How Can Wheat Landraces Contribute to Present Breeding?

L. DOTLAČIL, J. HERMUTH, Z. STEHNO, V. DVOŘÁČEK, J. BRADOVÁ and L. LEIŠOVÁ

Crop Research Institute, 161 06 Prague-Ruzyně, Czech Republic, e-mail: dotlacil@vurv.cz

Abstract: Two sets of winter wheat landraces and obsolete cultivars were studied in three-year field experiments, and compared with 3 modern control cultivars. The higher spike productivity in modern cultivars could mainly be attributed to an increased number of grains in a spikelet and harvest index (HI), whereas thousand grain weight (TGW) has only a slight effect. Landraces and old cultivars proved to have a higher content of crude protein. Spike productivity characteristics, except for TGW, showed a negative correlation with the crude protein content in the grain. The number of kernels in a spikelet strongly affected the spike's productivity, whereas the TGW has only half the effect. The mean yield of four modern cultivars was 51% higher than the mean yield of 31 landraces and obsolete cultivars. Regression analysis proved the much stronger response of modern cultivars to environment (b = 1.63), then was the response of old cultivars (b = 0.87). Different responses to environments were found within the set of 31 landraces, as well. We could also identify potentially valuable donors of earliness and winter hardiness among the old cultivars. High crude protein content (up to 18%), and other valuable quality characteristics, were rather frequent. In both sets, HMW *Glu*-subunits were described, and we have additionally studied 67 selected lines. Among them, 10 lines showed the crude protein content of 17.5% to 18.3% (where the gluten index and Zeleny test varied from 28.5 to 54.0 and 36.8 to 61.7, respectively). High values of all quality characteristics showed lines gained from the cultivars Mindeszentpusztai (HUN), Szekacz 19 (HUN), Bartweizen linie a (AUT), Viglašská červenoklasá (CZE), as well as some others.

Keywords: donors of traits; genetic diversity; grain quality; landraces; stress tolerance; yield stability

Many modern cultivars, in wheat and in other crops as well, are often genetically similar, with a rather narrow genetic base. Therefore, in breeding we need to also utilize sources of new diversity. Landraces, which have arisen through a combination of natural selection and the selection performed by farmers (Belay *et al.* 1995), usually have a broader genetic base and can therefore provide valuable characteristics important for breeding (Keller *et al.* 1991; Tesemma *et al.* 1998). Tolerance to local stresses (Li *et al.* 1997) and the resulting good yield stability are also often referred to in landraces (Tesemma *et al.* 1998). Landraces and obsolete cultivars can be considered as a valuable portion of the gene pool (Vojdani & Meybodi 1993; Zou & Yang 1995), because they represent the broad intra-specific genetic diversity of crops, from which new cultivars have arisen. Due to those valuable characteristics, the direct practical utilization of some landraces by farmers is also discussed (Brush & Meng 1998).

Protein content and some other grain quality traits of wheat belong to the features in which landraces usually provide a much broader diversity than do current cultivars. Keller *et al.* (1991), Wang and Guo (1992), Rodriguez-Quijano *et al.* (1994), and Yang and Liang (1995) refer to the high protein content in some landraces of common wheat (*Triticum aestivum* L.). In our previous experiments, the selected landraces not only showed a high protein content, but also desirable values of some other quality characteristics (Michalová & Dotlačil 1992).

MATERIALS AND METHODS

Two sets of winter wheat landraces and obsolete cultivars (122 accessions in Set I and 101 in Set II,

respectively), originating from the European region and maintained in the Czech wheat collection, were sown in 3-year non-replicated micro-plot (2.5 m^2) field trials in Praha-Ruzyně (jointly with 3 modern Czech cultivars Samanta, Šárka and Ilona as controls). Beside the evaluation of important agronomic characteristics in the field, we also estimated spike productivity, HI, and some grain quality characteristics in the laboratory tests.

The 31 selected landraces and obsolete cultivars were further evaluated in standard field trials, using 4 randomized blocks (plots of 10 m^2, 3 years and two localities: Praha-Ruzyně and Piešťany, Slovakia). In this set, we estimated the grain yields and yield response to environment, using analyses by both Finlay and Wilkinson (1963) and Eberhart and Russel (1966). The analysis was based on linear regression of the particular cultivar to the mean values of all cultivars in a range of environments.

Simultaneously, we analyzed the HMW-*Glu* patterns (100 individual halved grains) with SDS-PAGE. The gained lines were characterized by HMW Glu-alleles, according to Payne and Lawrence (1983).

Further, we evaluated the selected 67 high-protein lines with the identified HMW-*Glu* alleles, which were derived from earlier tested materials. The lines were sown in 3-year trials in Praha-Ruzyně (the same experimental design as in Set I and Set II). We analyzed the agronomic characteristics (including spike morphology, productivity, and harvest index). Protein content was evaluated by Kjeldahl; plus the Zeleny test (ml) and Gluten index (%) were carried out.

All the experiments were successively performed during 1998 to 2007. In the field experiments, we used neither growth regulators nor N-fertilizers during the growing season (fertilizers were only applied in autumn before sowing). We used UNISTAT statistical software for the data processing.

RESULTS AND DISCUSSION

The Increase in spike productivity in modern cultivars can mainly be attributed to the increased number of grains in a spikelet and increased HI, whereas TGW has only a smaller effect. On average, old cultivars had a 2 to 3% higher crude protein content in the grain than do the modern ones (Table 1). Among the 10 characteristics measured, a relatively wide variability (*CV* 11–20%) has been estimated in spike length and the characteristics of spike productivity (except of the grain weight, with *CV* close to 9%). It was difficult to distinguish

Table 1. Differences in evaluated characteristics between modern winter wheat cvs. versus landraces and obsolete cvs.; variability of characteristics as recorded in two field experiments

	Check cvs (3)		Landraces and obsolete cvs			
	mean values		mean values		*CV* (%)	
	set I	set II	set I	set II	set I	set II
Days to heading	153,00	143.00	160.00	150.00	2.7	4.5
Days to maturity	211.00	200.00	215.00	205.00	0.9	1.9
Grain filling period (days)	49.00	53.00	47.00	50.00	5.1	4.7
Plant height (cm)	86.00	85.00	114.00	117.00	6.8	8.7
Spike length (cm)	7.90	8.80	9.20	8.40	12.3	13.7
Grain weight per spike (g)	1.34	1.95	1.23	1.49	19.9	16.4
Grains per spikelet	1.99	2.51	1.71	1.83	11.1	12.0
Thousand grain weight (g)	39.80	47.90	39.60	44.40	8.9	9.5
Harvest index	0.48	0.51	0.39	0.39	9.0	9.9
Crude protein content (%)	13.30	13.20	16.20	15.30	6.5	6.9

Set I: n = 124 including 3 control cvs.; Set II: n = 103 including 3 control cvs.; *CV* – coefficient of variation

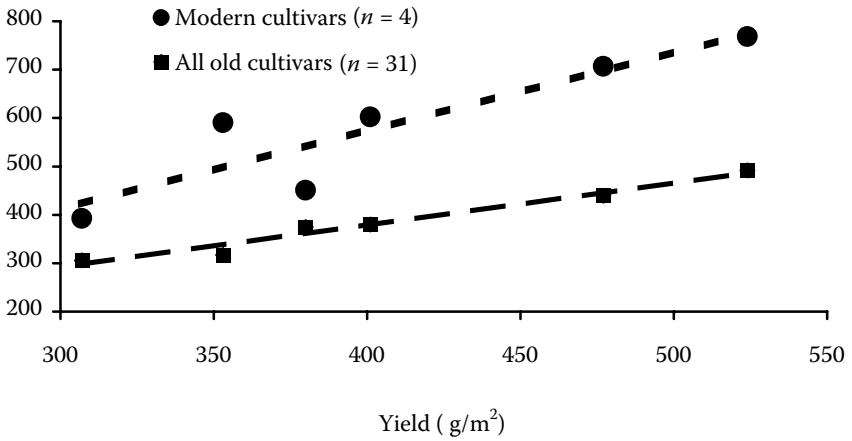

Figure 1. Mean yields (g/m^2) of modern and old winter wheat cultivars evaluated in six environments (years × sites, n = 6)

the cultivars according to the country of origin; however, earliness and lower spike productivity were characteristic for South-Eastern Europe, whereas cultivars from North-Western Europe showed the opposite characteristics.

Correlation analyses proved a close relationship between earliness in heading and in maturity; and a negative relationship between late heading and grain filling period, which was positively correlated with TGW and HI (r = 0.26 up to 0.38). The number of grains in a spikelet correlates with spike productivity and HI (r = 0.62 up to 0.69); whereas relationships between these two characteristics and TGW were lower (r = 0.20 up to 0.51). Spike productivity characteristics, except for TGW, are in negative correlation with the crude protein content in grain (r = –0.34 to –0.50). As regression analyses confirmed, the main deciding characteristic for spike productivity was the number of kernels in a spikelet (about 40% variation), while the TGW has only about half of the effect. The crude protein content was positively affected by plant height (15–30% of variation). The impact of grain weight per spike was lower (14–17% of variation), and a negative one.

Potentially valuable donors of earliness and longer grain filling period were identified for further studies and for utilization in breeding programs. We found a 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.

Estimated grain yields in the 31 selected landraces and old cultivars were always lower than in modern cultivars. When we analyzed mean yields over 6 environments, the four modern cultivars provided grain yields of 151.2%, compared to the mean value of landraces and obsolete cultivars. This shows that the breeding gain, relevant to the tested materials, was about 51%; which is very close to the estimates of MacKey (1993), who found a 49% yield increase. The Czech landraces Bíla od Dukovan, Vouska z Třemošnice, and Židlochovická jubilejní osinatka provided relatively good yields (over 4.3 t/ha).

To estimate the relative yield response of cultivars to the environment (in experiments within the Czech Republic and Slovakia) we calculated the linear regression to mean yield values of all cvs. in particular environments (Figure 1). The higher mean response of modern cultivars to environment (b = 1.63) than in old cultivars (b = 0.87) was confirmed. However, some landraces also showed as effective a response as did the modern ones (Bílá od Dukovan, Brauner Fuchs, Barbu du Maconnais, Baltischer Winterweizen, and Gammel Svensk Landhvedte). On the other hand, we found a very low response in some ancient landraces (e.g. Dolis Puri). The higher yield stability of old cultivars can be demonstrated from the mean yields of both groups in different environments (years × sites). Here, the yield difference between environments did not exceed 1.95 t/ha in the old cultivars; whereas in the modern cultivars it was almost double that value (3.76 t/ha). The lower yield decrease of old cultivars in environments with lower mean yields (when compared with modern ones) further supports this theory. On the other hand, a higher yield stability of old cultivars

Table 2. Winter-hardy cvs. (9 the highest rating) identified in the Czech winter wheat core collection (which includes 435 accessions)

Rokycanská sametka	CZK	9
Česká presívka	CZK	9
Červená perla	CZK	9
Dobrovická přesívka P 2	CZK	9
Dregerova původní 126	CZK	9
Selecty červená vouska	CZK	9
Selecty Z Vb	CZK	9
Slapská vouska	CZK	9
Sparta	CZK	9
Hadmerslebener Qualitas	DEU	9
Diplomat	DEU	9
Olympia	FIN	9
Shireffs square head	GBR	9
Skandia III B	SWE	9
Mironovskaja 808	UKR	8

CZK – Czech Republic; DEU – Germany; FIN – Finland; GBR – Great Britain; SWE – Sweden; UKR – Ukraine

could be partially explained as the poor response of landraces to favourable growing conditions. However, because we carried out the experiments under a low-level of input conditions, the effective response of modern cultivars was obviously limited by this fact. We assume that the differences in the responses to the environment were not the only source of dissimilarity in yield stability between both groups of cultivars.

We could also find potential donors of winter hardiness among the Czech and European landraces. For instance, in the Czech core collection of winter wheat, we identified several landraces and obsolete cultivars, which scored the highest value 9 (Table 2); whereas cv. Mironovskaja 808 (often considered as a standard for winter hardiness) only scored an 8.

High protein content is obviously one of the important characteristics which can often be found in wheat landraces (Liu 1988) and could be utilized by wheat breeders. Following the selection of HMW-*glu* lines in populations of landraces, we evaluated 67 selected high-protein lines and 3 control cultivars in 3-year field trials. Some results for the top 10 lines, with the highest protein content (17.5% up to 18.3%), are given in Table 3. As expected, high protein content was negatively linked with the number of grains per spike ($r = -0.47$) and HI ($r = -0.38$). In contrast, earliness and especially plant height ($r = 0.52$), were positively correlated with protein content. However, we were able to find high protein lines with acceptable plant height and spike productivity. Unfortunately, we recorded

Table 3. Selected high-protein lines derived from landraces (mean values of 3-year field trials)

Cultivar	Line	Plant height (cm)	Harvest index	Protein content (%)	Zeleny test	Gluten index (%)
Mindeszentpusztai	44/B	131	0.39	18.3	38	54.6
Szekacz 19	37/B	128	0.42	18.3	42	55.0
Eszterhazi Mindenes	117/C	125	0.38	18.3	54	55.8
Bartweizen	16/B	135	0.40	18.0	29.5	50.7
Bergland	18/B	134	0.46	17.8	25.5	36.8
Ostka Czerwona	111/C	136	0.41	17.8	32	53.2
Slovenská 2	63/A	134	0.46	17.6	28.5	37.3
Mos 4	105/A	132	0.40	17.5	40.5	41.2
Mos 4	105/B	131	0.35	17.5	33.5	45.4
Bartweizen	16/C	122	0.38	17.5	39.5	61.7
Ilona	check	85	0.52	13.7	40	67.8
Šárka	check	87	0.52	13.4	36.5	74.9

a negative relationship (r = –0.43) between the protein content and the Zeleny value. However, in this case we also found Hungarian cvs. Eszterhazi Mindenes and Szekacz 19, which proved to have high protein content (18.3%), but also an acceptable value on the Zeleny test (54.0 ml and 42.0 ml, respectively). This data suggests the possible use of some selected landraces and obsolete cultivars in breeding for improved wheat quality.

CONCLUSIONS

Research on landraces and obsolete cultivars of winter wheat, carried out at the Crop Research Institute Prague, point out that those old cultivars might be donors of important characteristics, such as earliness, winter hardiness, and grain quality. In general, they represent significantly broader genetic diversity than modern varieties and, therefore, they could contribute to extend the genetic base of modern cultivars.

Acknowledgements. This research was supported by the Ministry of Agriculture of the Czech Republic, Project No. QH72251.

References

Belay G., Tesemma T., Bechere E., Mitiku D. (1995): Natural and human selection for purple-grain tetraploid wheats in the Ethiopian highlands. Genetic Resources and Crop Evolution, **42**: 387–391.

Brush S.B., Meng E. (1998): Farmers' valuation and conservation of crop genetic resources. Genetic Resources and Crop Evolution, **45**: 139–150.

Eberhard S.A., Russel W.A. (1966): Stability parameters for comparing varieties. Crop Science, **6**: 36–40.

Finlay K.W., Wilkinson G.N. (1963): The analysis of adaptation in plant breeding programme: Australian Journal of Agricultural Research, **14**: 742–754.

Keller L., Schmid J.E., Keller E.R. (1991): Are cereal landraces a source for breeding? Landwirtschaft Schweiz, **4**: 197–202.

Li S., Sun F., Guo B., Liu L., Pang Ch. (1997): Evaluation of abiotic stress resistance in Hebei winter wheat genetic resources. Wheat Information Service, **85**: 1–6.

Liu L. (1988): Local varieties of winter wheat with a high protein content. Zouwu Pinzhong Ziyuan, **4**: 41.

Mackey J. (1993): Demonstration of genetic gain from Swedish cereal breeding. Sveriges Utsadesforenings Tidskrift, **103**: 33–43.

Michalová A., Dotlačil L. (1992): The evaluation of winter wheat gene pool of Czech, Moravian and Slovak origin. [Plant Genetic Resources – Annual Report.] VŠP Nitra, 2–9.

Payne P.I., Lawrence G.J. (1983): Catalogue of alleles for the complex gene loci, Glu-1, Glu-B1, Glu-D1, which code for high molecular weight subunits of Glutenins in hexaploid wheat. Cereal Research Communications, **11**: 29–35.

Rodriguez-Quijano K., Vazquez J.F., Garillo J.M. (1994): Variation of high molecular weight glutenin subunits in Spanish landraces of *Triticum aestivum* ssp. *vulgare* and ssp. *spelta*. Journal of Genetics and Breeding, **44**: 121–126.

Tesemma T., Tsegaye S., Belay G., Bechere E., Mitiku D. (1998): Stability of performance of tetraploid wheat landraces in the Ethiopian highland. Euphytica, **102**: 301–308.

Vojdani P., Meybodi M. (1993): Distribution and genetic diversity of primitive bread wheats in Iran. In: Damania A.B. (ed.): Biodiversity and Wheat Improvement. John Wiley & Sons, Chichester, 409–415.

Wang Z.N., Guo B.H. (1992): SDS-PAGE analysis for local wheat varieties in Hebei. Acta Agriculturae Baredli – Siniea, **7**: 35–39.

Yang J.Z., Liang Q. (1995): Yinchun 3 wheat germplasm with high protein content and resistance to drought. Crop Genetic Resources, **1**: 44.

Zou Z.T., Yang W.Y. (1995): Development of wheat germplasm research in Sichuean province. Crop Genetic Resources, **2**: 19–20