Wheat Growing and Quality in Organic Farming

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1. Introduction

Agricultural crop species represent a negligible part of the existing biodiversity. Over 50 percent of the daily global requirement of proteins and calories is met by just three crops – maize, wheat and rice (FAO, 1996) – and only 150 crops are commercialised on a significant global scale. On the other hand, ethnobotanic surveys indicate that, worldwide, more than 7,000 plant species are cultivated or harvested from the wild (Wilson, 1992). The composition of crops has significantly changed in farming history. Introducing new more efficient crops has jeopardized obsolete landraces being important genetic resources, serving for the breeding process (Collins & Hawtin, 1999). At present, genetic diversity in agriculture as well as in nature is often seriously endangered (Dotlačil et al., 2002).

At least 1.8 million hectares of main cereal species in the world are under organic management (including in-conversion areas). As some of the world's large cereal producers (such as India, China and the Russian Federation) did not provide land use details, it can be assumed that the area is larger than shown here (Willer & Kilcher, 2009). Comparing this figure with FAO's figure for the world's harvested cereal area of 384 million hectares (FAOSTAT, 2011), 0.5 percent of the total cereal area is under organic management. *Triticum* L., and bread wheat (*Triticum aestivum* L.) in particular, is the most frequent crop in organic farming, the same as in conventional farming. It is grown in organic system on a total surface of more than 700 000 ha (Willer & Kilcher, 2009).

2. Grown wheat species and their suitability for the organic farming system

Wheat species are the most frequently grown crops in the organic farming system. However, not all of them are suitable for organic farming, the ones grown in marginal regions in particular. Currently, a lot of alternative crops, including the marginal wheat species, have become attractive too. Such species have been bred neither in order to increase the yield rate nor for the intensive farming system. Although the baking quality is not high from the conventional point of view, these species have a lot of specific characteristics (e.g. a higher proportion of proteins, a favourable composition of amino acids, and a high proportion of mineral elements). Products made of such wheat species are considered specialities with a higher added value at the market and they may be applied well.

2.1 Grown wheat species

Bread wheat (*Triticum aestivum* L.) is a traditionally grown species in all farming systems in the Czech Republic. It is a species that began to be domesticated 10,000 years ago in the Levant region (Iraq, Iran, Syria and Jordan). As it has been brought closer to Central Europe, it has significantly changed and adapted to farming technologies. The selection of this species had been unconscious at first, nevertheless, it started to be conscious later. The continuity of the development of landraces has been maintained, the same as the interaction between these species and agrotechnological conditions of a particular farm. The first breeding farms had been established just after the industrial revolution and the breeding process had been converted from the field conditions to the sterile laboratory ones. Therefore, the profitable conventional varieties were created, whose ideotypes are not suitable for the low-input farming systems.

The landraces and obsolete cultivars of bread wheat (*Triticum aestivum* L.) contained 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 & 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 it is very variable from the point of view of genetics (Hammer et al., 2003).

Durum wheat (*Triticum durum* Desf.) is the second most important species of *Triticum* genus It is a tetraploid wheat species that comes from the Mediterranean. It represents about 9% of the wheat surface worldwide. It requires high temperatures, it grows especially in the regions characterised by long warm and dry summers. It is mostly used in the production of pasta and non-yeasty baked goods (biscuits). Caryopsis are naked, and have a glassy, amber colour, which is related to a higher proportion of carotenoids in their endosperm and it influences the semolina’s colour too, which is yellowish.

Einkorn (*Triticum monococcum* L.) is an old cereal known to have been grown 9,000 years ago, and its use had 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 % protein, a good supply of carotenoides and perfect characteristics for the production of biscuits and bakery products without the use of yeast (Frégeau-Reid & Abdel-Aal, 2005).

Emmer wheat [*Triticum dicoccum* Schrank (Schuebl)] has been traditionally grown and used as a part of the human diet (Marconi & Cubadda, 2005). As requirements for the diversity and quality of food products becoming more demanding, interest in this wheat variety is increasing (Hammer & 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 & Cubadda, 2005).

Spelta wheat (*Triticum spelta* L.) is thought to be an old European cultural wheat, interest in which has been prompted 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. The breeding process would aim to eliminate the particularly unfavourable characteristics of the spelt, by increasing spike productivity or resistance to lodging (Abdel-Aal & Hucl, 2005). Spelt wheat is a suitable crop for organic farming systems (Moudrý & Dvořáček, 1999).

2.2 Can the ideotype of 'the conventional variety' be suitable for the organic farming system?

Concerning the critical points of conventional and certified bred varieties of wheat, there are 4 groups of problems (Wolfe, 2006) and they are interconnected. They are: the efficiency of absorption and use of nutrients, competitiveness against weeds, resistance to diseases and pests, degree and stability of the yield and the qualitative parameters of production (See Table 1).

Criteria	Desirable Variety Characteristics
Nutrient Uptake and Use:	Adaptation to low, organic inputs and fluctuating nutrient dynamics, efficient in capturing water and nutrients, their uptake and their use; deep, intensive root architecture; ability to interact with beneficial soil microorganisms.
Weed Competiveness:	Plant architecture for early soil cover and more light-competitiveness.
Crop Health:	Durable resistance, field tolerance, plant morphology, combining ability for crop or variety mixtures, capable of interaction with beneficial microorganisms.
Yield and Yield Stability:	Maximum yield level and yield stability under low, organic input.
Product Quality:	High processing/baking quality, good taste, high storage potential.

Table 1. Criteria for organic plant breeding and propagation strategies derived from the non-chemical and agro-ecological approach) (according to Lammerts van Bueren, 2002)

2.2.1 Nutrient uptake and utilization efficiency

Organic farming is a system using a limited quantity of nutrients (especially nitrogen) and serial applications of nitrogen (Köpke, 2005). The possession or non possession of the ability to absorb nitrogen in early spring is an important issue in the growing of winter varieties of cereals in an organic farming system; cold wet soil is characterized by a low degree of microbial activity. The mineralization of nutrients (especially of nitrogen) is limited in this period (Moudrý, 2003). The efficient absorption of nitrogen is also an important factor; it provides good-quality production and development of plants in the early stages of growth. (Steinberger, 2002). Varieties must be adapted to the lower inputs of nutrition into the agroecosystem (Lammerts van Bueren, 2002).

A wide range of studies has been carried out in the last few years; their common purpose has been to determine the changes in efficiency of varieties during the breeding process, and changes in the efficiency of the exploitation of nutrients. Muurinen et al. (2006) studied the efficiency of the exploitation of nitrogen in wheat, oat and barley, bred in Finland between 1909 and 2002. Modern varieties of wheat and oat were more efficient, they absorbed more nitrogen and were able to use it more efficiently than the older ones. It was different in the case of barley. They also point out that the improvement in the efficiency of absorption and use of nitrogen was caused by the more efficient use of the absorbed nutrients in a plant, not the increased ability of absorption of nutritions by the root system.

Ericson (2006) states that modern varieties provide a higher efficiency in absorption and use of nutrients than landraces (various amounts of industrial fertilizers). This is valid for conventional farming systems. However, this statement is not so unambiguous for natural low-input farming systems. Gorny (2001) states in his study that landraces of baking wheat provide a higher efficiency in the absorption and use of nitrogen than modern European varieties in low-input farming systems. He clarifies the reason for this in his study. Slafer et al. (1990) studied 6 varieties of baking wheat which had been bred between 1912 and 1980 and found out that the ability of the root system to absorb nitrogen did not improve during the growing and flowering season of the breeding process. The breeding caused an increase in the grain yield thanks to a change of the harvest index, the harvest index of nitrogen and the increasing number of grains. The change in the harvest index was greater than the change in the harvest index of nitrogen; it led to a 'dilution' of nitrogen and a lower concentration of nitrogen in the grain. Because of that, the varieties being bred in conditions with an abundance of soluble nutrients (especially nitrogen) are not able to absorb nutrients from less accessible bonds and use the accessible nutrients more efficiently, and thus need less accessible nutrients. This fact supports the carrying out of the breeding process in the conditions of the organic farming system, and the selection of tribes with greater potential.

Baresel et al. (2005) also support this idea in their work. They were studying the varieties of wheat and found the conditions of organic farming very varied and dissimilar to the conditions of conventional farming. The varieties adapted to the conditions of conventional farms may not have been adapted to the conditions of low-input farming. The efficient genotypes (those able to absorb and use nitrogen in the first stages of their growth) are more suitable for the organic farming system. Most modern varieties are well used and applied in farming systems which are characterized by high inputs of nutrients. They provide a low degree of interaction between- genotype and the environment. They do not achieve the required baking quality in low-input conditions. On the other hand, old cultivars and biological varieties contain more protein in grains (in both organic farming and conventional systems). The higher proportion of protein is usually connected with a lower level of yield (Ericson, 2006).

A well-developed root system, responsive to the interaction with the soil edaphone in a positive way, is a very important aspect of the efficient absorption of nutrients (Lammerts van Bueren, 2002). The growth of roots is more important than the growth of upper phytomass in a soil characterized by a lower concentration of accessible nitrogen. On the other hand, the shape of the root system is influenced not only by the soil structure, but by the proportion of nutrients and water in the soil, by a genetic factor (Fitter, 1991, Fitter & Stickland, 1991) and by the selection of varieties which provide a high level of yield in the conditions of conventional farming, but with negative consequences (Siddique et al., 1990). This means that the selection of suitable varieties for the low-input farming system should be applied to the conditions of organic farming (Lammerts van Bueren, 2002).

The selection of an efficient root system, adapted to the absorption of nutrients from the soil, should take into account the limited competitiveness of varieties for the assimilates and a good position of the roots. A long and deep root system with a lot of small young roots

forms a better and richer branching with more capillary roots. The deep roots assure the sufficient absorption of water and nutrients from the deeper layers of the soil profile (Köpke, 2005).
The interaction between the root system and the other soil organisms (bacteria, fungi) is a very important aspect of the agroecosystem; it increases the extent of mineralization of nutrients (Lee & Pankhurst, 1992; Mäder et al., 2000). Hetrick et al. (1993) realised that modern varieties of wheat responded less to mycorrhizal symbiosis. The interaction between microorganisms and roots is determined by genetic factors; nowadays, this factor is not taken into consideration in the breeding process.

2.2.2 Weed suppression

Weed plants are one of the main factors limiting the level of agricultural yield. Because of the availability of herbicides in the last 50 years, the competitiveness of field crops to weeds has been overlooked. The relationship between the crops and the weed plant was supposed to be negative. However this relationship could contribute to the formation of a stable agroecosystem (Lammerts van Bueren, 2002) as the weeds can play a positive role in the agroecosystem (Wolfe, 2002). We cannot consider the cultured plant as naturally competitive to weed plants, because it has not confronted any important competitive weed plants during the breeding process. Modern conventional varieties are not selected in accordance with their indirect morphological or biological features; however, these features - the shape of a tuft, the length of a plant or the position of leaves - contribute to an increase in competitiveness. Nevertheless, the competitiveness of the currently bred conventional varieties can be tested in the conditions of an organic farming system. Sufficient tillering is one of the complex characteristics responsible for high competitiveness against weeds (Kruepl et al., 2006). Selection is also one of the main parameters in this respect (Köpke, 2005). The architecture of a plant also has an important effect (length of stalk, percentage of leaves, position, compactness and shape of leaves) (Regnier & Ranke, 1990). Medium to tall varieties are the most suitable in this respect (Moudrý, 2003). Kunz & Karutz (1991); Eisele & Köpke (1997); Müller (1998) and Köpke (2005) also point to the higher competitiveness of the taller varieties. However, the taller varieties also cause such problems as lodging (Kruepl et al., 2006). Fast growth of the plant in the first stages of life is a very important aspect as it allows an early achievement of a high LAI value. A planofile position of leaves (>45°) in the first stages of growth assures a higher degree of coverage of the soil surface, and a deterioration in the growing conditions for weeds, although in the worse nutritive stations this can also lead to slower development of the plants. An erectofile position of leaves is a more favourable feature for the later stages of the plant's growth (Hoad et al., 2005). The competitiveness of plants also depends on the speed of collumning, LAI, capacity of the upper phytomass and the tallness of plants in the DC 31-75 stage (Köpke, 2005).
A number of authors also point out that competitiveness is determined by a good ability to absorb nutrients in low-input farming conditions. Varieties must be adapted to the negligible use of nitrogenous fertilizers and be able to cover the soil as fast as possible (Kunz & Karutz, 1991; Eisele & Köpke, 1997; Müller, 1998). Alleopathic secretions may also influence the growth of other crops. However, according to studies, alleopathic secretions play an important role in the growing system of rye and oat, but not wheat (Köpke, 2005). Nevertheless, research results also rebut this fact; they point out that the aleopatic potential may lead to a reduction in yield and quality (Regnier & Ranke, 1990).

2.2.3 Disease resistance

A plant's health depends primarily on preventive measures, which can mean the creation of optimum conditions for growth, prevention against stressors, and the taking into account of the natural tolerance to plant competitors. Several diseases occur not because of poor growing conditions, but because of an imbalance between the plant and the environmental conditions; this can lead to an imbalance in the metabolism processes, and the attraction of insects, fungal and bacterial diseases (Tamis & Van den Brink, 1999).

The main selection criterion for good breeding is not the level of resistance; it is rather the ability of a specific plant to create a certain level of yield and quality in spite of the pressure of infectious diseases (Lammerts van Bueren, 2002). The resistant plant should not be just resistant, but its morphological features should also guarantee its resistance in conditions of higher infection. This fact is not taken into consideration in the selection process of conventional varieties. However, it is one of the reasons for the reduced resistance of conventional varieties, which are without any chemical protection against fungal diseases, as the following examples show: the occurrence of *Septoria nodorum* is influenced by a plant's architecture (Kunz, 1983), in that the transfer of spores from leaves to spikes by raindrops may be reduced by a longer distance between spike and flag leaf (Köpke, 2005); high plants are more resistant (Kunz, 1983) and *Fusarium* spp, an infection of spikes, is influenced by the distance between spike and flag leaf (Engelke, 1992).

2.2.4 Yield stability and product quality

Organic yield is in the case of the best organic farms about 20-30 % lower than the conventional (Mäder et al., 2002; Lammerts van Bueren et al., 2002; Konvalina et al., 2009). The quality and stability of the yield are the main priorities for organic farming which does not lay stress on the quantity of production. Farmers usually need to grow 'reliable' and 'solid' varieties which are able to tolerate potential fluctuations in the weather and the potential pressure of diseases; they must in any case be able to provide sufficient yield of grains and straw. The target variety should be bred to provide a lower, but stable yield. The selection of the conventional varieties is based on the yield level and it is carried out in uniform conditions. According to the results of tests carried out by organic farmers, conventional varieties which provide a high yield are not as efficient as organic varieties in marginal areas. The suitability of the conventional varieties may be tested in the conditions of the organic farming system where relatively stable varieties providing a high yield can be selected.

A variety may be characterized by specific features due to the interaction between genotype and environment; a favourable factor may be that such varieties can be marketed as a regional product. This aspect is based on the fact that its flavour adds special features and character to the variety (Lammerts van Bueren & Hulscher et al., 1999).

The high baking quality of the organic varieties is characterized by the proportion and total content of crude protein, high value of the Zeleny - sedimentation, flour binding capacity and flour yield, falling number and test weight. The baking quality of wheat is a complex feature; the breeding of such varieties (to a high quality) is a long and difficult process (Fossati et al., 2005).

Organic methods of farming may have negative effects on the technological value, especially in the case of crucial crude protein content (Moudrý & Prugar, 2002). The proportion of crude protein in grain is reduced because of the reduced availability of soluble nitrogen

(Krejčířová et al., 2006). The composition of storage proteins also changes, there are more protoplastic proteins (albumins and globulins) (Krejčířová et al., 2007), and this increases the nutritive value of grain.

2.3 Suitability of wheat species for organic farming

Exact small-plot trials with particular selected varieties (bread and durum wheat) and genetic resources of hulled wheat species (einkorn, emmer wheat, spelt wheat) were established at the authors' working places between 2005 and 2010. Significant and important characteristics for organic farming (morphological, biological characteristics, yield formation and structure of yield, qualitative parametres of the production) were evaluated.

2.3.1 Bread wheat (modern winter varieties)

In the experimental years 2006-2008, 10 varieties and strains of bread wheat (Capo, Eriwan, Element, Eurofit, Clever, Ludwig, Epsilon, Element, SE 304/05, SE 320/05), coming from the conventional and organic breeding programmes of Austrian breeding stations, were grown in small plot trials (10 m2) with two replications at the location of South Bohemia, experimental fields of the University of South Bohemia in České Budějovice.
Grain yield was strictly dependent on the year, analysis of the variation (ANOVA) punctuated the dominating effect of the year on the grain yield (93%). The average yield was highest in 2008. There were observed significant differences between the varieties. The Clever variety belonged to the least profitable ones (2,52 - 6,1 $t.ha^{-1}$). On the other hand, the Eurofit (4,21 - 7,2 $t.ha^{-1}$) and the Capo (4,47 - 7,40 $t.ha^{-1}$) varieties belonged to the most profitable (Table 2). Lack of available nitrogen proved to be the most limiting factor of the yield formation. The inflow of such nitogen depends on the total degree of absorption from the soil, translocation of assimilates into the grain and losses of the absorbed nitrogen (Papakosta, 1994; Bertholdsson & Stoy, 1995; Barbottin et al., 2005). The detailed analysis of crude protein yield ($t.ha^{-1}$) provides interesting results; it makes the positive correlation with the grain yield (r=0,96) (Table 3). The year had an even more significant and dominating effect (96%) (Table 3) than the grain yield. Crude protein yield is a more stable feature than the total grain yield. The cultivars reached 52 % of the grain yield level and 58 % of the crude protein yield level in 2006 (compared to 2008). It means the cultivars provide higher grain yield, but lower crude protein content in grain in more favourable years for the creation of the yield. Slafer et al. (1990) presents a possible explanation; he quotes the ability to absorb nitrogen from the soil, and this did not improve during the breeding process of modern cultivars; nevertheless, the distribution of the assimilate in a plant did improve – it leads to the dillution of the concentration of nitrogenous elements in grain, which is connected with the increase of the grain yield.
Table 2 shows the stability of the selected parametres of the baking quality, produced in the low-input farming system. Starch content is the most stable feature (CV = 1 in all the studied years). On the other hand, Zeleny sedimentation value is the least stable indicator of the baking quality in the nitrogen low-input farming system. The crude protein content and wet gluten content did not fluctuate.
Weather progress was favourable for the crude protein content in 2006 (Burešová & Palík, 2006); the average crude protein content amounted to 12.6 %. It reached 9.7 % in 2007 and 10.8 % in 2008. There were some cultivars exceeding the average values, e.g. Element (14.5%

- 2006; 11.2% - 2007; 11.6 - 2008), and some subnormal cultivars, e.g. Clever (10.6% - 2006; 8.7% - 2007; 10.7 – 2008). These examples show how the selection of an unsuitable variety may cause a significant negative difference in the crude protein content (up to 3.9% (2006); 2.4% (2007) or 1.7% (2008). Considering the close relationship (r=0.93) between the crude protein content and wet gluten content (Table 3), Element variety had the highest wet gluten content value (2006, 2007) and the second highest wet gluten content value in 2008. The relationship between the crude protein content and wet gluten content is in accordance with the results of Krejčířová et al. (2006) who quotes that there is an even closer relationship between these two idnicators in the low-input farming system than in the conventional one. Starch content increased in less favourable years for the protein formation (2007, 2008) (a negative relationship between the protein content and starch content, r=-0.37). In 2006, the Clever cultivar was characterised by the highest starch content, whereas it was characterised by the lowest crude protein content at the same time (Clever).

Variety	Yield Parametres		Selected Parametres of the Baking Quality			
	Grain Yield (t/ha)	Crude Protein Yield (t/ha)	Crude Protein Content (%)	Wet Gluten Content (%)	Zeleny Test (ml)	Starch Content (%)
Ludwig	5.32	0.57	10.8	20.4	39	67.7
Eurofit	5.27	0.57	11.0	19.1	38	67.2
Erivan	4.80	0.49	10.4	18.1	41	66.8
Element	4.50	0.54	12.4	23.6	50	66.3
Clever	4.42	0.45	10.0	19.5	30	67.3
Capo	5.60	0.63	11.3	21.9	47	67.5
408/04	5.02	0.53	10.3	19.6	37	67.2
322/04	5.60	0.59	10.6	20.0	36	67.0
320/05	5.85	0.60	10.4	19.2	37	67.6
304/05	5.29	0.60	11.3	20.8	42	66.1
Mean	5.2	0.6	10.9	20.2	39.7	67.1
SD	0.83	0.09	0.75	1.83	7.00	0.82
CV (%)	18	18	7	9	21	1

Table 2. Yeld and quality of winter wheat varieties (mean of 2006-2008)

Zeleny sedimentation value characterises the viscoelastic features and quality of the proteins, it allows the fermentation process in dough (Zimolka et al., 2005). Positive middle correlation was observed between the crude protein content and Zeleny sedimentation value (r=0.44). Element seems to be better from the perspective of protein quality (51 ml – 2006; 38 ml – 2007; 62 ml - 2008). On the other hand, the Clever variety proved the lowest values (24 ml – 2006 and 12 ml – 2007). In 2008, the values of Zeleny sedimentation increased in the cases of all the varieties (by 20 ml in comparison with 2006; by 32 ml in comparison with 2007).

Iendicator		1	2	3	4	5	6
Crude Protein Yield	1	1.00					
Grain Yield	2	0.96	1.00				
Crude Protein Content in Grain	3	-0.13	0.14	1.00			
Wet Gluten Content	4	-0.12	0.13	0.93*	1.00		
Zeleny Sedimentation Value	5	0.65*	0.78*	0.44*	0.41*	1.00	
Starch Content	6	0.81*	0.71*	-0.37*	-0.36*	0.56*	1.0

* statistically significant $p<0.05$

Table 3. Correlation analysis of the yield level and quality parametres

The results of the analysis proved the low-input (organic) farming system is connected with the reduction of the yield level and technological quality, expressed by the reduction of the crude protein content in grain and reduction of the protein swelling (Zelehy sedimentation values). The dominating effect of the yearly progress on these factors was also confirmed. According to the results of the analysis, a selection of „elite varieties" is recommended for the low-input farming systems – the varieties with high crude protein content and high Zeleny sedimentation values (e.g. Element). "Elite varieties" also respond to the absence of supporting elements (easily soluble nitrogenous fertilizers) by a reduction of the crude protein content in grain. Such a reduction is usually smaller than in worse-quality varieties, grown in the same conditions. On the other hand, „elite varieties" provide grains, characterised by better baking quality, but they provide lower yield than worse-quality varieties. This fact has to be taken into account when selecting suitable cultivars for food and feed processing.

2.3.2 Bread wheat (comparison of modern spring varieties and old varieties)

Tested varieties come from the Gene Bank of the Research Institute of Crop Production in Prague. Four old varieties of bread wheat and two top bread wheat modern cultivars, Vanek (German origin) and SW Kadrilj (Swedish origin), have been used as control varieties there. Varieties were sown in a randomized, complete block design on experimental parcels in Prague and Ceské Budejovice during 2007, 2008 and 2010.

We have evaluated particular agronomically significant characteristics influencing the total yield rate of the old and modern bread wheat varieties. Table 4 presents the results of the research from the point of view of a comparison of all the tested varieties. All the bread wheat varieties were affected by powdery mildew and rust. Especially the intermediate form of bread wheat (Rosamova přesívka) was less resistant to rust. Modern varieties of bread wheat were characterised by better and more efficient nutrient-management at the station that was supplied better with nitrogen. Correlation analysis (Table 5) has also proven a relationship between the quantity of nitrogen in the plant fytomass in the flowering period and the total quantity of nitrogen in the grains of bread wheat ($r = 0.77$). Old wheat varieties have also been characterised by a relatively low weight of one thousand grains (TGW) (39.55 g) in comparison to control (43.12 g) bread wheat varieties. The tested and evaluated old wheat varieties have achieved 69 % of the yield level control cultivars (SW Kadrilj, Vanek). Concerning the total hectare crude protein yield, the difference between the cultivars was at the same level. On the other hand, the old wheat varieties were characterised by higher crude protein content in grain (15.08 %) than the control (13.73 %) bread wheat varieties. The grain and protein yield were more stable in the case of the old wheat cultivars (Table 4). These results have indicated the fact that the old bread wheat landraces are more adaptable to different runs of the year and different nutritive states of different localities than the modern bread wheat varieties. However, the main disadvantage of its growing is lower productivity in comparison with modern bread wheat varieties.

Parameter	Old Varieties	New Varieties
Powdery Mildew Resistance (0-9 = resistant)	7.24±0.77[c]	8.03±0.89[b]
Rust Resistance (0-9 = resistant)	7.02±1.27[b]	7.33±1.01[b]
Plant Length (cm)	99.67±18.07[b]	89.42±13.14[c]
Index of Lodging	8.14±1.01[a]	8.81±0.45[a]
Number of Tillers	1.62±0.51[b]	1.52±0.49[b]
N Content in Plant (%)	1.72±0.42[a]	1.77±0.55[a]
N Content in Grain (%)	15.08±1.66[b]	13.73±1.22[c]
Yield (t/ha)	4.24±1.74[b]	5.02±2.29[a]
Yield of Dehulled Grain (t/ha)	4.24±1.74[b]	5.02±2.29[a]
Yield of Protein (t/ha)	0.629±0.24[a]	0.682±0.31[a]
Harvest Index	0.40±0.05[b]	0.46±0.03[a]
Thousand Grain Weight (g)	39.55±7.51[b]	43.13±4.70[a]

Different letters document statistical differences between varieties for theTukey HSD test, P < 0.05

Table 4. Differences in Selected Agronomically Important Traits in Different Groups of Varieties (mean + SD of three years, two localities)

Parameter	Bread Wheat – Old Varieties			Bread wheat – Modern Varieties		
	Protein Content	Grain Yield	Protein Yield	Protein Content	Grain Yield	Protein yield
Powdery Mildew Resistance	-0.40[ns]	-0.53*	-0.68**	-0.20[ns]	-0.77*	-0.30[ns]
Rust Resistance	0.15[ns]	0.02[ns]	0.03[ns]	0,42 [ns]	-0.81*	-0.24[ns]
Plant Length	-0.48[ns]	0.63**	0.56*	-0.56[ns]	0.81*	0.74*
Index of Lodging	-0.26[ns]	-0.62*	-0.75*	-0.20[ns]	-0.68*	-0.73*
Number of Tillers	0.15[ns]	0.07[ns]	0.10[ns]	0.12[ns]	0.21[ns]	0.23[ns]
N content in plant	0.40*	0.41[ns]	0.54*	0.77*	0.26[ns]	0.39[ns]
Harvest index	-0.23[ns]	0.25[ns]	0.20[ns]	0.78*	-0.54[ns]	-0.43[ns]
TGW	-0.06[ns]	0.22[ns]	0.18[ns]	-0.15[ns]	0.54[ns]	0.53[ns]

statistically significant P < 0.05; ** highly statistically significant P < 0.01; nsnot significant

Table 5. Correlation Between Selected Agronomically Important Traits

2.3.3 Hulled wheat species

Competitiveness against weeds and resistance to lodging are the essential factors influencing the productivity of wheat growing. Longer plants are more resistant and competitive with weeds (Cudney et al., 1991). Plants must be resistant to lodging (Konvalina et al., 2010). As for the studied and evaluated wheat species, spelt and emmer wheat plants were longest (127 cm) (Table 6). On the other hand, SW Kadrilj, a control variety, had short stalks (88.7 cm). It may be a cause of danger if this cultivar is grown in an overweeded crop stand. Resistance to lodging was an important factor too. Short plants do not have to be automatically more resistant to lodging (Pagnotta et al., 2005). SW Kadrilj, a control variety, did not inclinate to lodging at all. As for the hulled wheat species, all of them attained a similar rate of resistance to lodging.

The good disease resistance of plants is extremely important in nature-friendly farming systems because they perform under limited chemical treatment and protection of plants (Wolfe et al., 2008). Our research assessed the resistance to mildew and brown rust attacks. Genetic resources are usually considered as originators and carriers of such resistance (Heisey et al., 1997). All einkorn varieties were resistant to brown rust and powdery mildew as well and most of emmer wheat varieties were also resistant (Table 6). Spring spelt wheat varieties were not greatly infested with powdery mildew. All the varieties were, nevertheless, less resistant to brown rust; it might cause serious problems if a strong brown rust infection attacked the crop stand. Brown rust is considered as one of the most serious wheat diseases in developing countries (Heisey et al., 1997). Health and wholesomeness of farm products have to be guaranteed in the sustainable farming system. If the cropping is neither suitable nor well compiled (Vogelgsang et al., 2008) or if less resistant varieties are grown (Ittu et al., 2010), the crop stands may be attacked by *Fusarium* spp. Such infections can result in yield losses, but more important in contamination of the grain with mycotoxins produced by the pathogens (Köhl et al., 2007). Harvested products are contaminated due to the accumulation of toxins such as deoxynivalenol (DON) produced by *Fusarium* spp. (Nedělník et al., 2007). Mean grain contamination rates did not exceed the permitted limit norms (1.25 mg/kg = limit for contamination according to EC Regulation No. 1126/2007). Spelt wheat grains contained a low proportion of DON (0.11 mg/kg) and there were minimum differences between spelt wheat varieties. Most emmer wheat varieties were also very minimally contaminated with DON (Rudico, Weiser sommer, May emmer). Triticum dicoccon (Tapioszele) was, on the other hand, a problematic variety (0.79 mg/kg). Its grains would be greatly contaminated with DON if this variety was grown after an unsuitable forgoing crop or if the crop stand was lodged (Vogelgsang et al., 2008). Such grains would not be good for consumption by people. Hulls may highly contribute to a reduction of the DON grain contamination rate. They protect grains and they are peeled away from grains just before the final processing of grains (Buerstmayr et al., 2003).

Mean world wheat yield rates attain 3 t/ha at maximum (Mitchell & Mielke, 2004). The yield rate is lower in organic farming systems as supporting instruments are limited in such farming systems (mineral fertilizers, pesticides) (Neascu et al., 2010). A stable (even if it is lower) yield rate is the most important aspect (Wolfe et al., 2008). As for our research, control varieties attained a mean yield rate of 3.0 t/ha (SW Kadrilj - 3.7 t/ha). Hulled wheat species attained lower yield rates (Table 6). Einkorn varieties attained the lowest yield rates which were not very variable. As for emmer wheat varieties, Rudico attained the highest yield rate (2.8 t/ha) and Triticum dicoccon (Tapioszele) attained the lowest yield rate (1.5

t/ha). Concerning spring spelt wheat varieties, the yield rates varied from 2.5 to 2.7 t/ha. The hulled wheat usually attain lower values of the harvest index (Marconi & Cubadda, 2005). Therefore, some of the wheat landraces may be grown in farming systems working with less nutrients in the soil (organic farming) (Trčková et al., 2005) or on less fertile parcels (Marconi & Cubadda, 2005).

Comparison of the per hectare crude protein yield showed an interesting fact. It attained a mean value of 389.3 kg/ha in the control varieties (SW Kadrilj - 450.1 kg.ha), whereas it was lower in einkorn varieties where it varied from 301.4 to 346.8 kg/ha. Emmer wheat varieties attained similar values too, except from Rudico (432.3 kg/ha). Two spelt wheat varieties attained higher values of the per hectare crude protein yield than the control ones (Triticum spelta Tabor 22 – 453.2 kg/ha; Triticum spelta No. 8930 – 475.0 kg/ha).

Many literary sources present specific parametres of the production as a frequent reason for the growing of the hulled wheat species (Suchowilska et al., 2009). The proportion of proteins in grain is the crucial wheat quality indicator (Shewry, 2009). The control varieties attained the lowest values in our research (SW Kadrilj – 12.3%). Muurinen et al., 2006, explain it in such a way that the modern breeding process should provoke an increase of the yield rate by "grain dilution." Emmer wheat varieties attained the highest proportion of proteins in grain – a mean value of 16.8% (Triticum dicoccon Tapioszele – 17.4%), whereas spelt wheat varieties attained a mean value of 16.5% (Triticum spelta No. 8930 – 17.5%) and einkorn varieties attained a mean value of 15.8%n (Triticum monococum 44 – 16.9%).

The hulled wheat varieties contained more wet gluten than the control wheat varieties. The technological quality of the wheat species was very different. Generally said, the wheat species may be divided into two different groups: the first one involves the varieties suitable for baking (production of yeasty goods) and the second category involves the varieties suitable for other sorts of production (Shewry, 2009). The varieties suitable for baking should attain high gluten index values (70) and high sedimentation values (50 ml). Einkorn and emmer wheat varieties attained very low gluten index values (12.7 – 20.7 ml) which was caused by an absence of the D genome (Marconi & Cubadda, 2005). Such gluten is weak and is not good for the production of yeasty goods. Einkorn and emmer wheat varieties also attained low values on the SDS test (einkorn – a mean value of 29.9 ml; emmer wheat – mean value of 31.8 ml). The sedimentation test values are reflected in a volume of bakery products, which means that einkorn or emmer wheat bakery products are not too yeasty and they are flat. Spelt wheat attained higher gluten index values (28.2 – 44.5) and higher sedimentation values (46.2 – 70.2 ml), which were close to the values attained by the control bread wheat varieties like SW Kadrilj (gluten index = 75.0; SDS test = 74.7 ml).

Resistance to diseases (powdery mildew and brown rust) is the crucial advantage of einkorn and emmer wheat varieties (it has been confirmed by our research and trials). They have been also characterised by a lower DON grain contamination rate than bread wheat varieties. Some of the spelt wheat varieties have been infested and damaged by brown rust, but the DON grain contamination rates have been lowest there. Particular varieties have been less resistant to lodging. The selection of suitable and resistant varieties should be, therefore, done very carefully. Concerning the total yield rate, the studied hulled wheat varieties have attained lower yield rate values. Higher per hectare crude protein yield has been an important advantage of particular varieties (spelt wheat, emmer wheat) (being compared to SW Kadrilj, a control bread wheat variety). As for the yield formation, the hulled wheat varieties are suitable for growing in less favourable conditions (montane areas, dry regions) or in low-input and organic farming systems.

Parameter	Einkorn	Emmer	Spelt	Bread Wheat Control
Plant Length (cm)	114.1±10.6	127.0±15.6	126.8±10.4	103.4±22.0
Lodging (0-9)	5.6±2.9	6.0±2.1	5.9±2.6	7.6±2.0
Mildew (0-9)	8.9±0.1	8.8±0.3	8.5±0.6	8.4±0.6
Rust (0-9)	8.8±0.2	8.5±0.6	6.8±1.0	6.2±1.9
DON (ppb)	168.8±321.1	192.7±696.3	110.6±253.1	234.2±314.1
Yield (t/ha)	2.1±1.3	2.1±1.2	2.6±1.4	3.0±1.7
Protein Yield (kg/ha)	324.1±210.8	348.0±195.3	422.6±238.6	389.3±228.9
Protein Content (%)	15.8±2.4	16.8±2.4	16.5±2.0	13.2±2.2
Wet Gluten (%)	38.5±9.8	41.4±8.3	44.4±7.7	31.6±8.6
Gluten Index	15.0±4.9	15.2±9.9	36.4±14.7	66.0±15.5
SDS (ml)	29.9±9.6	31.8±12.8	59.6±13.5	66.9±15.6

Table 6. Agronomic and Quality Parameters of Hulled Wheat Species

Concerning the quality, the hulled wheat varieties have contained a higher proportion of proteins in grain. Spelt wheat is suitable for direct baking (the selection of varieties has to be done, however, very carefully). On the other hand, einkorn and emmer wheat varieties are suitable for production of unyeasty goods (e.g. pasta, biscuits, etc.) as they have attained low sedimentation values and gluten index values. All the hulled wheat species are good for the production of traditional food goods or they may be processed in so called craft bakery machines. Growing and processing of the hulled wheat species as organic products would bring higher added value to farmers.

3. Conclusion

More than 50 % of a acreage of organic arable land is cropped with cereals. Bread wheat (*Triticum aestivum* L.) is the most important market cereal species. As organic farming has undergone a significant development and it is still unevenly set up in various countries, there is a deficiency of suitable varieties for the sustainable farming systems. High costs for breeding, weak and uneven representation of the organic farming are the main reasons of such a state. Almost any modern bred varieties of bread wheat which are conventionally grown are not suitable for organic farming. Different selective criteria from the ones applied to the selection of varieties for organic farming are among the main reasons. E.g. less efficient root system, low competitiveness to weeds, low resistance to usual diseases or reduced baking quality provoked by a reduction of the proportion of nitrogen in the soil. Organic farmers have several options when selecting suitable varieties for organic farming:

1. Selection of a conventional bred variety - almost no conventional varieties of bread wheat (*Triticum aestivum* L.) and durum wheat (*Triticum durum* Desf.) have been tested in organic farming conditions. Organic farmers may base the selection of varieties on results of official trials that were carried out in the conventional farming system, they may follow the advice of advisors, distributors of seeds, research and their own experience and knowledge.
2. Selection of organic bred varieties of wheat – very narrow and an unsufficient range of available varieties, just in a small number of countries.

3. Application of a wide diversity of species and growing of various wheat species (not only bread wheat), e. g. einkorn (*Triticum monococum* L.), emmer wheat (*Triticum diccocum* Schrank) or spelt wheat (*Triticum spelta* L.). A competitiveness to weeds, efficient root systems and resistance to usual wheat diseases are the main advantages of the above-mentioned wheat species. Concerning the production marketing, a grain with a specific quality is an important advantage too.

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