Earliness, spike productivity and protein content in European winter wheat landraces and obsolete cultivars

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ABSTRACT

European winter wheat landraces and obsolete cultivars (121 accessions in set I and 101 accessions in set II) with modern check cultivars were evaluated in three-year field trials. Increased spike productivity in modern cultivars could be attributed mainly to increased number of grains in spikelet and increased HI, whereas TGW has marginal effect. Old cultivars had on average by 2–3% higher crude protein content in grain than modern ones. Among selected 10 characters, relatively wide diversity (*C.V.* 11–20%) has been estimated in spike length and characters of spike productivity (except of grain weight with *C.V.* close to 9%). It was difficult to distinguish the cultivars according to the country of origin, however, earliness and lower spike productivity seems to be characteristic for South-East origin whereas cultivars from North-West Europe showed opposite characters. Correlation analyses showed close relations between earliness in heading and in maturity and negative relation between late heading and grain filling period, which was positively correlated with TGW and HI (r = 0.26 to 0.38). Number of grains in spikelets was highly correlated with spike productivity and HI (r = 0.62 to 0.69) whereas relations between these two characters and TGW were lower (r = 0.20 to 0.51). Spike productivity characters, except of TGW, are in negative correlation with crude protein content in grain (r = –0.34 to –0.50). Regression analyses confirmed that main determining character for the spike productivity is number of kernels in spikelet (about 40% of variation) while effects of TGW are about half-size. Crude protein content was positively affected by plant height (15–30% of variation) impact of grain weight per spike was lower (14–17% of variation) and negative. Potentially valuable donors of earliness and longer grain filling period were identified for further studies and/or utilization in breeding programs. As especially valuable character can be considered very high crude protein content (around 18% in cvs Bergland, Ukrajinka, Sippbachzeller, Innichen Nr. 25001 and Barbu du Finistre). High crude protein content combined with relatively good spike productivity and/or long grain filling period or earliness was found in cvs Visperterminen 640 E, Hatvan, Szekacz 1242, Berchtesgardener Vogel, Ble du Lot and Barbu du Finistere.

Keywords: wheat; geographic origin; genetic diversity; relations among characters; donors

Many modern cultivars, in wheat and in other crops as well, are often rather similar, with relatively narrow genetic base. Therefore, utilization of new sources of diversity in breeding is often discussed (Devkota and Shah 1998, Moghaddam et al. 1998). Landraces, which have arisen through combination of a natural selection and selection performed by farmers (Belay et al. 1995) have some valuable characters which can contribute significantly to improvement of newly bred cultivars and broadening their diversity (Keller et al. 1991, Tesemma et al. 1998). Tolerance to the locally appearing stresses (Li et al. 1997) and on that dependent yield stability are often mentioned as a characteristic features (Tesemma et al. 1998). Landraces and obsolete cultivars represent very valuable part of gene pool (Vojdani and Meybodi 1993, Zou and Yang 1995) because they cover most of intra-specific genetic diversity of crops. Also direct practical utilization of some landraces by local farmers is lately discussed (Brush and Meng 1998).

Beside historical sources and comparative studies, diversity of cultivars can be estimated by means of biochemical techniques and DNA analyses. A cluster analysis is an efficient mathematical method, which makes possible to study diversity among landraces using all available data (Zeven and Schachl 1989, Jaradat 1992, Zeven and Hintum 1992). Significant variability of landraces and old cultivars can be caused by their origin, then through climate, geographical and other conditions of the regions of origin (Hintum and Elings 1991). Wang and Guo (1992) found similarity in gluten alleles in accordance with geographical origin. Ehdaie and Waines (1989) estimated significant genetic variability in grain weight per spike and in productive tillering. Li et al. (1997) found forms with resistance to stresses (frost, drought, salinity) among screened 486 samples from four localities.

Obari (1990) confirms earliness and good adaptability of landraces to high temperatures. Ehdaie and Waines

Experiments and research on European winter wheat landraces and obsolete cultivars were carried out with kind support of the Grant Agency of the Czech Republic (Grant GA CR 521/00/1595).

(1989) point out longer straw and higher amount of non-productive tillers, lower number and mass of kernels per spike as well as lower harvest index in landraces. They confirmed that under conditions of considerable stress, the old cultivars were more productive because of their adaptation to the regularly occurring stresses. Jafari-Shabestari et al. (1995) have found salt-tolerant types among landraces. Grain quality of some wheat landraces should be of special interest because much broader diversity can be found here than in presently grown cultivars. Keller et al. (1991), Wang and Guo (1992), Rodriguez-Quijano et al. (1994) and Yang and Liang (1995) refer to very high protein content in kernels of some landraces of common wheat. In our experiments, the selected landraces proved not only high protein content but also convenient parameters of some other traits of quality (Michalová and Dotlačil 1993).

MATERIAL AND METHODS

Two sets of winter wheat landraces and obsolete cultivars (121 in set I and 101 in set II) originating from European countries (Table 2) with modern cultivars as a check (Sparta, Samanta and Ilona in set I, Samanta and Šárka in set II) were studied in three-years field experiments (set I 1995–1998, set II 1998–2001). Trials were sown on micro-plots (1.5 m^2) in Prague-Ruzyně using standard growing practices when omitting application of growth regulators and fertilizers during vegetation. Earliness and plant height were recorded in field conditions. At the maturity, 30 stems with spikes were taken from each plot to analyse spike morphology, productivity and Harvest index. In addition, crude protein content in seeds was analysed using Kjeltec Auto System II (method by Kjeldahl).

Statistical analysis has been carried out by means of software Unistat; ANOVA and general statistics were calculated on the base of primary experimental data, Spearman coefficients of correlation and parameters of linear regression as well as stepwise regression were calculated using mean values of characters from three years.

RESULTS AND DISCUSSION

A comparison of value of evaluated characters in landraces and old cultivars to modern cultivars, which were used as check in the both experimental sets, can indicate the changes achieved through breeding. Of course, the modern cultivars embody higher spike productivity (grain weight per spike was higher by 9% and 31%, respectively) than old ones (Table 1). Considerable difference between both sets of cultivars can be first attributed to the higher productivity of advanced check cultivars in the set II, in some extent also to the better climatic conditions during trials with set II where check cultivars could better assert their potential. It is obvious that this progress was mainly due to the significant increase in the number of grains per spikelet (16% and 37%, respectively) whereas weight of grains did not change substantially. The increase of spike productivity was facilitated by the increase of harvest index (in our experiments by 23% and 31%, respectively) due to stem shortening (33% and 38%, respectively). It seems that spike length was influenced by breeding much less. No significant differences were observed in earliness; however, it was difficult to make the reliable conclusions due to very narrow spectra of modern cultivars in trials. Still it seems that breeding led to somewhat longer grain filling period (by 2–3 days) in modern cultivars.

Beside increased productivity characters, the decreased crude protein content in seeds is rather general phenomenon (in our experiments by 22% and 16%, respectively). Even when we can found low protein culti-

Table 1. Diversity in evaluated characters within the two sets of winter wheat landraces and old cultivars of European origin

Character	Check cultivar		Landraces and obsolete cultivars of winter wheat									
	mean values		mean values		variance		coefficient of variance (%)		maximum value		minimum value	
	set I	set II	set I	set II	set I	set II	set I	set II	set I	set II	set I	set II
Days to heading	153	143	160	150	19.0	45.6	2.7	4.5	170	165	150	131
Days to maturity	211	200	215	205	4.1	15.1	0.9	1.9	219	213	211	195
Grain filling period (days)	49	53	47	50	5.9	5.5	5.1	4.7	52	56	41	45
Plant height (cm)	86	85	114	117	59.6	103.2	6.8	8.7	131	133	83	77
Spike length (cm)	7.9	8.8	9.2	8.4	1.2	1.3	12.3	13.7	12.0	12.3	6.3	6.1
Grain weight per spike (g)	1.34	1.95	1.23	1.49	0.06	0.06	19.9	16.4	2.00	2.07	0.67	0.90
Number of grains per spikelet	1.99	2.51	1.71	1.83	0.04	0.05	11.1	12.0	2.25	2.70	1.24	1.27
Thousand grain weight (g)	39.8	47.9	3.96	44.4	12.3	17.7	8.9	9.5	47.9	56.6	29.8	34.9
Harvest index	0.48	0.51	0.39	0.39	0.001	0.002	9.0	9.9	0.53	0.53	0.23	0.25
Crude protein content (%)	13.3	13.2	16.2	15.3	1.12	1.13	6.5	6.9	19.9	18.1	13.3	13.0

set I: n = 124 including 3 check cvs, set II: n = 103 including 2 check cvs

Table 2. Mean values of selected characters in groups of cultivars assessed by the country of origin

Country of origin	Number of accessions in experimental sets		Plant height (cm)		Spike length (cm)		Grain weight per spike (g)		Thousand grain weight (g)		Number of grains per spikelet		Harvest index	
	set I	set II	set I	set II	set I	set II	set I	set II	set I	set II	set I	set II	set I	set II
Czech/Slovak	19	2	108	85	9.1	8.8	1.35	1.95	41.1	47.9	1.80	2.52	0.42	0.51
Austria	9	9	118	120	9.5	8.0	1.27	1.30	40.6	42.3	1.73	1.84	0.39	0.40
Bulgaria	3	5	111	119	9.5	9.0	0.95	1.55	41.5	45.3	1.46	1.88	0.40	0.40
Switzerland	10	5	112	124	9.3	8.3	1.16	1.24	37.3	43.9	1.72	1.63	0.38	0.35
Denmark	8	3	114	113	9.0	8.5	1.25	1.53	36.3	39.8	1.76	1.93	0.37	0.40
France	13	16	113	121	9.4	9.0	1.11	1.38	40.7	45.2	1.57	1.86	0.36	0.40
Great Britain	5	–	113	–	7.8	–	1.48	–	38.5	–	1.90	–	0.39	–
Germany	16	31	116	120	8.9	8.5	1.29	1.64	40.1	45.1	1.70	1.91	0.39	0.40
Hungary	10	–	113	–	8.6	–	1.04	–	39.6	–	1.73	–	0.40	–
Netherlands	3	7	115	111	9.0	7.3	1.11	1.51	36.7	43.6	1.64	2.01	0.35	0.39
Poland	5	6	120	121	9.7	8.3	1.47	1.46	41.7	43.6	1.82	1.86	0.39	0.39
Russia/Ukraine	17	5	115	122	9.2	8.8	1.13	1.46	39.2	46.5	1.63	1.92	0.39	0.42
Sweden	5	5	116	108	8.6	7.8	1.34	1.62	38.6	42.1	1.72	1.89	0.38	0.40
Other	–	7	–	113	–	8.6	–	1.34	–	44.4	–	1.86	–	0.41
F-test			2.5*	7.6*	2.8*	2.8*	6.4*	3.1*	2.6*	3.1*	3.5*	2.5*	4.6*	3.2*
LSD (Sheffe, 95%)			5	4	0.4	0.4	0.07	0.09	2.1	2.2	0.18	0.19	0.01	0.02

*$P < 0.05$

vars among landraces and obsolete cultivars as well, most of them (especially those with long stem) are characterized by high protein content.

Diversity in evaluated characters within both experimental sets of landraces and obsolete cultivars is characterized in Table 1. Higher variability in earliness has been found at heading time (*C.V.* = 2.7% in set I and 4.5% in set II, respectively) and this variability has decreased in maturity (*C.V.* = 0.9% and 1.9%, respectively). When comparing landraces and obsolete cultivars to modern check cultivars the mean vegetation period was shorter in modern ones by 7 days in heading and by only 4 or 5 days in the maturity. Variability in grain filling period was higher than in the previous characters (*C.V.* = 5.1% and 4.7%, respectively) and it was by 2 or 3 days longer in the modern cultivars. The longest grain filling period in the set I (52 days) had cultivars Guttet 491, Sarrayer 602 H and Landvete fran Uppsala, in the set II cultivars Lovink, Ljutescens 192, Ackermanns Bayernkoenig, Bon Fermier, Allies (54 days) and French cv. Ble du Lot (56 days).

Rather high variability within both sets was estimated in spike length (*C.V.* = 12.3% and 13.7%, respectively), whereas variability in plant height was relatively lower (*C.V.* = 6.8% and 4.7%, respectively). Whereas it was hardly possible to find unambiguous changes is spike length in the modern cultivars the plant height has been significantly reduced by about 30 cm. This fact is commonly known and especially most of landraces had very long stem (110–133 cm), somewhat shorter stem was found in obsolete bred cultivars. Nevertheless, some exceptions could be found, e.g. obsolete cultivars Rimpaus frueher Bastard and Pyšelka in the set I and Lovink, Aquilela and Jafet in the set II shoved reduced plant height (less than 1 m).

Huge diversity was estimated in characters of spike productivity. Among these characters, thousand grains weight proved the lowest variation (*C.V.* = 8.9% and 9.5%, respectively), followed by number of grains per spikelet (*C.V.* = 11.1% and 12.0%, respectively). Grain weight per spike as a composite character has the highest variability among spike productivity parameters (19.9% and 16.4%, respectively). Within the set I a high grain weight per spike has been estimated in cv. Tschermacks Marchfelder (2.0 g), which was based on the high number of grains per spikelet (2.06) as well as high grain mass (TGW = 46.2 g). Grain weight per spike over 1.7 g was also recorded in cultivars Antoninska Wczesna (balanced high values of all characters), Židlochovická jubilejní osinatá (TGW 46.7 g) and Victor (2.05 grains per spikelet). These cultivars were middle-early in maturity, with longer grain filling period. Cultivars Nordharzer Burg, Little Tiche, Slazaczka and Rimpaus Brauner Weizen evaluated in the set II showed mean grain weight per spike 1.9–2.0 g, the spike productivity was based mainly on high number of grains per spikelet (2.03–2.07) whereas TGW vary between 47–54 g. These cultivars were middle early to middle-late in maturity and showed medium grain filling period.

Harvest index was very low in landraces (due to long stem and relatively low productivity) and increased in obsolete cultivars and of course in modern check cultivars with short stem and high productivity. The estimated variability (*C.V.* = 9.0% and 9.9%, respectively) can be caused mainly by the differences between above-mentioned groups. However, also some obsolete cultivars had high HI (Hatvan 0.48, Židlochovické jubilejní osinatá and Česká přesívka 0.45 within set I, Japet 0.47, A 15–0.48 and Lovink 0.50 within the set II). On the opposite, some landraces showed HI close to 0.3 (Gelderse Ris, Blanc de Lorraine, Saumur d'Automne in the set I, Willem I and Bretonniers in the set II).

Variability in crude protein content in grains can be considered as medium (*C.V.* = 6.5% and 6.9%, respectively) and its value is comparable to the variability in e.g. plant height. Most of landraces and obsolete cultivars had higher protein content than check cultivars, in some of them very high crude protein content was found (in the set I e.g. Bergland 18.7%, Ukrainka 18.1%, Sipbachzeller zu 213004 19.0%, in the set II Barbu du Finistere 18.0% and Innichen [Suedtirol] 18.1%). Even when high crude protein content in landraces has been frequently referred, e.g. by Keller et al. (1991), Wang and Guo (1992), Michalová and Dotlačil (1993), Rodriguez-Quijano et al. (1994) and Yang and Liang (1995), the high values as we have found should always be considered carefully and in relation to different growing conditions. However, crude protein content in check cultivars did not exceed 13.4% in the set I and 13.5% in the set II, which conforms to known characteristics of these cultivars. In addition, relations between high-protein landraces and check cultivars in particular years were rather conforming.

Above-mentioned results support the hypotheses, that mainly gluten quality has been improved through breeding, whereas protein content has decreased in present cultivars. However, forms with high crude protein content as well as high protein quality could be found in old cultivars studied (e.g. Bergland, Barbu du Maconnais or Mindeszentpusztai in the set I and No. 14 [Ruse], Givrins and Zlota Maczuga in the set II). Some of studied landraces and old cultivars could be utilized in breeding, especially as donors of high crude protein content and probably protein quality. Among other important characters the earliness and the length of grain filling period can be of breeders' interest and some donors of these characters could be found among landraces and obsolete wheat cultivars, too.

It is obvious, that conditions of climate and soil in regions from which cultivars originate can influence their characters, especially in landraces, where environmental conditions can have substantial impact (Belay et al. 1995, Tesemma et al. 1998). Therefore, simple classification of cultivars according to the country of origin has been used to estimate the impact of geographic origin on selected evaluated characters; results are summarized in Table 2. Cultivars from the territory of former Czechoslovakia are classified as one group (Czech and Slovak cultivars), as well as cultivars from the territory of former Soviet Union (now Russia and Ukraine). In addition to the two above-mentioned groups, cultivars from other 11 European countries were studied.

Early heading and maturity were found especially in cultivars from Hungary and Bulgaria, on the contrary the late heading and maturity were characteristic for cultivars originating from West and North Europe (especially from the Netherlands, Great Britain, Denmark, Germany and Sweden). Plant height and spike length differed between particular groups; however, it was difficult to find some relations to the geographic origin of cultivars. Shorter stem and higher spike productivity in Czech and Slovak cultivars is caused mainly by the fact that check cultivars and some old cultivars bred from original landraces (but with shorter stem) were involved. Hardly any conclusions can be made for the harvest index, due to the high heterogeneity of cultivars and differences between both evaluated sets. As concerns the spike productivity, low grain weight per spike has been found in cultivars from France, Switzerland and Austria (also due to the frequent occurrence of old local cultivars). On the contrary, cultivars from Great Britain, Germany, Sweden, Poland and Denmark seem to have higher grain weight per spike. Higher number of grains per spikelet was found in cultivars originating from Great Britain (1.90), Denmark (1.76 and 1.93, respectively) and from some other West-European countries. As concerns grain weight and crude protein content, it was not possible to draw some conclusions on the base of geographic origin.

Clustering according to the country of origin enabled only very rough description of few characters. It seems that within the evaluated landraces and cultivars two groups with some specific characters responding to warmer arid and colder humid climates can be distinguished:

1. Cultivars from (South)-East Europe (Bulgaria, Hungary, partially also Russia and Ukraine), where earliness and lower spike productivity are characteristic
2. Cultivars from (North)-West Europe (Great Britain, Sweden, Denmark, the Netherlands and partially other countries), with higher spike productivity and a bit longer period of vegetation

However, such distinction is not too convincing. It seems that within the European region the geographic origin itself is not sufficient criterion for characterization of landraces and obsolete cultivars, probably also due to the extensive exchange of materials in the past and later due to their utilization in breeding throughout the Europe.

Landraces were developed by combination of a natural selection and simple selection made by farmers (Belay et al. 1995), later they were used in breeding as a base of newly bred cultivars. Therefore, landraces and obsolete cultivars represent very valuable part of gene pool (Vojdani and Meybodi 1993, Zou and Yang 1995) because they cover most of intra-specific genetic diversity of crops. This is a reason why these materials are suitable for studies of genetic diversity and relations between characters, which can be estimated e.g. by means of correlation and regression analyses used in this study.

Correlation analysis showed rather similar results for most characters in both experimental sets (Table 3). Due to a high number of variants (n = 124 in set I and n = 103 in set II), even relatively low values of correlation coefficients are significant.

Table 3. Correlations (*r* by Pearson) among characters in two sets of winter wheat cultivars

Characters	Experimental set	2.	3.	4.	5.	6.	7.	8.	9.	10.
1.	I	0.80*	–0.81*	0.19*	–0.11	–0.12	–0.32*	–0.02	–0.44*	–0.14
	II	0.88*	–0.51*	0.19*	0.05	–0.11	–0.27*	0.23*	–0.38*	–0.27*
2.	I	–	–0.35*	0.25*	–0.01	–0.17*	–0.24*	–0.03	–0.50*	–0.02
	II	–	–0.15	0.14	0.07	–0.05	–0.10	0.38*	–0.32*	–0.32*
3.	I	–	–	–0.05	0.22*	0.05	0.29*	0.05	0.27*	0.20*
	II	–	–	–0.17*	–0.01	0.15	0.38*	0.14	0.26*	0.02
4.	I	–	–	–	0.34*	–0.05	0.01	0.08	–0.31*	0.35*
	II	–	–	–	0.28*	–0.39*	0.12	–0.17*	–0.53*	0.55*
5.	I	–	–	–	–	–0.04	0.28*	0.21*	–0.04	0.19*
	II	–	–	–	–	–0.00	0.24*	0.19*	–0.05	0.10
6.	I	–	–	–	–	–	0.09	0.67*	0.64*	–0.34*
	II	–	–	–	–	–	–0.01	0.62*	0.69*	–0.44*
7.	I	–	–	–	–	–	–	0.51*	0.26*	–0.06
	II	–	–	–	–	–	–	0.44*	0.20*	0.12
8.	I	–	–	–	–	–	–	–	0.43*	–0.38*
	II	–	–	–	–	–	–	–	0.49*	–0.50*
9.	I	–	–	–	–	–	–	–	–	–0.35*
	II	–	–	–	–	–	–	–	–	–0.43*

1. days to heading, 2. days to maturity, 3. grain filling period, 4. plant height, 5. spike length, 6. number of grains per spikelet, 7. thousand grain weight, 8. grain weight per spike, 9. harvest index, 10. crude protein content
set I: $n = 124$, set II: $n = 103$, $*P > 0.01$

Earliness in heading was in both sets closely related to the earliness in maturity ($r = 0.80$ and 0.88, respectively) and negatively influenced the grain filling period ($r = –0.81$ and –0.51, respectively). Relation between the length of vegetation and the grain filling period was low and negative and significant only in set I ($r = –0.35$). Earliness in heading and also in maturity has negative influence on HI (–0.44, –0.38 and –0.50, –0.32, respectively) and TGW (–0.32, –0.27 and –0.24, –0.10, respectively); negative relation to crude protein content was proved only in set II ($r = –0.27$ and –0.32) as well as positive influence on grain weight per spike ($r = 0.23$ and 0.38). Slight increase of plant height with number of days to heading and maturity was also shown. The length of grain filling period was positively correlated with TGW ($r = 0.29$ and 0.38, respectively) and with HI ($r = 0.27$ and 0.26, respectively).

Among morphological characters, there is a lower positive correlation between plant height and spike length in the both sets of cultivars ($r = 0.34$ and 0.28, respectively). Both these characters were positively correlated to the crude protein content (especially plant height, where $r = 0.35$ and 0.55, respectively). Spike length has low positive influence on TGW ($r = 0.28$ and 0.24, respectively) and grain weight per spike ($r = 0.21$ and 0.19, respectively), whereas increased plant height results in lower HI ($r = –0.31$ and –0.53, respectively) and in the set II also in lower number of kernels per spikelet and lower spike productivity.

An important outcome is that in both experimental sets the mutual independency of both basic elements of spike productivity (that is TGW and number of grains per spikelet) has been confirmed. Among these characters, number of grains in spikelet is more closely correlated to the grain weight per spike ($r = 0.67$ and 0.62) and HI ($r = 0.64$ and 0.69) than TGW ($r = 0.51$, 0.44 and 0.26, 0.20, respectively); correlation between HI and grain weight per spike was rather high ($r = 0.43$ and 0.49, respectively). Spike productivity characters, except of TGW and HI are in negative correlation with crude protein content in grain ($r = –0.34$ to –0.50). This conclusion implies close linkage between increased productivity and number of grains per spikelet (and spike) whereas TGW reflects more environmental conditions and it is not linked with the breeding progress.

In the next step, the effects of particular characters on two final important characters – grain weight per spike (GWS) and crude protein content (CPC) were estimated by means of stepwise regression analyses; the results are compiled in Table 4. The stepwise regression provides information which independent variables should be included in the regression equation (*s*).

Results of regression analyses for both sets of experimental materials were less conforming than those from correlation analyses, probably due to interactions among characters appraised in regression. Grain weight per spike was predominantly determined by the number of grains per spikelet (coefficient of determination $R^2 = 46\%$ and 39%, respectively), increased number of kernels in spikelet by one would theoretically result in increased grain weight per spike by 0.79 g or 0.53 g in the sets I or II, respectively). This rather different effect in the two sets

Table 4. Stepwise regression of characters (independent variables) on the grain weight per spike and crude protein content (dependent variable in two sets of winter wheat

Independent variables	Grain weight per spike						Crude protein content					
	set I			set II			set I			set II		
	step	R^2	*cr**	step	R^2	*cr**	step	R^2	*cr**	step	R^2	*cr**
Days to heading	3	0.70	0.01	–	–	–	–	–	–	4	0.57	– 0.04
Days to maturity	–	–	–	3	0.80	0.03	–	–	–	–	–	–
Grain filling period (days)	–	–	–	6	0.84	–0.01	3	0.35	0.11	–	–	–
Plant height (cm)	–	–	–	–	–	–	2	0.29	0.05	1	0.30	0.05
Spike length (cm)	4	0.71	0.03	–	–	–	–	–	–	–	–	–
Number of grains per spikelet	1	0.46	0.79	1	0.39	0.53	–	–	–	–	–	–
Thousand grain weight (g)	2	0.66	0.03	2	0.59	0.03	–	–	–	3	0.55	0.06
Grain weight per spike (g)	–	–	–	–	–	–	1	0.14	–1.83	2	0.47	– 2.06
Harvest index	–	–	–	5	0.83	1.04	–	–	–	–	–	–
Crude protein content (%)	–	–	–	4	0.82	–0.03	–	–	–	–	–	–

R – cumulative values of R^2 (coefficient of determination) particular steps (independent variables involved), *cr* – coefficient of regression, only those coefficients of regression are given where $*P > 0.05$
set I: $n = 124$, set II: $n = 103$

can be predicated to the higher level of spike productivity within cultivars gathered in the set II (mean values 1.83 grains per spikelet and spike yield 1.49 g) when compared to the set I (1.71 and 1.23 g, respectively) due to higher presence of landraces and older materials in the set I. Identical results in both sets were obtained in the second step of regression analyses, when TGW contributed by 20% to the spike productivity (see cumulative values of $R^2 = 0.66$ and 0.59, respectively) and increase of TGW by 1 g could theoretically contribute to the spike yield improvement by 0.03 g. The different trends for number of kernels per spikelet and TGW in two experimental sets confirm less important role of TGW by spike productivity improvement and prevailing effect of spikelet fertility increase. Significant but low contribution to the spike productivity was noted for time to heading (4% of variability) and spike length (1%) in the set I, whereas in the set II period to maturity has the same effect on spike yield (21% of variability) as TGW and marginal effects were confirmed for crude protein content (2%), HI (1%) and slight negative effect for long grain filling period (1%).

While in spike yield 71% and 84% of variability could be assigned to other variable characters, significantly lower level of determination has been documented in second final character – crude protein content (35% and 57%). In both experimental sets plant height and grain weight per spike strongly influenced crude protein content (cumulative values of $R^2 = 0.29$ and 0.47, respectively). While plant height was responsible for 15% and 30% determination of this character respectively and 10 cm elongation of plant would indicated 0.5% increase in crude protein content, increasing grain weight per spike affected significant decrease of protein content and it was responsible for 14% or 17% of variability, respectively. Positive effect of longer grain filling period was demonstrated only within the set I (4% of variation), whereas in the set II positive influence of TGW (8% of variation) and slight negative effect of later heading (2% of variation) were significant. Stepwise regression analyses did not acknowledge negative linkage between number of grains per spikelet and crude protein content in kernels, as indicated by correlation analyses ($r = -0.34$ and –0.44, respectively). This might be due to the nature of simple correlations, which summarize composite effects whilst stepwise regression could analyse impacts of particular characters.

The results proved, that donors of valuable characters can be found among landraces and obsolete cultivars and some of them were mentioned in discussion on diversity in particular characters. For practical reasons it is important to have knowledge, beside requested character, also about other agronomically important characters of potential donors (in our case about earliness, spike productivity and protein content). In spite the negative relations between spike productivity and protein content, some high-protein cultivars with acceptable level of spike productivity (and/or earliness) could be found in the both sets. Within the set I, cvs Visperterminen 640 E, Hatvan and Szekacz 1242 provided over 17.4% of protein content, 1.92–2.03 kernels per spikelet (mean value 1.71) and spike productivity 1.28–1.33 g (mean value 1.23 g) and grain filling period was over 50 days (mean was 47) in all of them. In addition, the last two Hungarian cvs were also early maturing. Within the set II, cvs Berchtesgardener Vogel, Ble du Lot and Barbu du Finistere showed crude protein content over 17% when number of kernels per spikelet was 1.87–2.10 (by mean value 1.83). Berchtesgardener Vogel and Ble du Lot have also relatively good spike productivity (1.57 g and 1.43 g, mean value was 1.49 g) and beside that, the French cv. Ble du Lot was very early with very long grain filling period (56 days, when mean value was 50 days).

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Received on October 3, 2002

ABSTRAKT

Ranost, produktivita klasu a obsah bílkovin u evropských krajových a starých odrůd ozimé pšenice

Evropské krajové a staré odrůdy ozimé pšenice (121 položek v souboru I a 101 položek v souboru II) spolu s kontrolními moderními odrůdami byly hodnoceny v tříletých polních pokusech. Vyšší produktivita klasu u moderních odrůd může být přisouzena především zvýšenému počtu zrn v klásku a zvýšenému HI, zatímco HTS měla malý efekt. Mezi deseti vybranými znaky byla zjištěna relativně velká diverzita (*Vk* 11 až 20%) v délce klasu a charakteristikách produktivity klasu (s výjimkou hmotnosti zrna, u níž *Vk* dosáhl 9%) a některých ukazatelích kvality zrna (SDS-test a zvláště pak gluten index, u něhož byla nalezena vůbec nejvyšší variabilita). Rozlišit odrůdy podle země původu bylo obtížné, nicméně odrůdy z jihovýchodní Evropy se vyznačovaly raností a nižší produktivitou klasu, zatímco odrůdy ze severozápadu Evropy měly opačné charakteristiky. Korelační analýza prokázala úzký vztah mezi raností v metání a ve zralosti a negativní korelaci mezi pozdním metáním a dobou tvorby zrna, která byla pozitivně korelována s HTS a HI (hodnota r = 0,26 až 0,38). Počet zrn v klásku byl vysoce korelován s produktivitou klasu a HI (r = 0,62 až 0,69), zatímco korelace mezi těmito dvěma znaky a HTS byly nižší (r = 0,20 až 0,51). Znaky produktivity klasu byly s výjimkou HTS negativně korelovány s obsahem hrubého proteinu v zrnu (r = –0,34 až –0,50). Regresní analýza potvrdila, že hlavním určujícím znakem produktivity klasu je počet zrn v klásku (asi 40% variability) a HTS má pouze asi poloviční efekt. Obsah hrubého proteinu byl pozitivně ovlivněn výškou rostliny (15%, resp. 30% variability), negativní efekt hmotnosti zrna na klas byl nižší (14% až 17% variability). Byly nalezeny potenciálně cenné donory ranosti a delší doby plnění zrna pro další studie a případné využití ve šlechtitelských programech. Za zvláště cenný znak je možné považovat vysoký obsah hrubého proteinu v zrnech (kolem

18% u odrůd Bergland, Ukrajinka, Sippbachzeller, Innichen Nr. 25001 a Barbu du Finistre). Vysoký obsah hrubého proteinu spolu s relativně dobrou produktivitou klasu nebo dlouhou dobou plnění zrna či raností byl zjištěn u odrůd Visperterminen 640 E, Hatvan, Szekacz 1242, Berchtesgardener Vogel, Ble du Lot a Barbu du Finistere.

Klíčová slova: pšenice; geografický původ; genetická rozmanitost; vztahy mezi znaky; donory

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