley grain (Sleziak 2003).

The most important components of hemicelluloses and gummy substances are in the barley grain β-glucans. From the chemical point of view, β-glucan ([1-3][1-4]-β-D-glucan) consists of glucose units connected by β-(1-3)- and β-(1-4)- glycosidic bonds in variable proportions, most frequently in the ratio 30 : 70. Grains of barley contain the highest amount of β-glucan among all cultivated cereals (Henry *et al.* 1985). The average β-glucan content in barley grains is 7.5% in high amylose, 6.9% in waxy, 6.3% in zero amylose waxy, and 4.4% in normal starch types (Baik *et al.* 2008). The amount and composition of hemicelluloses and gummy substances and particularly in them containing β-glucans and pentosans depends on growing conditions. Short growing season, high temperatures, and drought during growth increase not only the protein content but also the content of non-starch polysaccharide. The effect of genotype is also significant (Prugar & Hraška 1989). According to Rey *et al.* (2009), 66% of variability in the content of β-glucan can be attributed to the genotype.

A low β-glucan and protein content and contrarily higher content of starch in the grain are desirable for malting barley. β-glucans fulfill the function of building materials in the endosperm cell walls in contrast to starch, which serve as a storage substance. β-glucans stop the entry of enzymes into cells, thus negatively affecting the speed of deciphering of the grain during malting. On the other hand, higher β-glucan content is the most important attribute for barley varieties destined for the human food market (Rey *et al.* 2009). In terms of functional foods, barley β-glucans have a great importance as a health-enhancing ingredient (Huth *et al*. 2000). This component significantly supports the immune system, effectively prevents cardiovascular diseases, and protects from excessive physical or mental stress. It also serves as a antibiotic and assists in chemotherapy and radiotherapy (Charalampopoulos *et al*. 2002).

Based on the assessment of technological quality of selected parameters such as β-glucan, protein, and starch content in the barley grain, the aim of our work was to identify the potential of historical, later-created, and new Slovak varieties usable for human nutrition and consumption.

MATERIAL AND METHODS

Samples of spring barley grains in 43 genotypes of the Slovak origin within a year of cultivation or registration from 1938 to 2009 were obtained from the Gene Bank SR in PPRC Piešťany (Table 1). Samples were consequently multiplied and evaluated in the field small-plot trials with the harvest area of 2.5 m^2, on the experimental basis in Piešťany for two years 2010 and 2011. This experiment was arranged in a randomized block design with two replications. The obtained samples were analyzed for selected parameters of technological quality: β-glucans content [%], protein content [%], and starch content [%]. The data obtained have been converted to 100% dry weight basis. Collection of genetic resources consisted of barley malting quality as elite – A (13 genotypes), standard quality – B (12 genotypes), non-malting quality – C (13 genotypes) and five genotypes of unspecified malting quality – U (5).

T a b l e 1

Characteristics of Slovak spring barley genotypes set released from years 1938–2009

Number	Genotype	Year of release	Malting quality type
1	Diosecký Kneifel	1938	unspecified
2	Terrasol pivovarský	1944	unspecified
3	Diosecký 802	1946	A
4	Diosecký Sprinter	1946	unspecified
5	Nitriansky Export	1946	B
6	Slovenský Dunajský trh	1946	A
7	Slovenský jemný	1946	A
8	Slovenský kvalitný	1946	A
9	Pudmerický pivovar	1948	unspecified
10	Bučiansky Kneifel	1955	B
11	Vigľašský polojemný	1958	unspecified
12	Dvoran	1965	B
13	Sladar	1967	A
14	Fatran	1980	B
15	Horal	1982	C
16	Orbit	1986	B
17	Novum	1988	B
18	Galan	1990	B
19	Jubilant	1991	A
20	Sladko	1992	A
21	Svit	1992	C
22	Donum	1993	C
23	Stabil	1993	C
24	Garant	1994	B
25	Kosan	1994	C
26	Zlatan	1994	C
27	Amos	1995	C
28	Kompakt	1995	A
29	Vladan	1996	B
30	Progres	1998	C
31	Expres	1999	A
32	Cyril	2000	C
33	Ludan	2002	B
34	Nitran	2003	A
35	Ezer	2004	B
36	Pribina	2005	C
37	Argument	2006	C
38	Nadir	2006	B
39	Poprad	2006	C
40	Slaven	2007	C
41	Levan	2008	A
42	Donaris	2009	A
43	Sladar new	2009	A

After growing, the grains were dried and milled to pass a 0.5 mm screen using Ultracentrifugal Mill (ZM 100, Retsch GmbH & Co. KG, Haan/Germany). Before each analysis they were stored in hermetic boxes under temperatures of 5°C.

Nitrogen content was determined by the Dumas method on the CNS-2000 (Leco Corp., US), and the coefficient 6.25 was applied for recalculation. Starch content was determined by the Ewers polarimetric method (STN 461011-37), and optical activity was recalculated to starch concentration by the coefficient for barley 5.5096. β-glucan level was determined using Mixed-linkage βeta-glucan assay procedure (Megazyme, Ireland) (McCleary 2011). This method is accepted by the AOAC (Method 995.16) and the AACC (Method 32-23). Samples were suspended and dissolved in a 0.02 M sodium phosphate buffer (pH 6.5), incubated with purified lichenase enzyme, and an aliquot of filtrate was reacted with purified β-glucosidase enzyme. The glucose product was assayed using an oxidase/peroxidase reagent recalculated to β-glucan content.

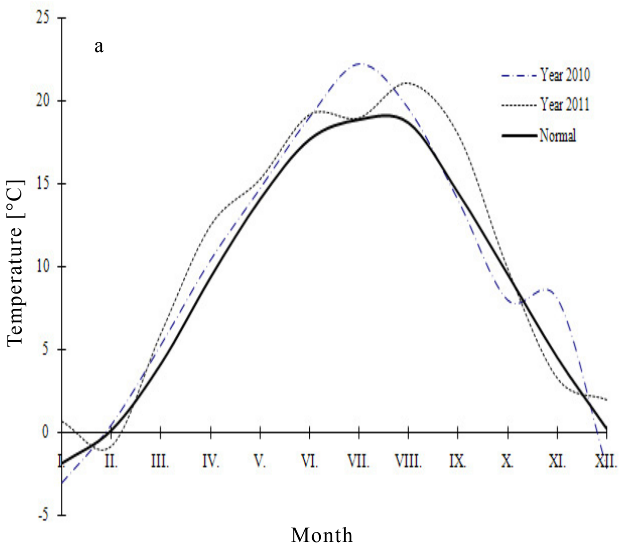
Analysis of data was performed using statistical software (Statistica 8.0, Statsoft, Inc. 2008) with analysis of variance (ANOVA) and Pearson's correlation coefficient. Differences were considered significant at $P < 0.05$, unless otherwise specified.

Experimental fields were situated in the maize production area, a subtype maize-wheat. Altitude is 162 m; soil is Luvic chernozem (World Reference Base for Soil Resources 2006). The humus horizon is around 40–50 cm deep. Soil reaction of top layers is neutral, and it becomes moderately alkaline in deeper layers. Long-term normal precipitation is 595 mm, with an average annual temperature of 9.2°C (years 1961–1990).

Course of vegetation

Average temperatures during the vegetation of barley in 2010 and 2011 corresponded to the long-term normal. In 2010 during sprouting there was half the amount of precipitation in comparison to the long-term normal. Therefore, the crop was less involved. During the beginning of the heading period the amount of rainfall was three times heavier when compared to the long-term average. Supernormal rainfall extended the heading period for many varieties of barley and caused a high occurrence of diseases, especially powdery mildew.

In 2011, during sprouting precipitation was on an equal level with that of the long-term average. Gradually the precipitation was added at the time of heading and milk ripeness and exceeded the long-term average of more than 40%. There was sufficient rainfall to ensure a rapid increase in leaf area, although it did not



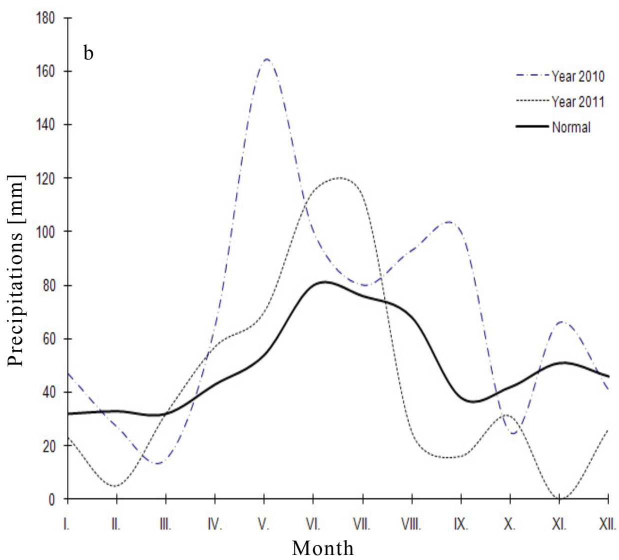


Figure 1. Mean monthly temperatures (a) and total monthly precipitation (b) for the years 2010 and 2011 compared to normal (50 years)

cause the occurrence of diseases, as in 2010, which was reflected in improved grain yield. The detailed course of weather in years 2010 and 2011 is given in the Figure 1.

RESULTS AND DISCUSSION

It was important to determine the factors affecting the analyzed traits while assessing a total of 43 Slovak spring barley genotypes in terms of selected characteristics. The ANOVA (Table 2) detected significant ($P < 0.01$) influence of genotype and environmental conditions (years) on protein, starch, and β-glucan content in the barley grain. Genotype × year interaction had a statistically significant effect ($P < 0.01$) on all monitored characters, too.

Protein content is generally considered as the most important parameter of the processing value of malting barley. It can vary within a very wide range (7–18% in dry matter). Good quality malting barleys should have protein content within 10.00–11.5% (Kosař *et al.* 2000). The average protein content in the monitored genotypes was higher in the year 2010 (12.36%) in contrast to year 2011, when it was only 10.98% (Table 3). The mean value per two years was 11.67%. The distribution of rainfall for barley cultivation is very important. Humidity is needed especially during the stems and grains production, but intensive rainfall increases the nitrogen content (Sleziak 2003), which resulted in higher protein content in the grain. This observation is confirmed by our results (Figure 2). In the year 2010, intensive rainfall during heading and grain production decreased quality of the malting barley, and protein content was highly increased. The average protein content was statistically different in genotypes from the group with undetermined malting quality (12.89%) (Table 4). The average protein content of genotypes from the group of good malting quality (A) was 11.53% and lowest content was in genotypes of non-malting quality (C), 11.23%. These results were affected by extreme humidity during vegetation in the year 2010. In the whole experiment, the value of protein content fluctuated from 8.76% (Jubilant) to 14.85% (Bučiansky Kneifel) (Figure 2). Some genotypes responded very sensitively to the humidity in 2010. For example we recorded the average protein content in Nitran, a malting variety, to be over 14.0%. During the two years we recorded high average protein content at malting quality genotypes of type B (Bučiansky Kneifel – 14.34%) and similarly high protein content was recorded in genotypes with undetermined malting quality like in Diosecký Kneifel – 13.72% and Terrasol pivovarský – 14.4% (Table 5). We found out that protein content in older genotypes was higher in comparison with more recent genotypes.

On the other hand, contents of starch and β-glucan were higher during the 2011 vegetation period (Figures 3, 4). Starch content is decisive for the extract formation, and therefore it is a significant parameter of barley quality. In malting barley, starch content in dry matter moves around 63–65%, and it should not be lower than

T a b l e 2

Analysis of variance of protein, starch and β-glucan contents in 43 spring barley genotypes

Source of variation	df	Protein [%]			Starch [%]			ß-glucan [%]		
		SS	MS	F	SS	MS	F	SS	MS	F
Genotyp	42	236.78	5.64	1030.5++	773.90	18.40	455.0++	24.41	0.58	38.2++
Year	1	77.55	77.55	14174.9++	160.10	160.10	3956.0++	7.91	7.91	520.4++
Genotyp × Year	42	82.79	1.97	360.3++	327.30	7.80	193.0++	14.11	0.34	22.1++
Residual	86	0.47	0.01		3.50	0.01		1.31	0.02	
Total	171	397.59			1264.74			47.73		

++significant at 0.01 probability level

60% (Prugar & Hraška 1989). Higher starch content affects extract content directly. When there is a lack of starch in the grain, it is not possible to increase the percentage of extract by any other technology. Starch amount depends not only on protein content but also on the state of growth and sunshine period during the final phases of vegetation (Sleziak 2003).

Genotypes and experimental years affected variability of the starch content significantly (Table 2). Atypical humid years influenced the content of starch in barley grain, when the average value of starch content in 2010 was only 53.89% and in 2011 it was 55.82% (Table 3). Higher rainfall during grain produce and the ripening period reduced the malting quality. The aver-

T a b l e 3

Basic statistical characteristics of qualitatively parameters of barley genotypes in two analyzed years

Characteristics	Years	$\bar{x}$	SD	v [%]	Min.	Max.
Protein [%]	2010	12.36[a]	1.27	10.24	8.81	14.67
	2011	10.98[b]	1.49	13.58	8.76	14.85
	Total	11.67	1.54	13.19	8.76	14.85
Starch [%]	2010	53.89[a]	2.59	4.81	46.12	58.71
	2011	55.82[b]	2.51	4.49	50.04	60.47
	Total	54.85	2.72	4.96	46.12	60.47
ß-Glucan [%]	2010	4.00[a]	0.50	12.53	2.88	5.03
	2011	4.43[b]	0.47	10.51	3.50	5.93
	Total	4.22	0.53	12.53	2.88	5.93

Values in the same column with different letters are significantly different (P < 0.05).
SD − Standard deviation

T a b l e 4

Average value of protein, starch and β-glucan contents within individual groups of barley genotypes

Characteristics	Malting quality type	$\bar{x}$	SE	Confidence limits for mean	
				−95%	+95%
Protein [%]	A	11.53[a]	0.18	11.17	11.89
	B	11.81[a]	0.19	11.44	12.18
	C	11.23[a]	0.18	10.88	11.59
	U	12.89[b]	0.29	12.32	13.47
Starch [%]	A	55.18[a]	0.33	54.53	55.83
	B	54.97[a]	0.34	54.29	55.64
	C	55.47[a]	0.33	54.82	56.12
	U	52.11[b]	0.53	51.07	53.16
ß-Glucan [%]	A	4.12[a]	0.07	3.98	4.25
	B	4.24[a]	0.07	4.10	4.38
	C	4.28[a]	0.07	4.15	4.42
	U	4.25[a]	0.11	4.04	4.47

A − malting quality elite C − no malting quality SE − Standard error
B − standard malting quality U − undetermined malting quality
Values in the same column with different letters are significantly different (P < 0.05)

T a b l e 5

Variations in average protein content in barley genotypes of malting quality types in two years

Malting quality groups/Genotype	Protein [%]*	Confidence limits for mean	
		–95%	+95%
Group A			
Diosecký 802	12.22^{o}	12.14	12.29
Donaris	10.27^{d}	10.19	10.34
Expres	11.55^{klm}	11.47	11.62
Jubilant	8.94^{a}	8.87	9.01
Kompakt	11.17^{h}	11.10	11.25
Levan	11.60^{klm}	11.52	11.67
Nitran	14.06^{u}	13.99	14.14
Sladar	11.41^{ijk}	11.34	11.48
Sladar-new	10.73^{ef}	10.66	10.81
Sladko	11.13^{gh}	11.06	11.21
Slovenský kvalitný	11.95^{n}	11.87	12.02
Slovenský Dunajský trh	12.07^{no}	11.99	12.14
Slovenský jemný	12.80^{rs}	12.73	12.88
Average (n=13)**	11.53^{a}	11.17	11.89
Group B			
Bučiansky Kneifel	14.34^{v}	14.27	14.42
Dvoran	10.94^{fg}	10.87	11.02
Ezer	9.60^{b}	9.52	9.67
Fatran	10.46^{d}	10.39	10.54
Galan	10.29^{d}	10.21	10.36
Garant	11.96^{n}	11.88	12.03
Ludan	11.47^{jkl}	11.40	11.54
Nadir	12.70^{qr}	12.63	12.77
Nitriansky Export	12.83^{rs}	12.75	12.90
Novum	12.95^{s}	12.88	13.03
Orbit	11.70^{m}	11.62	11.77
Vladan	12.50^{pq}	12.43	12.58
Average (n=12)**	11.81^{a}	11.44	12.18
Group C			
Amos	12.12^{no}	12.05	12.19
Argument	11.59^{klm}	11.52	11.67
Cyril	10.36^{d}	10.28	10.43
Donum	9.92^{c}	9.84	9.99
Horal	11.44^{ijkl}	11.37	11.51
Kosan	10.69^{e}	10.62	10.77
Poprad	11.65^{lm}	11.58	11.72
Pribina	10.94^{fg}	10.86	11.01
Progres	11.08^{gh}	11.01	11.15
Slaven	12.11^{no}	12.04	12.19
Stabil	12.07^{no}	11.99	12.14
Svit	10.84^{ef}	10.76	10.91
Zlatan	11.24^{hi}	11.16	11.31
Average (n=13)**	11.23^{a}	10.88	11.59
Group undetermined			
Diosecký Kneifel	13.72^{t}	13.64	13.79
Diosecký Sprinter	11.27^{hij}	11.19	11.34
Pudmerický pivovar	12.43^{p}	12.36	12.51
Vigľašský polojemný	13.02^{s}	12.94	13.09
Terrasol pivovarský	14.04^{u}	13.97	14.12
Average (n=5)*	12.89^{b}	12.32	13.47

*Values in the same column with different letters are significantly different ($P < 0.05$)
**Average of each malting quality groups. Values in the same column with different letters are significantly different ($P < 0.05$)

age starch content was lower in all groups (Table 4) and hardly reached 60% in any genotype, even in the high quality malting varieties (Jubilant, Expres, Nitran). The highest content of starch was determined in the 2011 vegetation period in genotypes Ezer (60.47%) and Galan (59.90%) from the group of malting quality B (Figure 3, Table 3). The average value of starch content during years 2010 and 2011 (Table 6) ranged from 48.26% (Terrasol pivovarský) to 58.86% (Ezer), which is a very low content. Average starch content in older and modern genotypes in the studied set was nearly identical, which confirms a high quality of older malting varieties in spite of the fact that the breeding aims during the last 10 years have been focused on improving malting quality and thus also increasing starch content.

Similar to starch also the β-glucan content (Figure 4, Table 3) was higher in 2011 (4.43%) compared to 2010 (4.00%). Differences between years and cultivars (Table 2) and interaction of this combination were statistically significant ($P < 0.01$). In the literature, water stress has been found either to reduce (Macnicol *et al.* 1993) or to increase (Savin *et al.* 1996) the β-glucan content. According to Zhang *et al.* (2001), wet days, associated with lower temperatures, were positively correlated with β-glucan content. The β-glucan is deposited in walls of the endosperm cells during the later stages of grain filling. Thus conditions favorable to endosperm development would increase the accumulation of β-glucan in the grain. High precipitation is unfavorable for endosperm development, and high temperatures may shorten the duration of grain filling. Relatively less β-glucan will be synthesized and accumulated on the walls of the endosperm cells in comparison with total dry matter, mainly starch and protein, leading on the other hand to lower β-glucan content. It can be assumed that similarly in our case the high rainfall in the month of May (Figure 1) in 2010 (164 mm) during the formation of grain caused reduction of β-glucan in barley genotypes.

Low β-glucan and protein content are desirable qualities for malting barley. According to the malting

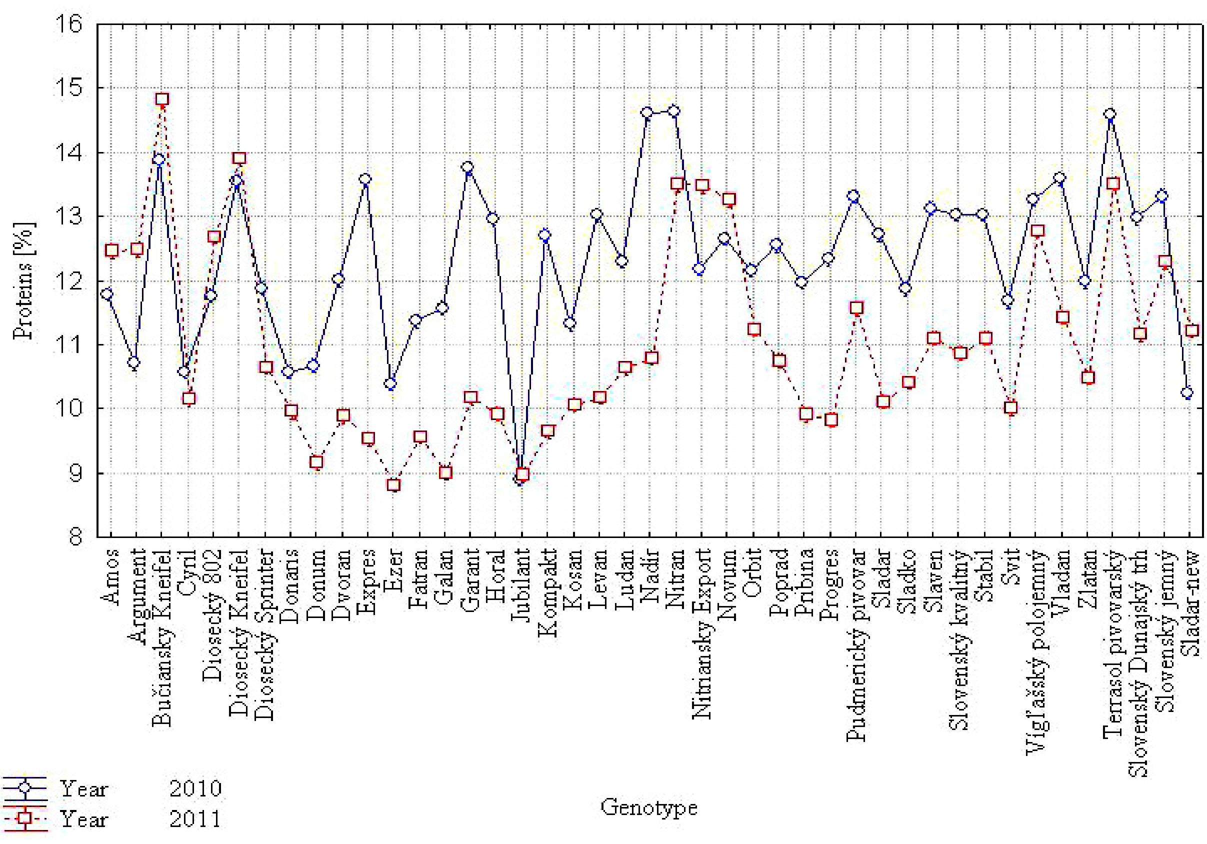


Figure 2. Variability of protein content in barley genotypes in two analyzed years

T a b l e 6

Variations in average starch content in barley genotypes of malting quality types in two years

Malting quality groups/Genotype	Starch [%]*	Confidence limits for mean	
		–95%	+95%
Group A			
Diosecký 802	55.26[lmn]	53.33	57.19
Donaris	57.60[tu]	55.67	59.53
Expres	53.75[gh]	51.82	55.68
Jubilant	58.01[u]	56.08	59.94
Kompakt	55.52[mnop]	53.59	57.45
Levan	56.33[rs]	54.40	58.26
Nitran	57.24[t]	55.31	59.17
Sladar	55.86[opqr]	53.93	57.79
Sladar-new	55.37[lmno]	53.44	57.30
Sladko	55.13[klm]	53.20	57.06
Slovenský kvalitný	52.79[de]	50.86	54.72
Slovenský Dunajský trh	51.93[c]	50.00	53.86
Slovenský jemný	52.52[d]	50.59	54.45
Average (n=13)**	55.18[a]	54.48	55.88
Group B			
Bučiansky Kneifel	51.19[b]	49.26	53.12
Dvoran	56.14[qrs]	54.21	58.07
Ezer	58.86[v]	56.93	60.79
Fatran	55.72[nopq]	53.79	57.65
Galan	58.08[u]	56.15	60.01
Garant	53.49[fg]	51.56	55.42
Ludan	56.03[pqrs]	54.10	57.96
Nadir	55.96[pqr]	54.03	57.89
Nitriansky Export	53.60[g]	51.67	55.53
Novum	52.68[d]	50.75	54.61
Orbit	54.94[jkl]	53.01	56.87
Vladan	52.91[de]	50.98	54.83
Average (n=12)**	54.97[a]	54.24	55.69
Group C			
Amos	56.40[rs]	54.47	58.33
Argument	56.59[s]	54.66	58.52
Cyril	55.55[mnop]	53.62	57.48
Donum	57.33[t]	55.40	59.26
Horal	55.05[jklm]	53.12	56.98
Kosan	56.37[rs]	54.44	58.30
Poprad	54.25[hi]	52.32	56.18
Pribina	56.23[qrs]	54.30	58.16
Progres	55.71[nopq]	53.78	57.64
Slaven	53.31[efg]	51.38	55.23
Stabil	52.97[def]	51.04	54.90
Svit	55.99[pqr]	54.06	57.92
Zlatan	55.36[lmno]	53.43	57.29
Average (n=13)**	55.47[a]	54.77	56.16
Group undetermined			
Diosecký Kneifel	51.56[bc]	49.63	53.49
Diosecký Sprinter	54.52[ij]	52.59	56.45
Pudmerický pivovar	54.61[ijk]	52.69	56.54
Vigľašský polojemný	51.61[a]	49.68	53.54
Terrasol pivovarský	48.26[bc]	46.34	50.19
Average (n=5)**	52.11[b]	50.99	53.24

*Values in the same column with different letters are significantly different ($P < 0.05$)
**Average of each malting quality group. Values in the same column with different letters are significantly different ($P < 0.05$)

Table 7

Variations in average β-glucan content in barley genotypes of malting quality groups in two years

Malting quality groups/Genotype	β-glucan [%]*	Confidence limits for mean	
		–95%	+95%
Group A			
Diosecký 802	4.82[qrs]	4.69	4.94
Donaris	4.41[jklmnop]	4.29	4.53
Expres	4.29[hijklmnop]	4.16	4.41
Jubilant	3.55[abc]	3.43	3.67
Kompakt	3.48[ab]	3.36	3.60
Levan	3.31[a]	3.19	3.44
Nitran	3.31[a]	3.18	3.43
Sladar	4.51[mnopqr]	4.38	4.63
Sladar-new	4.24[fghijklmno]	4.11	4.36
Sladko	4.53[nopqr]	4.41	4.66
Slovenský kvalitný	4.26[ghijklmno]	4.13	4.38
Slovenský Dunajský trh	4.83[rs]	4.71	4.95
Slovenský jemný	4.00[defghi]	3.88	4.12
Average (n=13)**	4.12[a]	3.97	4.26
Group B			
Bučiansky Kneifel	4.29[hijklmnop]	4.17	4.41
Dvoran	4.44[klmnop]	4.31	4.56
Ezer	4.27[hijklmnop]	4.15	4.40
Fatran	4.62[pqr]	4.49	4.74
Galan	4.03[defghi]	3.91	4.15
Garant	4.40[jklmnop]	4.28	4.53
Ludan	3.78[bcd]	3.66	3.91
Nadir	4.02[defghi]	3.90	4.15
Nitriansky Export	3.85[cde]	3.73	3.98
Novum	3.97[defgh]	3.85	4.10
Orbit	4.58[opqr]	4.46	4.70
Vladan	4.63[pqr]	4.50	4.75
Average (n=12)**	4.24[a]	4.09	4.39
Group C			
Amos	4.47[lmnopq]	4.34	4.59
Argument	3.91[cdefg]	3.78	4.03
Cyril	5.05[s]	4.93	5.17
Donum	4.09[defghijk]	3.97	4.21
Horal	4.54[nopqr]	4.42	4.66
Kosan	3.99[defgh]	3.87	4.11
Poprad	4.35[ijklmnop]	4.23	4.47
Pribina	4.41[jklmnop]	4.29	4.53
Progres	4.15[gfghijklm]	4.03	4.28
Slaven	4.39[jklmnop]	4.27	4.51
Stabil	4.03[defghi]	3.90	4.15
Svit	3.90[cdef]	3.77	4.02
Zlatan	4.43[klmnop]	4.31	4.56
Average (n=13)**	4.28[a]	4.14	4.43
Group undetermined			
Diosecký Kneifel	4.56[nopqr]	4.44	4.69
Diosecký Sprinter	4.11[defghijkl]	3.99	4.23
Pudmerický pivovar	4.06[defghij]	3.94	4.19
Vigľašský polojemný	4.21[fghijklmn]	4.09	4.33
Terrasol pivovarský	4.31[hijklmnop]	4.18	4.43
Average (n=5)**	4.25[a]	4.02	4.48

*Values in the same column with different letters are significantly different ($P < 0.05$)
**Average of each malting quality group. Values in the same column with different letters are significantly different ($P < 0.05$)

quality group (Table 4), the highest average value of β-glucan content was acchieved in the group C (4.28%), and the lowest in the group of malting quality A (4.12%). According to Baik *et al.* (2008), the average β-glucan content was in barley grains of normal starch types (4.4%). In our work, despite this fact there were no strong differences observed in the group; in individual years we found greater differences in β-glucan content among genotypes. In the vegetation period of 2010, the highest content of β-glucan was determined in the genotypes Slovenský Dunajský trh (5.03%) and Horal (4.80%). In 2011, the highest level of β-glucan content was detected in Cyril (5.93%), Diosecký 802 (5.51%), and Diosecký Kneifel (5.25%).

However, looking on the average for 2 years, the highest content of β-glucan had the genotype Cyril (5.05%) from of the group C; genotypes Diosecký 802 (4.82%) and Slovenský Dunajský trh (4.83%) from the group A; and Vladan (4.63%) and Orbit (4.58%) from the group B (Table 7). Havrlentová *et al.* (2006) confirmed higher β-glucan content in grains of Orbit.

Based on the evaluation, we found out that older genotypes had higher content of β-glucan in comparison with modern genotypes. According to Fastnaught *et al.* (1996), higher β-glucan content was also in relation to the effect of the heat and drought. Our monitored growing seasons in 2010 and 2011 were within the normal temperature, but they were very wet, and this negatively affected all three analyzed malting quality parameters in barley.

There is a recognized negative correlation between the content of starch and protein in a grain; by increasing protein content, the values of other parameters decline with the exception of degree of attenuation and diastatic power (Prugar & Hraška 1989). Higher positive correlations between β-glucan and protein content were observed by Güler *et al.* (2003). According to Hang *et al.* (2007), simple correlations including the effects of genotype and environmental factors showed that amylose in barley was negatively correlated with β-glucan and protein, but on the other hand β-glucan was posi-

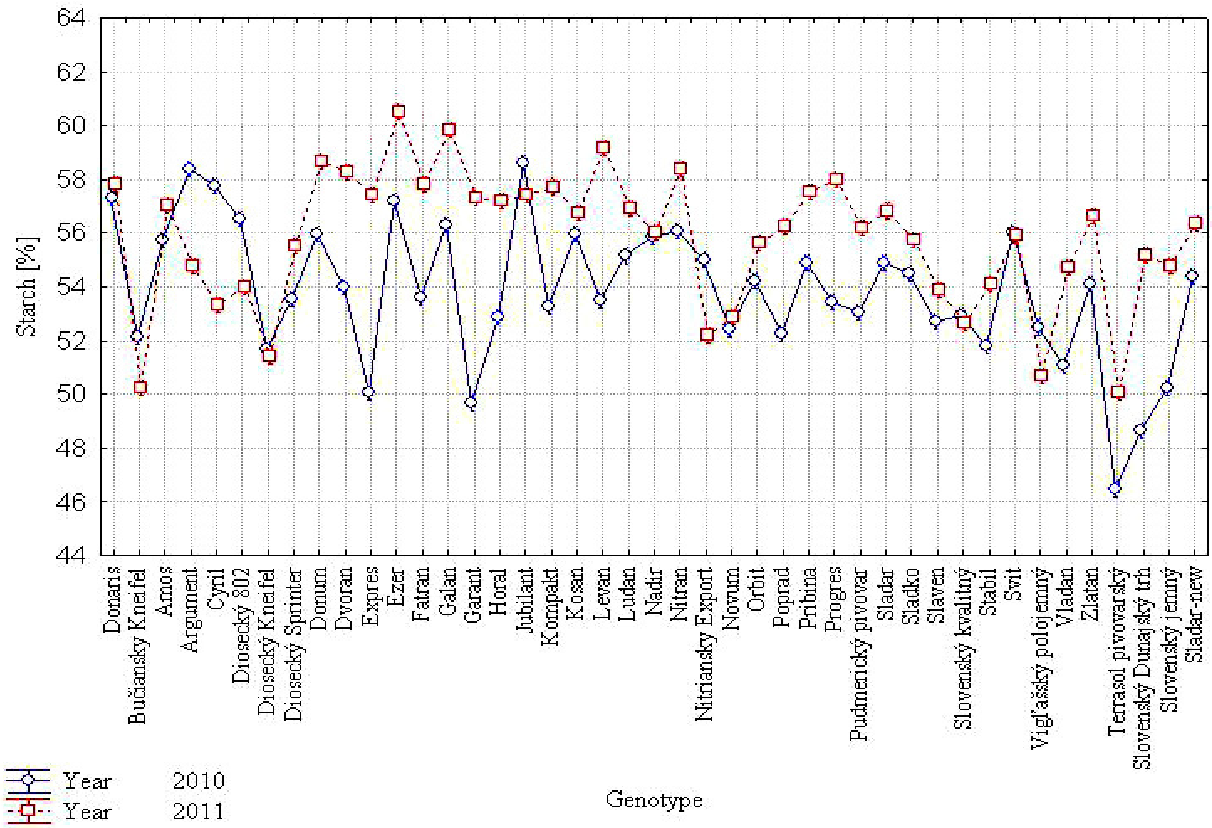


Figure 3. Variability of starch content in barley genotypes during two analyzed years

tively correlated with protein. Positive correlations between β-glucan and protein and β-glucan and grain plumpness are both advantageous to breeders, as each of these traits is desirable for all end uses involving grain consumption. Other authors observed an opposite trend, negative and statistically nonsignificant relationship between β-glucan and protein content (Saastamoinen *et al*. 1992; Welch *et al*. 1989). Our results correspond with these observations only partially. We observed statistically significant negative correlations (Table 8) between the contents of starch and protein (r = –0.775; $P < 0.01$) and between the contents of starch and β-glucan (r = –0.423; $P < 0.01$). Between the contents of protein and β-glucan was observed a statistically significant negative correlation (r = –0.344; $P < 0.05$) too.

T a b l e 8

Correlation matrix of qualitatively parameters in barley genotypes

	Starch	ß-Glucans
Protein	–0.775^{++}	–0.344^{+}
Starch		–0.423^{++}

$^{+}$ significant at 0.05 probability level, $^{++}$ significant at 0.01 probability level

CONCLUSION

In the assessment of 43 Slovak spring barley genotypes, we detected significant (P < 0.01) influence of genotype and environmental conditions (years) on protein, starch, and β-glucan content in the grain. Geno-

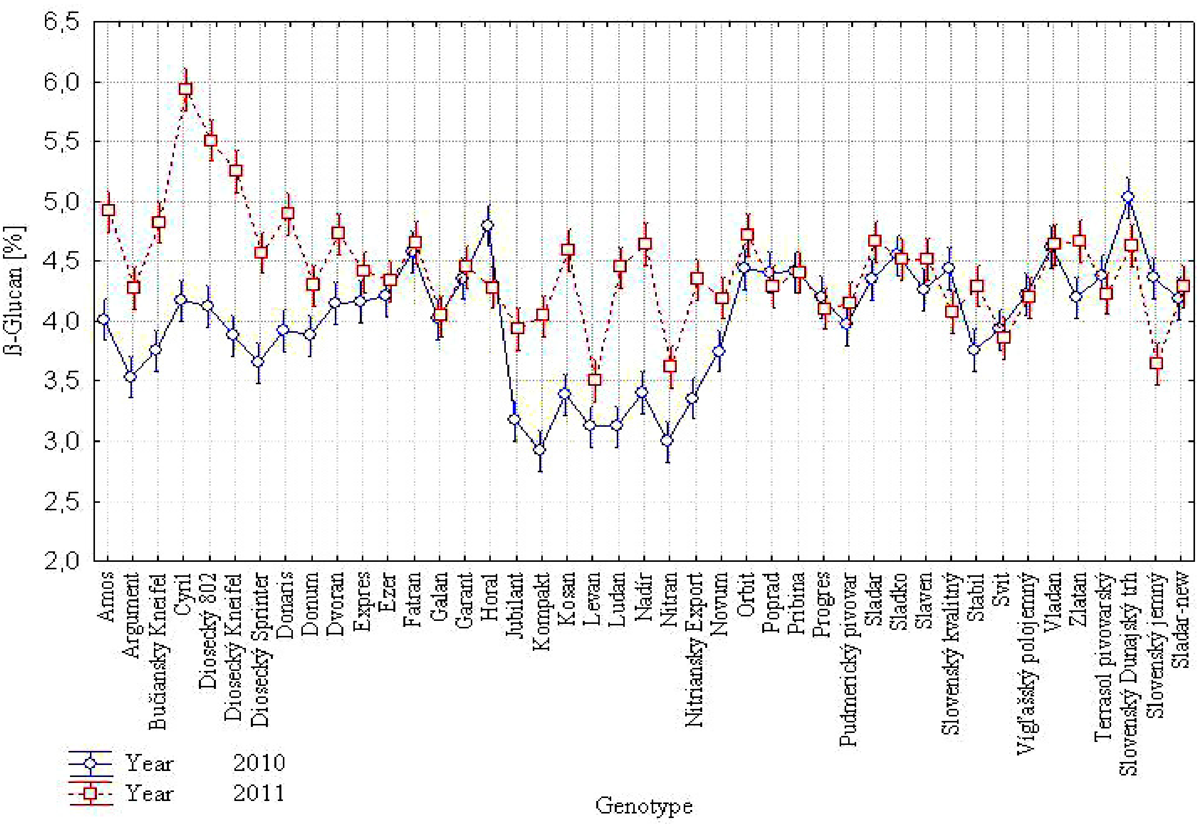


Figure 4. Variability of β-glucan content in barley genotypes during two analyzed years

type × year interaction also had statistically highly significant effects on all monitored parameters. Our study showed that monitored growing seasons (2010, 2011) were within the normal temperature but were very wet, and so this negatively affected all three selected malting quality parameters. The average protein content was the highest in the genotypes from the group with undetermined malting quality. We found out that protein and β-glucan contents in older genotypes were higher in comparison with more recent genotypes. Atypical humid years influenced the content of starch in barley grain and reduced the malting quality. The average starch content was lower in all groups and hardly reached 60% in any genotype, even among high quality malting varieties. The average starch content in both older and modern genotypes in the studied set was nearly identical. This confirms a high quality of the older malting varieties. According to malting quality group, the highest average value of β-glucan content was in the group of no malting quality (C), and the lowest in the group with best malting quality (A). In individual years we found differences in the β-glucan content among genotypes. Despite the atypical years we found out that some good sources of β-glucan were newer genotypes such as Cyril (2000), older genotypes such as Orbit (1986) and Vladan (1996), and also historically old genotypes created in the year 1946 such as Diosecký 802 and Slovenský Dunajský trh. These genotypes, mainly old landraces, are a store of many rare genes and properties, such as resistance to drought and earliness and could be use and destined as a donors of not only significant agronomic but also qualitative properties usable in the food industry.

***Acknowledgements*:** Thanks to the support within Operational Programme Research and Development for the project "Transfer, use and dissemination of research results of plant genetic resources for food and agriculture" (ITMS: 26220220058), cofinanced from the resources of the European Union Fund for Regional Development. The authors are grateful to Ing. M. Bieliková for analyzing proteins and I. Šugrová for cultivating the plant material.

REFERENCES

BAIK, B.K. – ULLRICH, S.E. 2008. Barley for food: Characteristics, improvement, and renewed interest. In *Journal of Cereal Science,* vol. *48*, 2008, no. 2, pp. 233–242.

CANDRÁKOVÁ, E. – KULÍK, D. – BAKUĽA, J. 2000. Využitie jačmeňa na potravinárske účely [Utilization barley for food]. In *Jačmeň výroba a zhodnotenie* : Zborník z odborného seminára. Nitra : SPU Nitra, 2000. ISBN 80-7137-681-7, pp. 100–104.

EHRENBERGEROVÁ, J. – VACULOVÁ, K. – PSOTA, V. – HAVLOVÁ, P. – ŠERHANTOVÁ, V. 2003. Effects of cropping system and genotype on variability in important phytonutrients content of the barley grain for direct food use. In *Plant Soil Environment*, vol. *49*, no. 10, 2003, pp. 443–450.

EHRENBERGEROVÁ, J. 2006. Ječmen potravinářského typu [Barley of food type]. In *ZIMOLKA, J. et al. 2006. Ječmen formy a užitkové směry v České republice* [Barley forms and utility orientations in the Czech Republic]. Praha : Profi Press, 2006. ISBN 80-86726-18-5, pp.171–177.

FASTNAUGHT, C.E. – BERGLUND, P.T. – HOLM, E.T. – FOX, G.J. 1996. Genetic and environmental variation in β-Glucan content and quality parameters of barley for food. In *Crop Science,* vol. *36*, no. 4, pp. 941–946.

GÜLER, M. 2003. Barley grain β-glucan content as affected by nitrogen and irrigation. In *Field Crops Research,* vol. *84*, no. 3, 2003, pp. 335–340.

HANG, A. – OBERT, D. – GIRONELLA, A.N. – BURTON, CH.S. 2007. Barley amylose and β-Glucan: Their relationships to protein, agronomic traits, and environmental factors. In *Crop Science,* vol. *47*, 2007, no. 4, pp. 1754–1760.

HAVRLENTOVÁ, M. – KRAIC, J. 2006. Content of β-glucan in cereal grains. In *Journal of Food and Nutrition Research,* vol. *45*, 2006, no. 3, pp. 97–103.

HAVRLENTOVÁ, M. – BIELIKOVÁ, M. – MENDEL, Ľ. – KRAIC, J. – HOZLÁR, P. 2008. The correlation of (1 → 3) (1 → 4)- β - D-glucan with some qualitative parameters in the oat grain. In *Agriculture (Poľnohospodárstvo)*, vol. *54*, 2008, no. 2. pp. 65–71.

HENRY, R.J. 1986. Genetic and environmental variation in the pentosan and β-glucan contents of barley, and their relation to malting quality. In *Journal of Cereal Science,* vol. *4*, 1986, no. 3, pp. 269–277.

HUTH, M. – DONGOWSKI, G. – GEBHARDT, E. – FLAMME, W. 2000. Functional properties of dietary fibre enriched extrudates from barley. In *Journal of Cereal Science*, vol. *32*, 2000, no. 2, pp. 115–128.

CHARALAMPOPOULOS, D. – WANG, R. – PANDIELLA, S.S. – WEBB, C. 2002. Application of cereals and cereal components in functional foods a review. In *Food Microbiology,* vol. *79*, 2002, no. 1, pp.131–141.

KOSAŘ, K. – PROCHÁZKA, S. 2000. *Technologie výroby sladu a piva* [Technology of malt and beer production]. Praha : Výskumný ústav pivovarský a sladařský, 2000, 43 p. ISBN 80-902658-6-3.

KRAIC, J. – BENKOVÁ, M. 2004. Trends in biological and molekular variation of Barley Driven by long-term breeding. In *9th International barley genetics symposium*

: Proceedings : CD-ROM. – Brno : ARI Kroměžíř Ltd., Czech Republic, 2004, pp. 286–293.

LEKEŠ, J. 1997. *Šlechtění obilovin na území Československa* [Cereal breeding in the territory of Czechoslovakia]. Brázda Praha : Plant Select, 1997, p. 80. ISBN 80-209-0271-6.

Listina registrovaných odrôd [List of registered varieties 2011]. 2011. In *Vestník MPRV SR,* [*Bulletin of the Ministry of Agriculture and Rural Development SR*] vol. *43*, 19 September 2011, part 20.

McCLEARY, B.V. 2011. Megazyme: Mixed-linkage beta-glucan assay procedure (McCleary method) [on line], [cited: 2011-08-20]. Available from <www.megazyme.com>. 80-209-0271-6.

MACNICOL, P.K. – JACOBSEN, J.V. – KEYS, M.M. – STUART, I.M. 1993. Effect of heat and water stress on malt quality and grain parameters of Schooner barley grown in cabinets. In *Journal of Cereal Science,* vol. *18*, 1993, no. 1, pp. 61–68.

National Biodiversity Strategy of Slovakia (adopted by the Government of the Slovak Republic and endorsed by the National Council of the Slovak Republic in 1997 [on line]. Bratislava: Ministry of Environment SR, 2007 [cited: 2010-06-15]. Accessible www: <http://www.enviro.gov.sk/servlets/files/352>.

PRUGAR, J. – HRAŠKA, Š. 1989. *Kvalita jačmeňa* [Quality of barley]. Bratislava : Príroda, 1989, 219 p. ISBN 80-07-00353-3

PSOTA, V. – BRADOVÁ, J. 2009. Historical varieties of spring barley (*Hordeum vulgare* L.) and their use as genetic resources of malting quality. In *Agriculture (Poľnohospodárstvo)*, vol. *55*, 2009, no. 1, pp. 2–9.

REY, J.I. – HAYES, P.M. – PETRIE, S.E. – COREY, A. – FLOWERS, M. – OHM, J.B. – ONG, C. – RHINHART, K. –ROSS, A. S. 2009. Production of Dryland Barley for Human Food : Quality and Agronomic Performance. In *Crop Science*, vol. *49*, 2009, no. 1, pp. 347–355.

SAVIN, R.S. – NICOLAS, M.E. 1996. Effect of short periods of drought and high temperature on grain growth and starch accumulation of two malting barley cultivars. In *Australian Journal of Plant Physiology,* vol. *23*, 1996, no. 1, pp. 201–210.

SAASTAMOINEN, M. – PLAAMI, S. – KUMPULAINEN, J. 1992. Genetic and environmental variation in β-glucan content of oats cultivated or tested in Finland. In *Journal of Cereal Science*, vol. *16*, 1992, no. 3, pp. 279–290.

SLEZIAK, Ľ. 2003. Šľachtenie a semenárstvo jačmeňa [Breeding and barley seed production]. In HOLKOVÁ *et al.* 2003. *Jačmeň, biológia, pestovanie, využívanie* [*Barley, biology, cultivation, utilization*]. Nitra : Agrogenofond, n.o., 2003. ISBN 80-969068-2-8, pp. 51–71.

STATSOFT, Inc. 2008. STATISTICA – data analysis software system, version 8.0.

WELCH, R.W. – LLOYD, J.D. 1989. Kernel (1→3), (1→4)-β-glucan content of oat genotypes. In *Journal of Cereal Science*, vol. *9*, 1989, no. 1, pp. 35–40.

World reference base for soil resources 2006. A framework for international classification,correlation and communication. Rome : FAO, 2006, no. 103, 128 pp. ISBN 92-5-105511-4

ZHANG, G. – CHEN, J. – WANG, J. – DING, S. 2001. Cultivar and environmental effects on (1→3,1→4)-β-D-Glucan and protein content in malting barley. In *Journal of Cereal Science*, vol. *34*, 2001, no. 3, pp. 295–301.

Received: August 23th, 2012