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ORIGINAL ARTICLE

Agronomic characteristics of the spring forms of the wheat landraces (einkorn, emmer, spelt, intermediate bread wheat) grown in organic farming

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Abstract
Organic farmers look to the possibilities of growing neglected crops, such as the spring forms of hulled wheat – einkorn, emmer and spelt – for support in developing the organic farming system. In 2008, 169 landraces from the gene bank at the Crop Research Institute in Prague were tested on certified organic plots. The experiment was aimed at finding suitable varieties for the organic farming system. In summary, our findings show that einkorn (*Triticum monococcum* L.) and emmer wheat [*Triticum dicoccum* Schrank (Schuebl)] are resistant to powdery mildew and brown rust, spelt wheat (*Triticum spelta* L.) is less resistant to these two diseases, and the intermediate forms of bread wheat are very sensitive to such infestation. The varieties evaluated incline to lodging, as they have long and weak stems. Einkorn and emmer wheat have short and dense spikes and a low thousand grains weight, whereas spelt wheat has long and lax spikes. The level of the harvest index is low. Potentially useful varieties were found during the field experiment and evaluation, and our future efforts will therefore focus on improving resistance to lodging and increasing the productivity of the spike.

Key words: economic characteristics; organic farming; einkorn; emmer; spelt; intermediate forms of bread wheat

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INTRODUCTION

Cereals do not have a share of much more than 50% of the total acreage of organic products; nonetheless they are the most important crops of the organic farming system (Konvalina et al. 2009), and animportant activity influencing organic farming is to increase the diversity of the species and varieties of agricultural crops in order to minimize negative effects on the environment and to establish the conditions for sustainable development. This diversity may be further increased by the use of hitherto neglected species, such as hulled wheat forms or landraces of the bread wheat.

Einkorn (*Triticum monococcum* L.) is an old cereal known to have been grown 9 000 years ago, and its use extended to the Balkans and Central Europe in the neolithic period. It has attracted farmers because of such valuable characteristics as resistance to diseases and the quality of its grain, which contains 17.0–22.5% of protein, a good supply of carotenoides and perfect characteristics for the production of biscuits and bakery products without the use of yeast (Frégeau-Reid and Abdel-Aal 2005).

Emmer wheat [*Triticum dicoccum* Schrank (Schuebl)] has been traditionally grown and used as a part of the human diet (Marconi and Cubadda 2005), and as requirements for the diversity and high quality of food products become more demanding, interest in this wheat variety is increasing (Hammer and Perinno 1995). The grains contain more crude protein than the grains of modern varieties (Marconi et al. 1999); wholemeal flour is a valuable source of dietary fibre in its insoluble forms, cellulose and hemicellulose, and it contains high quantities of P, Zn, Cu, K, Mg and Mn (Marconi and Cubadda 2005).

Spelt wheat (*Triticum spelta* L.) is thought to be an old European cultural wheat, interest in which has been prompted recently by the development of organic farming. It contains more proteins, mineral elements, lipids, fibre and vitamins than bread wheat and it also has a more suitable composition of amino acids. A breeding process would aim to eliminate the particularly unfavourable characteristics of the spelt, by increasing spike productivity or resistance to lodging (Abdel-Aal and Hucl 2005). The spelt wheat is a suitable crop for organic farming systems (Moudrý and Dvořáček 1999).

The landraces and obsolete cultivars of the intermediate forms of bread wheat (*Triticum aestivum* L.) maintained in the gene bank collection at the Crop Research Institute in Prague (CRI) deserve particular care and attention, and a number of authors – e.g. Gregova et al. (2006) in pointing this out, have also referred us to the high level of proteins contained in the grains – much higher than in the modern wheat varieties. The landraces are not able to compete with the modern bred varieties from the point of view of the yield level, but they have many valuable characteristics, which make them very interesting. They are characterised by high nutritive and dietetic values (Marconi and Cubadda 2005). They have been selected by the natural and environmental conditions of a particular region (Belay et al. 1995) and thus the material is very well adapted to the domestic environment and conditions and is very modifiable from the point of view of genetics (Hammer et al. 2003).

The aims of this work are to describe the differences in the agronomic characteristics of the spring forms of the genetic resources of wheat landraces and evaluate their potential for growing in organic farming.

MATERIAL AND METHODS

24 samples of the einkorn landraces, 103 samples of the emmer wheat landraces, 15 spring landraces of the spelt wheat and 27 intermediate forms of the bread wheat were selected from the above mentioned collection in 2008. The selection was influenced by their area of origin (similar to the conditions in Central Europe). Two modern varieties – Granny and SW Kadrilj – were included as the check varieties of the bread wheat.

The certified organic trial plot of the CRI is situated in a warm and mid-dry area, with clay-loamy soil, at an altitude of 340 m above sea level, with a mean annual temperature of 7.8 °C and a mean annual precipitation of 472 mm (Table 1). The results of the soil analysis are shown in Table 2 (Mehlich 3 analysis). 173 samples of the above-mentioned landraces and varieties were sown on the trial plot (120 of them were sown on plots of 4 m^2 and 53 on plots of 2 m^2). The check varieties of the bread wheat were sown on each eleventh trial plot. The sowing was carried out by an Oyjord seed drill. The rows had a standard width of 12.5 cm. The treatment of the crops during the growing season respected the principles of organic farming. Particular characteristics were measured and evaluated during the growing season and post-harvest period according to a methodology developed for the selection and evaluation of the genotypes of the spring forms of well used wheat species suitable for sustainable farming systems (Konvalina et al. 2008). The methodology is divided into four parts: each respectively focusing on the morphological, biological, economic and quality characteristics.

In this methodology, users find a code, a name, a description and a scale for the evaluation of each characteristic, combined with its importance for the organic farming system. We used a nine-degree scale (9 = no disease infestation noticed) for the evaluation of a powdery mildew and/or brown rust attack. Lodging was measured by the index of lodging which combines the intensity and range of the lodging on a plot (9 = no lodge). The other data are represented by a concrete value. The results were also evaluated with basic statistical methods and the Honestly Significantly Different (HSD) test using the Statistica program.

Table 1. Temperature and precipitation characteristics of the location in Prague-Ruzyně (growing season from April to August 2008)

	Month						Mean / sum in the growing season
	3	4	5	6	7	8	
Longtime normal values between 1961 and 1990							
Temperature (°C)	3.0	7.7	12.7	15.9	17.5	17.0	14.2
Precipitations (mm)	28.1	38.2	77.2	72.7	66.2	69.6	323.9
2008							
Temperature (°C)	3.7	8.2	14.1	17.7	18.5	18.2	15.3
Precipitations (mm)	20.0	56.8	54.9	66.0	73.7	67.8	319.2

Table 2. Agrochemical soil analysis of the certified organic parcel in Ruzyně

Soil reaction pH/KCl	Soil reaction pH/H_2O	Content of the available nutrients in the soil (mg.kg^{-1})				Cox (%)	Humus (%)	Nt (%)
		P	K	Ca	Mg			
7.63	8.42	87.1	270	4 680	129	2.79	4.81	0.165

Table 3. Disease / lodging resistance and plant yield characteristics of the of 24 landraces of einkorn

Evaluated characteristic		Parameter					
		Mean	SD	RSD	Median	Lower quartile	Upper quartile
Powdery mildew (points)	BBCH 39; 59; 77	9.00	0	0	9.0	9.0	9.0
Index of lodging (points)	BBCH 59	9.00	0	0	9.0	9.0	9.0
	BBCH 87	8.13	1.18	14.5	8.7	7.6	9.0
Brown rust	BBCH 77	9.00	0	0	9.0	9.0	9.0
Length of plant (cm)		101	6.25	6.2	100.0	95.0	105.0
Length of spike (cm)		4.75	0.80	16.9	4.7	4.1	5.0
Number of grains in spike		15.20	3.24	21.3	14.8	13.8	17.0
Number of grains in spikelet		0.73	0.10	13.7	0.7	0.7	0.8
Weight of grains in spike (g)		0.34	0.12	35.3	0.4	0.3	0.5
TGW (g)		26.00	3.41	13.1	26.5	23.8	28.1
Spike density (spikelet 10 cm^{-1})		43.98	3.68	8.4	43.5	42.2	47.1
Harvest index		0.34	0.03	8.8	0.3	0.3	0.4
Share of hulls (%)		29.75	2.93	9.9	29.6	28.7	30.7

TGW = thousand grain weight; SD = standard deviation; RSD = relative standard deviation; BBCH = scale used to identified phenological development stages of plant

RESULTS

The evaluated set of the einkorn includes 24 landraces. The material proved to be more resistant to the powdery mildew and brown rust attack in comparison with spelt or the intermediate forms of bread wheat (Table 8). Nevertheless, these wheat species inclined to lodging (the index of lodging before harvest was about 8.13); this characteristic was less variable (relative standard deviation = 14.5%). The selection of material which does not lodge excessively is possible, as 25% of the evaluated landraces did not lodge, shown by the value of the top quartile (Table 3). The plants were shorter than the emmer wheat and spelt wheat. The spike productivity was very low. The weight of thousand grains (TGW) was about 26.0 g; the grain weight per spike reached 0.3 g and the number of grains in one flower spikelet reached 0.7 in the tested landraces. They had short (4.8 cm at average) and very dense spikes (44.0 of spikelets per 10 cm of the spike length). On the other hand, the check varieties of bread wheat had more lax spikes (21.2 of spikelets per 10 cm of the spike length). They also had a very low harvest index (0.34) and a high proportion of hulls in the yield (29.75%) compared to the emmer wheat landraces (Table 8).

The landraces of emmer wheat were the most numerous in the evaluated set (103 landraces). They were resistant to the tested diseases (powdery mildew and brown rust). However, the results given in Table 4 show that particular landraces of the emmer wheat were less resistant to powdery mildew (because of the mean infestation of 8.70–8.86). However, the major part of the set, expressed by the median, was resistant enough. The results concerning tolerance to brown rust were similar. The landraces of emmer wheat were less resistant to lodging (8.59 after the heading: the minimum of the lodged landraces, and 6.88 before the harvest: a lower level of the resistance to lodging). As the coefficient of variation was high, particular landraces were more resistant to lodging than the others. The mean length of plants was 108 cm and the span of the top and lower quartiles was about 100–110 cm. However, it was a relatively stable characteristic (a low level of coefficient of variation). The emmer wheat landraces usually had shorter (6.1 cm) and very dense spikes (almost 33 spikelets per 10 cm of the spike length). The weight of grains per spike of emmer wheat plant (0.8 g) reached a half weight of grains in the spikes of the check plant (1.6 g). TGW was also slightly lower. The lower harvest index (0.40 at average and a median of 0.39) was one of the characteristics decreasing the productivity of the emmer wheat. The span of top and lower quartiles was 0.37–0.42. This characteristic is not very variable (relative standard deviation = 12.5%). Therefore, the selection of the material assuring a higher share of grain will be important.

15 landraces of the spelt wheat were evaluated in the trial. Organic farmers are becoming more interested in the growing of spring spelt wheat forms, but information on such forms and on the growing of spring spelt wheat forms under Central European conditions is limited. The evaluated landraces inclined to powdery mildew attack (it was the strongest after the heading stage but after that, the infestation rate reduced (Table 5). The resistance of the landraces was characterised by a higher coefficient of variation after the heading stage (22.40%). This would allow the selection of more resistant cultivars for growing. The brown rust attack was slighter; there were several samples unaffected within the set of the tested races. The spring spelt wheat forms inclined to lodging; 25% of the landraces had an index of lodging below 5.8 before the harvest stage. There were several samples which did not lodge (Table 5). The plants were very long (112.7 cm on average), but 25% of them were longer than 125 cm. The spikes of the spelt wheat plants were very long (11.3 cm) and sparse (there were only 16.6 spikelets per 10 cm of the spike length). The span of the top and lower quartiles was small (14.7–17.7 of the spikelets per 10 cm of the length of spike). The grain weight was almost 1 g per spike and TGW was slightly higher than that of the check bread wheat varieties (42.6 g). The harvest index (0.38) was comparable to the harvest index of the emmer wheat landraces (Table 4) and it was lower than the harvest index of the check bread wheat varieties (Table 7). The hulls represented 30.67% of the yield.

The intermediate forms of bread wheat landraces (Table 6) were characterised by the lowest resistance to powdery mildew (6.26–7.82) and brown rust (6.63) in comparison with the other evaluated wheat landraces and check bread wheat varieties (Table 8). The inclination to lodging (index of lodging = 6.11 before harvest) was a further disadvantage of the intermediate forms of bread wheat varieties, connected with the very long and weak stems of the plants: they were 116.7 cm long on average and they were not flexible or variable (relative standard deviation = 8.9%). The intermediate forms were also characterised by short (8.84 cm) and more lax spikes (22.2 of the spikelets per 10 cm of the length of spike). The TGW was lower (35.2 g) than that of the check varieties (40.5 g), but the number of grains in the spikelets of the intermediate forms was similar to the number of grains in the spikelets of the check varieties. The intermediate bread wheat forms had a lower harvest index (0.43) than the check varieties, and they were also less variable (relative standard deviation = 7.0%). There was no material, which did not lodge or was resistant to the diseases studied in the set of the evaluated landraces (compared with the other evaluated wheat species).

Table 4. Disease / lodging resistance and plant yield characteristics of the 103 landraces of emmer wheat

Evaluated characteristic		Parameter					
		Mean	SD	RSD	Median	Lower quartile	Upper quartile
Powdery mildew (points)	BBCH 39	8.79	0.68	7.7	9.0	9.0	9.0
	BBCH 59	8.70	0.90	10.3	9.0	9.0	9.0
	BBCH 77	8.86	0.34	3.8	9.0	9.0	9.0
Index of lodging (points)	BBCH 59	8.59	0.86	10.0	9.0	8.6	9.0
	BBCH 87	6.88	2.16	31.4	8.0	6.0	8.5
Brown rust	BBCH 77	8.89	0.77	8.7	9.0	9.0	9.0
Length of plant (cm)		108	8.39	7.8	110.0	100.0	110.0
Length of spike (cm)		6.13	1.10	17.9	6.0	5.3	7.0
Number of grains in spike		22.86	6.37	27.9	21.9	17.9	26.9
Number of grains in spikelet		1.15	0.24	20.9	1.2	1.0	1.3
Weight of grains in spike (g)		0.79	0.28	35.4	0.8	0.6	1.0
TGW (g)		34.19	5.13	15.0	33.3	31.0	36.8
Spike density (spikelet 10 cm^{-1})		32.81	4.28	13.0	33.0	29.4	35.6
Harvest index		0.40	0.05	12.5	0.4	0.4	0.4
Share of hulls (%)		24.59	2.87	11.7	24.1	22.6	26.0

Abbreviations as in Table 3

Table 5. Disease / lodging resistance and plant yield characteristics of the 15 landraces of spelt wheat

Evaluated characteristic		Parameter					
		Mean	SD	RSD	Median	Lower quartile	Upper quartile
Powdery mildew (points)	BBCH 39	7.80	1.21	15.5	8.0	7.0	9.0
	BBCH 59	7.20	1.61	22.4	8.0	6.0	8.0
	BBCH 77	8.20	0.41	5.0	8.0	8.0	8.0
Index of lodging (points)	BBCH 59	8.78	0.52	5.9	9.0	9.0	9.0
	BBCH 87	7.05	1.99	28.2	7.0	5.8	9.0
Brown rust	BBCH 77	8.47	1.41	16.7	9.0	9.0	9.0
Length of plant (cm)		113	19.07	16.9	120.0	105.0	125.0
Length of spike (cm)		11.30	2.08	18.4	11.2	10.3	13.0
Number of grains in spike		24.21	6.09	25.2	24.7	19.8	30.0
Number of grains in spikelet		1.33	0.32	24.1	1.3	1.1	1.6
Weight of grains in spike (g)		1.02	0.29	28.4	1.0	0.8	1.4
TGW (g)		42.59	7.23	17.0	40.7	36.9	46.1
Spike density (spikelet 10 cm^{-1})		16.59	3.24	19.5	15.7	14.7	17.7
Harvest index		0.38	0.06	15.8	0.4	0.3	0.4
Share of hulls (%)		30.67	2.03	6.6	30.9	29.4	32.0

Abbreviations as in Table 3

Table 6. Disease / lodging resistance and plant yield characteristics of the 27 intermediate forms of the bread wheat

Evaluated characteristic		Parameter					
		Mean	SD	RSD	Median	Lower quartile	Upper quartile
Powdery mildew (points)	BBCH 39	6.85	1.20	17.5	7.0	6.0	8.0
	BBCH 59	6.26	1.35	21.6	6.0	5.0	7.0
	BBCH 77	7.82	0.88	11.3	8.0	8.0	8.0
Index of lodging (points)	BBCH 59	9.00	0	0	9.0	9.0	9.0
	BBCH 87	6.11	2.27	37.2	6.3	3.6	8.1
Brown rust	BBCH 77	6.63	2.29	34.5	6.0	5.0	9.0
Length of plant (cm)		117	10.38	8.9	120.0	110.0	125.0
Length of spike (cm)		8.84	1.27	14.4	8.8	7.7	9.6
Number of grains in spike		32.52	6.06	18.6	32.1	29.0	35.3
Number of grains in spikelet		1.67	0.22	13.2	1.7	1.5	1.8
Weight of grains in spike (g)		1.15	0.29	25.2	1.1	1.0	1.2
TGW (g)		35.18	3.53	10.0	35.1	33.0	37.3
Spike density (spikelet 10 cm^{-1})		22.17	1.87	8.4	21.9	21.3	23.8
Harvest index		0.43	0.03	7.0	0.4	0.4	0.5

Abbreviations as in Table 3

Table 7. Disease / lodging resistance and plant yield characteristics of the of 2 check varieties of the bread wheat (SW Kadrilj, Granny – 5 replications)

Evaluated characteristic		Parameter					
		Mean	SD	RSD	Median	Lower quartile	Upper quartile
Powdery mildew (points)	BBCH 39	9.00	0	0	9.0	9.0	9.0
	BBCH 59	8.80	0.42	4.8	9.0	9.0	9.0
	BBCH 77	8.60	0.52	6.1	9.0	8.0	9.0
Index of lodging (points)	BBCH 59	9.00	0.0	0	9.0	9.0	9.0
	BBCH 87	9.00	0.0	0	9.0	9.0	9.0
Brown rust	BBCH 77	8.80	0.63	7.2	9.0	9.0	9.0
Length of plant (cm)		89	7.38	8.3	87.5	85.0	95.0
Length of spike (cm)		10.21	1.55	15.2	10.1	9.2	11.4
Number of grains in spike		39.68	10.47	26.4	39.3	32.6	46.9
Number of grains in spikelet		1.86	0.46	24.7	1.9	1.5	2.2
Weight of grains in spike (g)		1.62	0.49	30.3	1.5	1.3	1.8
TGW (g)		40.51	2.65	6.5	40.2	39.9	40.9
Spike density (spikelet 10 cm^{-1})		21.21	2.75	13.0	21.3	19.1	22.9
Harvest index		0.48	0.03	6.3	0.5	0.5	0.5

Abbreviations as in Table 3

Table 8. Results of HSD test (homogenous group, P=0.05) of evaluated wheat species

Evaluated characteristic		MS[1]	Mean[2]				
			E[3]	D[4]	S[5]	I[6]	C[7]
Powdery mildew (points)	BBCH 39	0.60	9.0a[2]	8.8a	7.8c	6.9b	9.0a
	BBCH 59	0.96	9.0a	8.7a	7.2b	6.3b	8.8a
	BBCH 77	0.21	9.0a	8.9a	8.2bc	7.8b	8.6ac
Index of lodging (points)	BBCH 59	0.46	9.0a	8.6a	8.8a	9.0a	9.0a
	BBCH 87	4.00	8.1a	6.9ab	7.1ab	6.1b	9.0a
Brown rust (points)	BBCH 77	1.31	9.0a	8.9a	8.5a	6.6b	8.8a
Length of plant (cm)		95	101.0a	107.9ab	112.7bc	116.7c	89.0d
Length of spike (cm)		1.51	4.8c	6.1d	11.3b	8.8a	10.2ab
Number of grains in spike		36.28	15.2c	22.9a	24.2a	32.5b	39.7b
Number of grains in spikelet		0.06	0.7c	1.2a	1.3a	1.7b	1.9b
Weight of grains in spike (g)		0.08	0.4c	0.8a	1.0ab	1.2b	1.6d
TGW (g)		23.39	26.0d	34.2a	42.6c	35.2ab	40.5bc
Spike density (spikelet 10 cm^{-1})		14.27	44.0d	32.8c	16.6b	22.2a	21.2a
Harvest index		0.01	0.34b	0.40a	0.38ab	0.43ac	0.48c
Proportion of hulls (%)		6.28	29.75a	24.59b	30.69a	–	–

[1]MS = mean square; [2]Average values followed by different letters are statistically different (P=0.05); [3]E = einkorn; [4]D = emmer; [5]S = spelt; [6]I = intermediate wheat; [7]C = check

DISCUSSION

The intensity of disease infestation is usually lower in the organic farming system than on conventional farms (Lammerts van Bueren 2002). Some authors (e.g. Wolfe et al. 2008) explain this by the fact that the tissue of the organically grown plants is riper due to the reduced nitrogenous nutrition. On the other hand, fungicides are forbidden in the organic farming system, and therefore the resistance of the variety plays a crucial role in the protection against diseases. Most of the evaluated landraces of emmer were resistant to powdery mildew and brown rust. The same results were noted by Frégeau-Reid and Abdel-Aal (2005) and Herrera-Foessel et al. (2005), who thought that certain landraces of emmer could be les resistant to mildew, whereas the spelt wheat inclines to both diseases. McVey (1990), Kema and Lange (1992), and Schmid et al. (1994), refer to the reduced resistance of the spelt wheat landraces to particular fungal diseases. The intermediate forms of the bread wheat landraces incline to powdery mildew and brown rust attack, as previous studies show (Konvalina et al. 2009).

An increased inclination to lodging was a negative recognition in most of the landraces, but particular samples of the landraces were more resistant to lodging. The length of plants is also connected with the lodging, and also influences competitiveness to weeds (Cudney et al. 1991, Gooding et al. 1993, Eisele and Köpke 1997, Müller 1998). All the evaluated species were very high (on average: einkorn – 101 cm, emmer wheat – 107 cm, spelt wheat – 112 cm, intermediate forms of bread wheat – 116 cm, and the check varieties of bread wheat – 89 cm). The plants were long enough to be able to compete with weeds, but on the other hand, the long plants were more inclined to lodging (Köpke 2005). However, the intermediate forms of bread wheat and emmer wheat were particularly inclined to lodging, while the high plants of the spelt wheat were not. Stehno et al. (2008) reported differences in lodging between the landraces; the authors state that the varieties with short and strong down internodes and high number of nodes on the stems are more resistant. Not only the length, but also the width of the stalks is important (Konvalina 2009).

Einkorn and emmer wheat have short and very dense spikes, whilst those of spring spelt wheat are very long and lax. The lower weight of grains in their spikes than the weight of grains in the spikes of the check varieties should be compensated for by a higher number of productive stems (Stehno et al. 2008). The thousand grains weight of the einkorn (26 g at average) and emmer wheat (34.19 g) were the lowest. Frégeau-Reid and Abdel-Aal (2005) refer to the fact that the small grain of the einkorn may cause serious losses during the peeling of the grains. On the other hand, bread wheat has a higher TGW; much like spelt (Marconi and Cubadda 2005). The low harvest index level was the main factor limiting the yield level (in comparison with the modern check varieties). The emmer wheat and landraces have a low harvest index in comparison to the bread wheat (Sehnalová 1990) and hard wheat (Marconi and Cubbada 2005). The proportion of hulls varies from 25 to 30% (einkorn, emmer wheat, spelt wheat).

169 wheat landraces were studied and evaluated in these trials in the organic farming system. The trials aimed to show the differences between the landraces and species and different possibilities of use of the landraces in this farming system. The evaluated set of the landraces was varied enough to allow us to select potentially useful strains. In terms of resistance to powdery mildew and brown rust, the einkorn and emmer wheat are the most suitable species of wheat. The spring forms of spelt wheat were attacked by these two diseases to a greater extent. On the other hand, the intermediate forms of bread wheat landraces were the least resistant; and they also inclined to lodging. When considering the effect of the height of plants on the inclination to lodging, it seems that the width of the stems plays a crucial role in the process of the selection of suitable landraces.

With the exception of the spring forms of spelt wheat, the evaluated material establishes yield through the higher number of spikes per area unit, as they have a low TGW. All the evaluated species were characterised by a lower level of harvest index. As this characteristic is less variable and there are not any bred varieties, we should focus preferably on increase in the spike productivity and resistance to lodging, and to a more limited extent on the changes in the distribution of assimilates in the plants (which runs very slowly during the selection process).

The results of our research show that some evaluated landraces may be grown under the organic farming system, especially in marginal areas, where there are worse farming and growing conditions. Farmers may extend the range of the crops grown and the market possibilities and may contribute to sustainable development and use of the genetic plant resources.

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REFERENCES

Abdel-Aal E-SM, Hucl P (2005): Spelt: A speciality wheat for emerging food uses. In Abdel-Aal E-SM, Wood P (eds.): Speciality Grains for Food and Feed. Minnesota, American Association of Cereal Chemists Inc., pp. 109–142.

Belay G, Tesemna T, Bechere E, Mitiku D (1995): Natural and human selection for purple-grain tetraploid wheats in the Ethiopian highlands. Genet Resour Crop Evol 42: 387–391.

Cudney DW, Jordan LS, Hall AE (1991): Effect of wild oat (*Avena fatua*) infestations on light interception and growth rate of wheat (*Triticum aestivum*). Weed Sci 39: 175–179.

Eisele JA, Köpke U (1997): Choice of cultivars in organic farming: new criteria for winter wheat ideotypes. Pflanzenbauwissenschaften 2: 84–89.

Frégeau-Reid J, Abdel-Aal E-SM (2005): Einkorn: A potential functional wheat and genetic resource. In Abdel-Aal E-SM, Wood P (eds.): Speciality Grains for Food and Feed. Minnesota, American Association of Cereal Chemists Inc., pp. 37–62.

Gooding MJ, Thompson AJ, Davies WP (1993): Interception of photosynthetically active radiation, competitive ability and yields of organically grown wheat varieties. Asp Appl Biol Physiol Varieties 34: 355–362.

Gregová E, Hermuth J, Kraic J, Dotlačil L (2006): Protein heterogeneity in European wheat landraces and obsolete cultivars: Additional information II. Genet Resour Crop Evol 53: 867–871.

Hammer K, Perinno P (1995): Plant genetic resources in South Italy and Sicily: studies towards *in situ* and on farm conservation. Plant Genet Resour Newsl 103: 19–23.

Hammer K, Gladis T, Diederichsen A (2003): *In situ* and on-farm management of plant genetics resources. Eur J Agron 19: 509–517.

Herrera-Foessel SA, Singh RP, Huerta-Espino J, Yuen J, Djurle A (2005): New Genes for Leaf

Rust Resistance in CIMMYT Durum Wheats. Plant Dis 89: 809–814.

Kema GHJ, Lange W (1992): Resistance in spelt wheat to yellow rust. II. Monosomic analysis of the Iranian accession 415. Euphytica 63: 219–224.

Konvalina P (2009): [Suitability of spring wheat *Triticum dicoccum* (SCHRANK) SCHUEBL and *Triticum aestivum* L. for low input and organic farming systems]. České Budějovice, PhD Thesis University of South Bohemia, Czech Republic, 171 pp. (in Czech).

Konvalina P, Stehno Z, Capouchová I, Moudrý J (2008): [Methodology of selection and evaluation of spring forms of neglected species of wheat genotypes, suitable for sustainable farming systems]. University of South Bohemia, České Budějovice, 85 p. (in Czech).

Konvalina P, Stehno Z, Moudrý J (2009): The Critical Point of Conventionally Bred Soft Wheat Varieties in Organic Farming Systems. Agronomy Research 7: 801–810.

Köpke U (2005): Crop ideotypes for organic cereal cropping systems. In Lammerts Van Bueren ET, Goldringer I, Ostergard H (eds.): Proceedings of the COST SUSVAR/ECO-PB Workshop on Organic Plant Breeding Strategies and the Use of Molecular Markers. Driebergen, The Netherlands, pp. 13–16.

Lammerts van Bueren ET (2002): Organic plant breeding and propagation: concepts and strategies, PhD Thesis, Wageningen University, The Netherlands, 208 pp.

Marconi M, Cubadda R (2005): Emmer wheat. In Abdel-Aal E-SM, Wood P (eds.): Speciality Grains for Food and Feed. Minnesota, American Association of Cereal Chemists Inc., pp. 63–108.

Marconi E, Carcea M, Graziano M, Cubadda R (1999): Kernel properties and pasta-making quality of five European spelt wheat (*Triticum spelta* L.) cultivars. Cereal Chem 76: 25–29.

McVey DV (1990): Reaction of 578 spring spelt wheat accessions to 35 races of wheat stem rust. Crop Sci 30: 1001–1005.

Moudrý J, Dvořáček V (1999): Chemical composition of grain of different spelt (*Triticum spelta* L.) varieties. Rostl Vyroba 45: 533–538.

Müller KJ (1998): From word assortments to regional varieties. In Wiethaler C, Wyss E (eds.): Organic plant breeding and biodiversity of cultural plants. Bonn, NABU/FiBL, pp. 81–87.

Schmid JE, Winzeler M, Winzeler H (1994): Genetic studies of crosses between common wheat (*Triticum aestivum* L.) and spelt (*Triticum spelta* L.). J Genet Breed 44: 75–80.

Sehnalová J (1990): Evaluation of significant biological features in the genetic resources of cultivated emmer wheat (*Triticum dicoccon* Schrank.). Pol'nohospodárstvo 36: 777–785.

Stehno Z, Konvalina P, Dotlačil L (2008): [Emmer wheat growing]. Praha, VÚRV, 22 pp. (in Czech).

Wolfe MS, Baresel JP, Deslaux D, Goldringer I, Hoad S, Kovacs G, Löschenberger F, Miedaner T, Ostergard H, Lammerts Van Bueren ET (2008): Developments in breeding cereals for organic agriculture. Euphytica 163: 323–346.