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Baking quality of winter wheat varieties in organic farming

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Abstract. The technological value of wheat is negatively influenced by organic methods of cultivation. The critical factor is the crude protein content and quality. The aim of this paper is to identify diferences in the quality of eight varieties and two strains of wheat recommended in conventional or organic conditions. Correlation analysis of the qualitative parameters of wheat shows a clear relationship between crude protein content, wet gluten content and Zeleny - sedimentation value. According to the test results, it is appropriate to use the content and quality of protein as selective criteria for the selection of varieties. The Level of baking quality is never reduced below the quality level of the worstquality varieties grown in the same conditions. On the other hand, the best quality varieties provide grains characterized by better baking quality, but lower yield level, than the others.

Key words: winter wheat, organic farming, baking quality

INTRODUCTION

Organic farming is a farming system characterised by a limited nutrient content (easily soluble nitrogen) and the absence of the separate and gradual application of nitrogen (Köpke, 2005). Toleration of nitrogen in early spring seems to be a significant problem in the cultivation of winter cultivars. In early spring, wet soil is characterised by a low degree of microbial activity and the process of mineralization of nutrients is limited (Moudrý, 2003). Efficient inflow of nitrogen, connected with the high quality of production and development of plants in the early growing stages are very important aspects (Renets, 2002). Cultivars should therefore have the ability to perform under a low input of organic fertilizers, possess a good root system to interact with the beneficial soil microorganisms and to suppress weeds (Lammerts van Bueren et al., 2002, 2003).

Organic yield is 20–30 % lower than the conventional yields (Moudrý, 1997; Mäder et al., 2002; Lammerts van Bueren et al., 2002). The quality and stability of the yield are the main priorities of 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 be able to provide sufficient yield of grains and straw (Lammerts van Bueren, 2002). The high baking quality of the organic varieties is characterized by crude protein content, high value of the Zeleny - sedimentation value, 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 (for high quality) is a long and difficult process (Fossati et al., 2005). Organic methods of farming may have negative effects on the technological value (Moudrý & Prugar, 2002).

Nowadays, farmers must use modern cultivars, which are not suitable for low-input farming system, until new wheat varieties are bred especially for organic farming systems (Lammerts van Bueren, 2002). New breeding programmes are emerging because of the different genetic background of the conventional varieties (Kunz & Karutz, 1991). Lammerts van Bueren (2003) points out that, in order to avoid the use of chemical fertilizers and pesticides in organic agriculture, agroecological principles should be applied to enhance the self-regulatory capacity of the agroecosystems. Organic farmers require cultivars that can be multiplied and grown in an organic farming system with no undue negative effects on the health and function of the agroecosystem (Kunz & Karutz, 1991).

The aim of this paper is to identify diferences in quality of eight varieties and two strains of winter wheat recommended in conventional or organic conditions and to establish appropriate criteria of the selection of suitable cultivars for organic farming (from the technological quality point of view).

MATERIALS AND METHODS

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), from conventional breeding programmes of Austrian breeding stations were grown in small plot trials (10 m^2) with two replicates at a location in South Bohemia, the experimental fields of the University of South Bohemia in České Budějovice (USB). The characteristics of the trial station: altitude of 388 m; mean air temperature of 8,2°C; total annual precipitation of 620 mm; sunshine duration of 1,564.3 hours; pH ($CaCl_2$) of 6.3; P – 138 $mg.kg^{-1}$; K – 155 $mg.kg^{-1}$; Mg – 163 $mg.kg^{-1}$; Ca – 1,557 $mg.kg^{-1}$. The experiments were carried out in a low input growing system (practically but not certificated organic farming system), without mineral fertilizers and pesticides. The previous crop was a mixture of legumes and cereals, at regular periods of 4 years a dose of manurewas applied. The quality parameters were analysed by an NIR spectroscopy system.

RESULTS AND DISCUSSION

Grain yield was dependent on the year, analysis of variance (ANOVA) demonstrated the dominant effect of year on the grain yield (93%). The mean yield was highest in 2008; which year was also mean in regard to precipitation and temperature. In 2008, the yield was doubled the yield in 2006 (+ 3.52 $t.ha^{-1}$). There were significant differences observed between the varieties. The Clever variety was one of the least profitable ones (2.52–6.1 $t.ha^{-1}$). On the other hand, Eurofit (4.21–7.2 $t.ha^{-1}$) and Capo (4.47–7.40 $t.ha^{-1}$) varieties were the most profitable cultivars. Lack of available nitrogen proved to be the most limiting factor for yield . The inflow of such nitogen depends on the total degree of absorption from the soil, translocation of assimilates into the grain and losses of absorbed nitrogen (Papakosta, 1994; Bertholdsson & Stoy, 1995; Barbottin et al., 2005).

Table 1. Correlation analysis of the yield level and quality parameters.

Indicator		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

Remark: * statistically significant *P* < 0.05

Table 2. Variation analysis (ANOVA) of the yield level and quality parameters.

F Factor	Selected parameters of the baking quality								Yield parameters			
	Crude protein content (%)		Wet gluten content (%)		Zeleny sedimentation value (ml)		Starch content (%)		Grain yield (t ha^{-1})		Crude protein yield (t ha^{-1})	
	F	%	F	%	F	%	F	%	F	%	F	%
V Variety	24.8**	8	16.7**	7	60.0**	4	15.0**	1	5.6*	5	2.2	2
Y Year	237.2 **	80	203.9 **	91	1589.6 **	95	1473.0 **	98	107.9**	93	111.1**	96
1 x 2	7.6**	2	4.4**	2	16.8**	1	10.0**	1	2.3*	2	2.2*	2

Remark: * statistically significant *P* < 0.05; ** statistically significant *P* < 0.01

The detailed analysis of crude protein yield (t.ha^{-1}) provided interesting results; a positive correlation with grain yield (*r* = 0.96) (Table 1). Year had a more significant effect (96%) (Table 2) than grain yield. Crude protein yield is more stable than total grain yield. The cultivars achieved 52 % of the grain yield and 58 % of the crude protein yield level in 2006 compared to 2008. This means that the cultivars achieved higher grain yields, but lower crude protein content in grain, in a more favourable year for yield. Slaffer et al. (1990) presents a possible explanation; he reports that the ability to absorb nitrogen from the soil did not improve during the breeding of modern cultivars; but nevertheless, the distribution of the assimilate in the plant did improve – this leads to dilution of the concentration of nitrogenous elements in grain, which is related to increase in grain yield.

The signicficant influence of year was confirmed for all of the evaluated quality indicators (Table 2). The influence was significant, but weak. It is caused by the fact that the amount of the wheat grain protein complex depends on environmental factors, and not so much on the genotype. Triboi et al. (2000) reports in his paper that the cultivar has a negligible effect on the content of nitrogenous elements (not more than 4%).

Table 3 shows the stability of the selected parameters for baking quality produced in a low-input farming system. Starch content is the most stable feature (CV = 1 in all the years studied). On the other hand, Zeleny sedimentation value is the least stable indicator of baking quality in a low-input nitrogen farming system. The crude protein content and wet gluten content did not change (Table 3).

Table 3. statistical evaluation of the yield level and quality parameters (two replications on average).

Variety	Yield parameters						Selected parameters of the baking quality											
	Grain yield (t ha^{-1})			Crude protein yield (t ha^{-1})			Crude protein content (%)			Wet gluten content (%)			Zeleny sedimentation value (ml)			Starch content (%)		
	6	7	8	6	7	8	6	7	8	6	7	8	6	7	8	6	7	8
Ludwig	.59	.67	.7	.41	.57	.73	1.4	0.1	0.9	2.7	8.4	0.2	9	8	0	4.8	8.0	0.3
Eurofit	.21	.4	.2	.56	.43	.72	3.3	.9	.9	2.3	7.2	7.9	4	0	0	4.9	5.2	1.4
Erivan	.67	.12	.6	.41	.39	.68	1.3	.4	0.4	0.7	5.5	8.2	9	9	6	4	6.3	0
Element	.71	.68	.1	.4	.41	.81	4.5	1.2	1.6	9.1	0.1	1.5	1	8	2	3.3	6.8	8.8
Clever	.52	.65	.1	.27	.41	.66	0.6	.7	0.7	1.8	6.9	9.9	4	2	4	5.5	6.5	9.8
Capo	.47	.94	.4	.55	.5	.85	2.4	0.1	1.5	4.6	8	3.1	7	8	5	4.9	7.8	9.9
408/04	.75	.1	.2	.51	.19	.89	0.7	.2	0.9	0.9	6.7	1.2	1	9	1	4.9	6.7	0.1
322/04	.31	.68	.8	.51	.43	.83	1.9	.2	0.6	3.7	7.0	9.4	0	3	5	4.1	6.2	0.6
320/05	.68	.76	.1	.41	.55	.84	1.1	.6	0.4	0.9	7.2	9.6	8	2	1	5.0	6.7	1
304/05	.02	.96	.9	.54	.38	.87	3.4	.5	0.9	5.9	6.3	0.1	6	1	0	2.7	5.5	0
mean	.79	.40	.31	.46	.43	.79	2.1	.7	0.8	3.3	7.3	0.1	7	5	7	4.4	6.6	0.2
SD	.73	.05	.70	.09	.11	.08	.04	.69	.51	.67	.27	.54	.88	.17	.95	.87	.87	.71
CV (%)	9	4	0	0	5	0				2			4	9				

The weather progress was favourable for crude protein content in 2006 (Burešová & Palík, 2006); the average crude protein content amounted to 12,6%. This was comparatively; 9.7% in 2007 and 10.8% in 2008. Some cultivars exceeded the mean 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 the selection of an unsuitable variety may cause a significant negative effect on the crude protein content (up to 3.9% (2006); 2.4% (2007) or 1.7% (2008) (Table 3).

Considering the close relationship (r = 0.93) between the crude protein content and wet gluten content (Table 1), the variety "Element" 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 accord with the results of Krejčířová et al. (2006) who states that there is an even closer relationship between these two indicators in a low-input farming system than a conventional system. The starch content increased in less favourable years for protein formation (2007, 2008) (there was a negative relationship between the protein content and starch content, *r* = -0,37). In 2006, the cultivar „Clever" was characterised by the highest starch content, whereas it was also characterised by the lowest crude protein content. The Zeleny sedimentation value characterises the viscoelastic features and quality of the proteins, it indicates the potential for the fermentation process in dough (Zimolka et al., 2005). A positive central correlation was observed between the crude protein content and Zeleny sedimentation value (*r* = 0,44). "Element" seems to have the moste potential from the protein-swelling point of view (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 value increased in all the varieties (by 20 ml in comparison with 2006; by 32 ml in comparison with 2007).

CONCLUSIONS

The results of the analysis showed that a low-input (organic) farming system is associated with a reduction in the yield level and technological quality, expressed by the reduction of the crude protein content in grain and reduction of protein swelling (Zelehy sedimentation values). The dominating effect of the year on these factors was also confirmed.

According to the results of the analyses, selection of "elite varieties" is recommended for 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 available minerals (easily soluble nitrogenous fertilizers) by a reduction in the crude protein content in grain. Such a reduction is usually smaller than wiht lowerquality varieties grown under the same conditions. On the other hand, "elite varieties" provide grains, characterised by better baking quality, but they provide lower yields than lower quality cultivars. This fact must be taken into account when selecting suitable cultivars for utility industries (food, feed and industry processing).

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REFERENCES

Barbottin, A., Lecomte, C., Bouchard, C. & Jeuffroy, M.H. 2005. Nitrogen remobilisation during grain filling in wheat: genotypic and environmental effects. *Crop Sci.* **45**, 1141–1150.

Bertholdsson, N.O. & Stoy, V. 1995. Yields of dry matter and nitrogen in highly diverging genotypes of winter wheat in relation to N-uptake and N-utilisation. *J. Agron. Crop Sci.* **175**, 285–295

Burešová, I. & Palík, S. 2006. Kvalita potravinářských obilovin ze sklizně 2006. In: *Sborník z konference Jakost obilovin* 2006, 9.11.2006, Kroměříž, pp. 6–12.

Fossati, D., Kleijer, G. & Brabant, C. 2005. Practical breeding for bread quality. In: *Proceedings of the COST SUSVAR/ECO-PB Workshop on Organic plant Breeding*

Strategies and the use of Molecular Markers. 17–19. January, Driebergen, The Netherlands, pp. 31–35.

Köpke, U. 2005. Crop ideotypes for organic cereal cropping systems. In: *Proceedings of the COST SUSVAR/ECO-PB Workshop on Organic Plant Breeding Strategies and the Use of Molecular Markers.* 17–19. January, Driebergen, The Netherlands, pp.13–16.

Krejčířová, L., Capouchová, I., Petr, J., Bicanová, E. & Kvapil, R. 2006. Protein composition and quality of winter wheat from organic and conventional farming. *Žembdirbysté* **93**, 285–296.

Kunz, P. & Karutz, C., 1991. *Pflanzenzüchtung dynamisch*. Die Züchtung standortpflangepasster Weizen und Dinkelsorten. Erfahrungen, Ideen, Projekten. Forschungslabor an Goetheanum, Dornach, Switzerland, 164 pp.

Lammerts van Bueren, E.T., Struik, P.C., Tiemens-Hulscher, M. & Jacobsen, E. 2003. *Concepts of intrinsic value and integrity of plants in organic plant breeding and propagation*. *Crop Science* **43**, 1922–1929.

Lammerts van Bueren, E.T. 2002. Organic *Plant Breeding and Propagation: Concepts and Strategies*. PhD Thesis, Wageningen University, The Netherland, 196 pp.

Mäder, P., Fließbach, A., Dubois, D., Gunst, L., Fried, P. & Niggli, U. 2002. Soil fertility and biodiversity in organic farming. *Science* **296**, 1694–1697.

Moudrý, J. 1997. *Přechod na ekologický způsob hospodařen*í (Conversion to organic farming). IVV MZe, Praha, 48 pp.

Moudrý, J. 2003. Polní produkce (Field production). In Urban, J. & Šarapatka, B. (eds): *Ekologické zemědělství.* MŽP, Praha, pp. 103–126.

Moudrý J. & Prugar, J. 1999. Kvalita rostlinných produktů ekologického zemědělství (Quality of bioproducts). *Studijní informace ÚZPI*, 5/1999, 40 p.

Papakosta, D.K. 1994. Analysis of wheat cultivar differences in grain yield, grain nitrogen yield and nitrogen utilization efficiency. *J. Agron. Crop. Sci*. **172**, 305–316.

Reents, H.J. 2002. *Sorteneigenschaften und Züchtziele für Getraidearten im Ökologischen Landbau*. Workshop: Züchtung für den Ökolandbau, Hannover (http://orgprint.org).

Slafer, G.A., Andrade, F.H. & Feingold, S.E. 1990. Genetic improvement of bread wheat (Triticum aestivum L.) in Argentina: relationship between nitrogen and dry matter. *Euphytica* **50**, 63–71.

Triboi, E., Abad, A., Michelena, A., Lloveras, J., Ollier, J.L. & Daniel, C. 2000. Environmental effects on the quality of two wheat genotypes: I. quantitative and qualitative variation of storage proteins. *Eur. J. Agron*. **13**, 47–64.

Zimolka, J. et al. 2005. *Pšenice – pěstování, hodnocení a užití zrna.* Profi Press, s. r. o., Praha, 180 pp.