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Grain yield and quality of winter wheat varieties in organic agriculture

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Abstract. During the period 2004–2006, grain yield and quality characteristics of ten winter wheat (*Triticum aestive* L.) varieties from the very good, good and satisfactory baking quality groups were investigated at the Lithuanian Institute of Agriculture under the conditions of organic agriculture. Results showed a marked influence of climatically different years on the winter wheat varieties' grain yield and quality characteristics (protein and gluten content, gluten quality by gluten index, sedimentation index according to Zeleny). When the growing conditions were rather dry and warmer (2006), compared with the long-term mean, grain yield was the poorest but grain quality was the best and grain of most of the winter wheat varieties met the requirements set for bread-making. The varieties 'Lars' and 'Zentos' combined high yield with stability, their sum of integral assessment of grain yield was respectively (11+) and (10+). From quality parameters in varieties a higher variability was noted for sedimentation (26.6–29.7%), but similar variation in separate years showed that this quality parameter was most stable over years. In overall high-quality varieties from the very good / good baking quality groups, an ecological way of growing may give good baking utilization possibilities but this strongly depends on environmental conditions. Varieties 'Širvinta 1' and 'Ada' were more stable concerning wet gluten content and sedimentation, 'Zentos' and 'Alma' – concerning gluten index. *Glu-1* score corresponded significantly and positively with higher sedimentation, hectolitre weight and gluten index.

Key words: organic agriculture, winter wheat, varieties, yield and grain quality

INTRODUCTION

Like the European Union's common agricultural policy, Lithuania's agricultural policy is oriented towards organic farming, which brings both environmental protection and social, economic benefits. In 2008, the certified area of organic production in Lithuania amounted to 127 362 ha, i.e. about 5% of the agricultural land declared for direct payment; cereals accounted for 49% in the structure of organic crops.

The interest in organic farming is stimulated not only by the concern about stable and well-balanced further development of the economy (especially in the light of costly energy resources – fuel, fertilisers, chemical plant protection products) but also by increasing consumer awareness of food safety. Currently, the demand for organically produced cereals, including wheat, still exceeds supply.

The relatively low nitrogen availability in organic farming systems limits winter wheat yields and grain nitrogen, moreover both are greatly influenced by environmental conditions and plant genotype (Lu et al., 2005; Mašauskienė, 2005;

Krejčirova et al., 2006; Sliesaravičius et al., 2006; Baresel et al., 2008). Wheat grain quality is dependent on weather conditions at grain formation and ripening stages, on the plants' ability to take up nitrate-N by the roots and subsequently to remobilize nitrogenous compounds from leaves and stems. It is important to have varieties well adapted to organic growing conditions. Different varieties are necessary in different environments and breeding may contribute to the improvement of yield and baking quality to a certain extent (Tarakanovas & Ruzgas, 2007; Baresel et al., 2008).

For organic production to be competitive, it has to meet certain quality standards. Unfortunately, organic farmers find it difficult to meet the quality standards for wheat (especially protein and gluten content), although they are paid a much higher price for organically produced grain.

The wheat grain quality resides primarily in insoluble storage proteins – glutenins and gliadins – which are major components of gluten. Great attention in determining the dough-forming properties is set to high molecular weight glutenin subunits (HMW-GS) composition (Pena et al., 2005, Horvat et al., 2006). Some studies of HMW-GS composition have shown significant influence on sedimentation value and gluten index (Horvat et al., 2006, Martinez-Cruz et al., 2007).

The aim of the study was to evaluate the grain yield and quality characteristics of winter wheat varieties under the conditions of organic agriculture.

MATERIALS AND METHODS

The studies were carried out at the Lithuanian Institute of Agriculture during 2004–2006. Ten registered winter wheat varieties were involved in the test.

The varieties were grown in 3 replications with a plot size of 5.0×1.5 m^2. The crop was sown at a rate of 5 million seed ha^{-1} into a well prepared seedbed with a Hege 80. The soil of the experimental site is Endocalcari-Epihypogleyic Cambisol (CMg-p-w-can) (55°24'N, 23°50'E), with pH 7.3, percentage of organic matter 2.1, available P_2O_5 150–180 mg kg^{-1} and K_2O 100–150 mg kg^{-1}. The nursery was sown after black fallow. The field was certified by agency 'Ekoagros' for organic agriculture. All practices followed organic certification standards.

The plots were harvested with a Wintersteiger harvester. Yield data were adjusted to 14% moisture content and the following grain quality parameters were determined. Grain from each plot was dried and a composite 500 g sub-sample was taken for quality (duplicate / triplicate) analysis. Hectolitre weight was obtained with a Shopper chondrometer equipped with a 250 ml cylinder (the result was reported kg hl^{-1} without reference to the moisture content). Protein (% dry matter) was calculated by multiplying the corresponding total nitrogen (by Kjeldahl) content by factor 5.7 (ICC 105/2) using a semi-automated N analyser (Kjeltec system 1002, Foss Tecator AB, Sweden). Sedimentation value (ml) was measured according to Zeleny (ICC 116/1, ICC 118).

The wet gluten quantity (reported % on a 14% grain moisture basis) was extracted from whole meal flour in an automated gluten washer and gluten index (unit) determined by Perten (Glutomatic 2100, Centrifuge 2015, Perten Instruments, Sweden; ICC 155). The electrophoretic analysis of HMW-GS composition of each variety was determined by SDS–PAGE using 12 % (w/v) acrylamide gels as described by Kraic et al. (1995).

Table 1. Weather pattern during the field trails at Dotnuva.

Month	Average temperature ºC				Sum of precipitation mm			
	2003/ 2004	2004/ 2005	2005/ 2006	1924-2008	2003/ 2004	2004/ 2005	2005/ 2006	1924-2008
April	7.6	7.6	6.7	5.8	11.1	23.9	19.2	37.2
May	11.2	12.4	12.6	12.2	27.8	46.1	45.0	52.1
June	14.2	15.3	16.8	15.6	44.2	50.3	6.8	61.1
July	16.9	19.3	21.3	17.6	81.6	46.3	40.4	73.3
Average (April–July)	12.5	13.7	14.4	12.8	41.2	41.7	27.9	55.9

The period 2004–2006 was rather favourable for winter cereal versatility evaluation because of the variable weather conditions (Table 1). Spring-summer vegetation period of the year 2004 was characterized as close to normal (anthesis period – July – wet), 2005 – close to normal (July – dry), 2006 – hot and dry.

For the comparison of grain yield and quality between years and varieties we used arithmetic means of the data, standard deviation (SD) and variation coefficients (CV). Interrelations between yield and grain quality indicators were estimated by linear correlation coefficients (r). The data were processed using software STAT_ENG from the package SELEKCIJA (Tarakanovas & Raudonius, 2003). The effects of the experimental year, genotype of the variety and its interactions with yield (analysis of variance by Fisher's criterion) and the stability of yield (integral evaluation of varieties based on rank evaluation sum by grain yield and stability) were established using the computer program STABLE (Khang & Magari, 1995) adapted by Dr. P. Tarakanovas in LIA.

RESULTS AND DISCUSION

Grain yield and quality parameters were affected most by the experimental year's weather conditions, but the genotype of the variety had some impact on the variation as well (Table 2). Winter wheat grain yield (GY) of the varieties tested in the partially wet year of 2004 was above the expected level for organic farming (5.30–8.14 t ha^{-1}); all of the varieties had high (7.67–8.23 kg hl^{-1}) grain hectolitre weight (HLW) with low variation (2.2%). In 2004, environmental conditions revealed differences between varieties of protein (PC) and wet gluten (WG) – variations of the accumulated contents were the highest (10.5 and 18.9%, respectively) compared with the other years, some varieties produced grains whose quality met bread making standards.

July, in both 2005 and 2006, was dry compared to the long-term mean, however 2006 was warmer than 2005. The 2006 grain yield was the poorest (1.67–2.94 t ha^{-1}), but compared with the other two years, grain quality was the highest and all varieties met the food/baking quality protein requirement of 11.5% (LST 1524:2003). By contrast, in 2005, excess moisture during the grain ripening period deteriorated grain quality indicators – all the varieties exhibited the poorest grain quality with the lowest PC, WG and SZ values of all experimental years.

A higher variability was noted for SZ (26.6–29.7%). Similar variation in separate years showed that this quality parameter was most stable over years. Higher SZ dependence of varieties than of years, estimated in analysis of variance by Fisher's criterion, was observed as in other investigations (Mašauskienė & Cesevičienė, 2006).

Table 2. Grain quality variance of winter wheat varieties as affected by seasonal weather conditions. Dotnuva, 2004–2006.

Trait	Year	Mean	SD	Min.	Max.	CV %
Grain yield (GY) t ha^{-1}	2004	6.85	0.810	5.30	8.14	11.8
	2005	3.87	1.142	1.79	5.74	29.5
	2006	2.10	0.386	1.67	2.94	18.4
Hectolitre weigh (HLW) kg hl^{-1}	2004	80.2	1.80	76.7	82.3	2.2
	2005	76.2	3.16	70.1	78.9	4.1
	2006	74.3	4.07	65.3	79.2	5.5
Protein (PC) %	2004	11.7	1.23	9.9	13.4	10.5
	2005	10.9	0.34	10.2	11.3	3.1
	2006	13.0	0.60	11.7	13.8	4.7
Sedimentation (SZ) ml	2004	39	11.5	19.0	60.0	29.7
	2005	33	8.6	15.0	45.0	26.6
	2006	46	13.3	21.0	64.0	28.7
Wet gluten (WG) %	2004	24.2	4.58	16.5	30.0	18.9
	2005	18.1	1.29	16.7	20.3	7.1
	2006	26.2	2.19	21.8	29.6	8.4
Gluten index (GI) unit	2004	64	19.6	28	95	30.7
	2005	90	6.0	74	96	6.8
	2006	77	22.0	28	97	28.4

A wide range of GI parameter in our study is in agreement with that reported by Linina & Ruza (2005). Gluten quality (GI) variation value in separate years was influenced by gluten content (WG): in 2005, when WG was low (20.3% and less), gluten was stronger, therefore GI values were higher (74 units and over) and less variable.

According to the F-test, the weather conditions and their interactions with cultivars had a significant ($P < 0.05$) impact on the grain yield of wheat (data not shown). Similarly, the analysis of variance of Tarakanovas & Ruzgas (2007) for 13 varieties and lines in 4 environments and 2 years suggests that winter wheat yield was most markedly affected by the year factor (38.7%), but variety (6,6%) and year-variety interaction (4.3%) had an influence too.

An ideal variety should have a high mean yield combined with a low degree of fluctuation when it is grown in diverse environments. The compatibility of grain yield stability performance is an informative characteristic for the selection of the best crop varieties. Table 3 shows assessment of winter wheat varieties according to grain yield and stability using the STABLE program. The varieties, which surpassed average integral evaluation of the trials, are indicated by (+). Among the varieties, 'Lars' (11+), 'Zentos' (10+) and the Lithuanian variety 'Lina' (5+) received an especially high integral assessment. These varieties combine high yield (4.53–4.75 t ha^{-1}) with low variance of stability (σ^2) (0.001–0.103). The variety 'Bill' received a similar assessment, also it was the highest-yielding according to three years' average, but it was distinguished by high variance of stability (σ^2) (4.062**). Our data is in accordance by Tarakanovas & Ruzgas (2007), where the variety 'Zentos' by yield was found one of best-suited for cultivation in a wide range of environments.

Table 3. Assessment of winter wheat varieties according to grain yield and stability. Dotnuva, 2004–2006.

Variety	Grain yield				Stability		Integral assessment (ranks)
	t ha^{-1}	ranks	revised rank evaluation	sum of ranks	σ^2	assessment (ranks)	
'Alma'	3.42	2	-2	0	-0.148	-8	-8
'Milda'	4.28	5	-1	4	0.885*	-4	0
'Širvinta 1'	4.09	4	-1	3	0.023	-8	-5
'Ada'	4.44	7	1	8	-0.150	-8	0
'Zentos'	4.75	8	2	10	0.103	0	10+
'Tauras'	3.37	1	-3	-2	5.375**	-8	-10
'Lars'	4.66	9	2	11	-0.076	0	11+
'Lina'	4.53	6	1	7	-0.001	-2	5+
'Bill'	5.28	10	3	13	4.062**	-8	5+
'Seda'	4.02	3	-2	1	2.053**	-8	-7
Mean	4.28						
LSD_{05}	0.628						

*, ** – least significant difference at $P < 0.05$, $P < 0.01$ probability levels

Hectolitre weight (HLW) in the varieties with very good and good properties varied from 77.3 to 80.0, in those with satisfactory properties from 70.7 to 74.6 (Table 4). The grain varieties were different in HMW-GS and their protein content varied between 11.1% (cultivar 'Bill') and 12.4% (cultivar 'Alma'). The variation of PC values between individual varieties was diverse, especially low variation was identified for the varieties 'Seda', 'Ada', 'Širvinta 1' and 'Tauras'. The varieties 'Širvinta 1' and 'Ada' from the very good baking quality group were more stable in terms of WG and SZ values. At zero fertilisation, the variety 'Ada' tended to meet the requirements of good quality more often, compared with the variety 'Zentos' (Masauskiene, 2005). According to GI, higher differences between varieties were revealed in 2004 and 2006. The varieties 'Zentos' and 'Alma' were noted for the stability of this indicator.

Table 4. Grain quality traits of winter wheat varieties. Dotnuva, 2004–2006.

Variety	HLW kg hl^{-1}	PC %	SZ ml	WG %	GI unit	*Glu-1* score
'Alma' [1]	78.9 ± 1.7	12.4 ± 1.3	46 ± 15	24.4 ± 6.0	90 ± 6	10
'Milda' [1]	78.7 ± 3.2	12.1 ± 1.4	50 ± 14	24.4 ± 4.9	86 ± 10	9
'Širvinta 1' [1]	77.9 ± 3.3	12.2 ± 0.8	37 ± 5	24.9 ± 4.6	74 ± 18	9
'Ada' [1]	80.0 ± 2.0	12.0 ± 0.8	40 ± 4	21.1 ± 3.9	79 ± 24	7
'Zentos' [1]	78.1 ± 2.2	11.6 ± 1.6	50 ± 11	20.3 ± 5.5	95 ± 0	7
'Tauras' [2]	74.8 ± 3.2	12.2 ± 0.9	33 ± 9	23.9 ± 6.4	73 ± 19	9
'Lars' [2]	77.7 ± 4.1	11.8 ± 1.8	45 ± 11	23.2 ± 5.6	76 ± 14	7
'Lina' [2]	77.3 ± 3.9	11.5 ± 1.6	41 ± 9	22.3 ± 4.8	73 ± 18	7
'Bill' [3]	74.6 ± 4.0	11.1 ± 1.8	31 ± 8	21.8 ± 5.4	80 ± 21	5
'Seda' [3]	70.7 ± 5.7	11.7 ± 0.5	18 ± 3	22.0 ± 4.6	43 ± 26	4
Mean ± SD	76.9 ± 3.0	11.8 ± 1.0	39 ± 7	22.8 ± 4.2	77 ± 13	7.4

Varieties possessing: 1 – very good baking qualities; 2 – good baking qualities; 3 – satisfactory baking qualities

Table 5. Coefficients of correlation *r* among winter wheat grain yield and quality traits. Dotnuva, 2004–2006

Trait	GY	HLW	PC	SZ	WG	GI	Glu-1
Grain yield (GY)	1.000						
Hectolitre weigh (HLW)	0.692**	1.000					
Protein (PC)	-0.483**	-0.157	1.000				
Sedimentation (SZ)	-0.157	0.316	0.631**	1.000			
Wet gluten (WG)	-0.157	-0.007	0.880**	0.569**	1.000		
Gluten index (GI)	-0.269	0.173	-0.159	0.331	-0.406*	1.000	
HMW *Glu-1* score (Glu-1)	-0.121	0.439*	0.255	0.480**	0.227	0.395*	1.000

*, ** – least significant difference at $P < 0.05$ and $P < 0.01$ probability levels

Many authors have focused their analyses on the different HMW subunits because of the influence on quality parameters. In the varieties with very good and good properties HMW *Glu-1* score varied from 7 to 10, and in those with satisfactory properties from 4 to 5. The varieties from the better quality groups (by *Glu-1* Score) have genetically dependent differences in the characters of the baking quality and act as technologically better. High-quality varieties from the very good / good baking quality groups, may give good baking utilization possibilities after organic growing but this strongly depends on environmental conditions.

The wheat grain quality parameters were assessed by correlation analysis, too (Table 5). Positive correlations were found between GY and HLW (r = 0.692**), but GY has a significant negative influence on PC (r = -0.483**). A statistically significant positive correlation was found between SZ, PC and WG (r = 0.569** ÷ 0.880**) and these results are in accordance with those described by Krejčirova et al. (2006). Whereas, when 10 different varieties were evaluated in conditions of intensive agriculture, a significant positive correlation was found just between SZ and WG (Linina & Ruza, 2005). Furthermore, we noticed a negative correlation between GI and WG (r = -0.406*). High molecular weight (HMW) glutenin subunit composition (*Glu-1* score) showed a positive influence on SZ, HLW and GI (r = 0,480**; 0,439*; 0,395*), similar to results reported by Horvat et al. (2006). Similarly, other authors suggest that not only HMW-GS composition is important, but also the amount of glutenin, which is more sensitive to growing conditions (Don et al., 2005).

CONCLUSIONS

Our results showed a marked influence in three climatically different years of organic growing on the winter wheat varieties' grain yield and quality characteristics (protein and gluten content, gluten quality by gluten index, sedimentation index according to Zeleny). The varieties 'Lars' and 'Zentos' combine high yield (4.66-4.75 t ha^{-1}) with stability, their sum of integral assessment of grain yield was respectively (11+) and '(10+). Varieties from very good and good baking quality groups, 'Širvinta 1' and 'Ada', were found to be more stable concerning wet gluten content and sedimentation, 'Zentos' and 'Alma' – by gluten index. *Glu-1* score showed positive influence on sedimentation, hectolitre weigh and gluten index (r = 0.480**; 0.439*; 0.395*).

REFERENCES

Baresel, J.P., Zimmermann, G. & Reents, H.J. 2008. Effects of genotypes and environment on N uptake and N partition in organically grown winter wheat (*Triticum aestivum* L.) in Germany. *Euphytica* **163**, 347–354.

Don, C., Lookhart, G., Naeem, H., MacRitchie, F. & Hamer, R.J. 2005. Heat stress and genotype affect the glutenin particles of the glutenin macropolymer-gel fraction. *J. cereal sci.* **42**(1), 69–80.

Horvat, D., Drezner, G. & Jurković, Z. 2006. The importance of high-molecular-weight glutenin subunits for wheat quality evaluation. *Agriculture: Scientific and Professional Review* **12**(1), 53–57.

Kang, M.S. & Magari, R. 1995. STABLE: a BASIC program for calculating stability and yield stability statistics. *Agron. J.* **87**, 276–277.

Kraic, J., Horvath, L., Gregova, E. & Žak, I. 1995. The standard methods of electrophoretic separation of glutenins and gliadins of wheat by SDS–PAGE and A–PAGE. *Rostlinna Vyroba* **5**, 219–223.

Krejčirova, L., Capouchova, I., Petr, J., Bicanova, E. & Kvapil, R. 2006. Protein composition and quality of winter wheat from organic and conventional farming. *Zemdirbyste-Agriculture* **93**(4), 285–296.

Linina, A. & Ruza, A. 2005. Variety – by - environment interactions for winter wheat quality traits. *Agronomijas vēsti* **8**, 122–126.

Lu, C., Hawkesford, M.J., Barraclough, P.B., Poulton, P.R., Wilson, I.D., Barker, G.L. & Edwards, K.J. 2005. Markedly different gene expression in wheat grown with organic or inorganic fertilizer. *Proc. R. Soc. B.* **272**(1575), 1901–1908.

Martinez-Cruz, E., Espitia-Rangel, E., Benitez-Riquelme, I., Pena-Batista, R.J., Santacruz-Varela, A. & Villasenor-Mir, H.E. 2007. Effect of different high molecular weight glutenin alleles of A and B genomes of bread wheat on rheological properties and bread volume of bread wheat. *Agrociencia* **41**, 153–160.

Mašauskienė, A. & Cesevičienė, J. 2006. Variation of winter wheat grain qualities as affected by NK fertilisation and grain storage period. I. Indirect bread-making qualities. *LLU Raksti* **16**(311), 50–58.

Masauskiene, A. 2005. Grain quality as criterion for bread grain production as affected by the zero and conventional fertilization. Proceedings of the seminar: *Environmental friendly food production system: requirements for plant breeding and seed production*. *(ENVIRFOOD).* Talsi, Latvia, pp. 27–33.

Pena, E., Bernardo, A., Soler, C. & Jouve, N. 2005. Relationship between common wheat (*Triticum aestivum* L.) gluten proteins and dough rheological properties. *Euphytica*. **143**, 169–177.

Sliesaravičius, A., Pekarskas, J., Rutkovienė, V. & Baranauskis, K. 2006. Grain yield and disease resistance of winter cereal varieties and application of biological agent in organic agriculture. *Agronomy research* **4**(special issue), 371–378.

Tarakanovas, P. & Raudonius, S. 2003. *Agronominių tyrimų duomenų statistinė analizė taikant kompiuterines programas ANOVA, STAT, SPLIT-PLOT iš paketo SELEKCIJA ir IRRISTAT*. LŽI, Akademija, 57 pp. (in Lithuanian).

Tarakanovas, P. & Ruzgas, V. 2007. Study of genotype – environment interaction of winter wheat varieties with respect to grain yield. *Zemdirbyste-Agriculture* **94**(2), 96–109.