EFFECTS OF ORGANIC WHEAT CULTIVATION IN WIDER ROWS ON GRAIN YIELD AND QUALITY*

I. Capouchová, E. Bicanová, J. Petr, L. Krejčířová, O. Faměra

Czech University of Life Sciences, Faculty of Agrobiology, Food and Natural Resources, Department of Plant Production, Prague, Czech Republic

Exact field small-plot trials with winter wheat varieties Ludwig and Sulamit (both the quality groups E–elite) in organic farming in the sugar-beet growing region of Central Bohemia were conducted in the years 2005 and 2006 to test the possibility of increase in the crude protein content in grain and improvement of baking quality (row spacing 125, 250 and 375 mm, sowing rates 200, 300 and 400 germinating grains per m^2) under the change of the stand structure. Statistically significant increase of crude protein content in wheat grain dry matter by approximately 0.6% was found at widening of row spacing from 125 to 250 mm and by about 1.2% at widening of row spacing from 125 to 375 mm. So, the variants cultivated in wider row spacings fulfilled the requirement for crude protein content in grain dry matter of food and baking wheat for minimum 11.5%. Wheat cultivation in wider rows had no negative impact on the grain yield.

organic cultivation; winter wheat; wide row spacing; crude protein content; sedimentation test Zeleny; grain yield

INTRODUCTION

The most significant differences in quality parameters of cereals cultivated in conventional and organic farming usually comprise the differences in the content of crude protein in grain dry matter. Higher need of nitrogen, particularly in late vegetation phases, when the grain is creating and ripening (in conventional agriculture just for this critical period quality additional nitrogen fertilization is applied for improvement of technological quality), in organic system with absence of fertilizers, fast acting, is a frequent reason of nitrogen deficit that is manifested by lower accumulation of storage proteins. This worsens possibilities of food, particularly baking processing (Prugar, 1999).

Other measures should be sought for when wheat is cultivated ecologically that should have allowed increase of protein content and hence, improvement of food, baking quality.

One of the possibilities is the selection of variety. Coefficient of heritability is relatively low ($H = 0.37$) (Kadar, Moldovan, 2003) for the protein content. It follows from it that the rate of influence of this quality trait by genotype is lower compared with the effect of environment (Triboi et al., 2000; Bushuk, Bekes, 2002).

However, the selection of a suitable variety in organic farming is very important input factor. The use of varieties of the quality group E (elite) (Förster et al., 2004) is above all a prerequisite of success of cultivation of food, baking wheat in organic farming, because as reported by Petr et al. (1998), the varieties with genetically established good milling and baking quality preserve these traits at different cultivation systems, i.e. also at lower inputs.

Protein production in grains, particularly gluten fractions of gliadins and glutenins, are affected by time and intensity of irradiation of plants in the stand (Petr et al., 1987). Therefore, different organisation and structure of winter wheat stand (wider row spacings and lower seeding rates) that should allow as best as possible irradiation benefit, are another possibilities of increase in crude protein content in grain compared with traditional system of wheat stand establishment in narrow rows, what could provide irradiation pleasure as the best as possible.

The system of wheat cultivation in wider row spacings was tested in Germany, where it had been proved that at wide row spacings not only the protein content is increasing but also the values of sedimentation test. The results of the tests showed globally that high baking quality can be achieved using this system (Förster et al., 2004).

Hiltbrunner et al. (2005) performed the similar research. They reported in their study a statistically significant increase in crude protein content in dry matter (by about 1%) at widening of row spacing from 187.5 to 375 mm. At the same time they add that no decrease in grain yield was found with increasing row spacing.

Our study was aimed at testing of the grain yields and quality of winter wheat cultivated in organic farming at different row spacings and different sowing rates and at judging of the possibilities of improvement of technological grain quality using these cultural practices.

MATERIAL AND METHODS

Precise small-plot field trials with two varieties of winter wheat Ludwig and Sulamit (both quality class E) were conducted in the years 2004/2005 and 2005/2006 on the

* Financial support by the Research Project of the Czech University of Life Sciences in Prague No. 6046070901 and Grant Project of the Ministry of Agriculture NAZV QG 50034.

experimental station of the Department of Plant Production of CULS Prague in Uhříněves, in sugar-beet growing region. The site is situated at 295 m above sea level, average annual temperature 8.4 ºC, average annual sum of precipitation 575 mm. Clay-loam cambisol with a good reserve of nutrients has a topsoil deep 25–30 cm. The topsoil is slightly to medium humus (1.74–2.12%), with neutral response in the whole profile, production potential of soils 84 points. Weather pattern on experimental station Uhříněves in experimental years and long-term average of temperatures and precipitation are in Table 1.

Experimental station Uhříněves is certified for conductance of experiments by organic growing, experiments are carried out according to the IFOAM (International Federation of Organic Agriculture Movement) principles and Methodological Instruction for ecological agriculture of the Ministry of Agriculture of the Czech Republic, without fertilizers and pesticides. Experiments were carried out by the method of randomised blocks in three replications; average size of experimental plot was 10 m^2. Three row spacings were used in the trial: 125, 250 and 375 mm and three sowing rates – 200, 300 and 400 germinating grains per m^2. Red clover was a forecrop. Experiments were two times harrowed by weeder-mulcher during spring vegetation, experimental variants with row spacing 250 and 375 mm were cultivated two times by Martínek's thrust how.

After harvest of the trials the yield was determined and crude protein was determined in grain dry matter (Czechoslovak Standard ČSN ISO 1871) and Zeleny's sedimentation test (ČSN ISO 5529).

Yield results and results of the quality evaluation were statistically assessed by analysis of variance of multiple classification (ANOVA) in the program Statgraphics Plus, version 5.1, with calculation of the testing criterion *F*. Significance of differences between means of varieties, years, sowing rates and rows was verified by LSD test on the level of significance $\alpha = 0.05$.

RESULTS AND DISCUSSION

The main criterion of our study was to test whether it is possible to achieve increase in crude protein content in wheat grain dry matter in wider row spacing, and hence to reach better technological, baking quality.

In both evaluated years the increase of crude protein content in grain dry matter was found with increasing row spacing. In 2005 at the row spacing of 250 mm higher content of crude protein by 0.67% was recorded, whereas at the row spacing of 375 mm this value was higher by 1.47 compared to variant with traditional narrow row spacing of 125 mm. In 2006 at row spacing of 250 mm crude protein content increased compared to narrow row spacing by 0.47%, in the variant with row spacing of 375 mm it was by 0.9% (Table 2). In the both evaluated years the variants with the widest row spacing fulfilled the requirement for crude protein content in grain dry matter of wheat of food baking quality 11.5% (Czechoslovak Standard 461100-2), in 2006 this requirement was fulfilled also in row spacing of 250 mm. In total the crude protein content in grain dry matter in 2006 was significantly higher compared with the previous year; the reason was probably an extraordinary dry and warm July of 2006 (Table 1). The fact that protein content in wheat grain should be affected also due to the water stress in the period of grain formation and ripening are demonstrated in their studies by H u b í k (1995) and Z h a o et al. (2005).

It follows from the values of the tested criterion *F* (Table 3) that the crude protein content in grain dry matter was in both evaluated years affected the most by row spacing (however, in 2005 the effect of row spacing was manifested more expressively), followed by the effect of variety on the crude protein and on average of both evaluated years the year was also manifested statistically significantly. On the contrary, sowing rate was not affected statistically significantly by the crude protein content.

The above-mentioned results are in congruency with the conclusions made by F ö r s t e r et al. (2004) and P e t r et al. (1987) that by different stand structure, which occurs during cultivation in wider row spacing, it is possible to support the synthesis of proteins in grain of wheat in organic farming.

These pieces of knowledge are supported also by the results of evaluation of different components in dry matter of above-ground biomass of plants (Table 4), from which a certain trend is visible testifying on slightly better nutritional state of plants cultivated in wider row spacing compared to the variants with traditional narrow row spacing.

A significant role for food, baking use is played not only by amount but also by quality of proteins. The quality of protein complex in view of baking utilisation is very well characterised by Zeleny's sedimentation test.

The Czechoslovak standard 46 1100-2 gives 30 ml as a bottom limit of Zeleny's test of food and baking wheat. It is evident from our results (Table 2) that both evaluated varieties Ludwig and Sulamit much exceeded this value. With an increase of row spacing also in the case of Zeleny's test increased the values of food and baking wheat that reached the evaluated varieties also in the variants cultivated in traditional narrow rows.

It is apparent from the values of testing criterion *F* (Table 3) that the values of Zeleny's test were affected in both evaluated years the most by variety, followed by row spacing that was applied more in 2005 than in the following year. The effect of the sowing rate and the year on the Zeleny's test was statistically insignificant. These results giving evidence of prevailing genotype dependence of Zeleny's test are in accord with e.g. conclusions made by M a t u z (1998) and K a d a r, M o l d o v a n (2003).

Except the quality of production in cultivation of organic wheat in wider row spacings, it is necessary to pay attention to the grain yields.

It is evident from the values of testing criteria *F* (Table 3) that the grain yield was the most affected by the sowing rate in 2005, in 2005 the effect of variety prevailed; on average of the both evaluated years 2005–2006 the yield was affected the most by variety, followed by the sowing

Table 1. Weather pattern on the experimental station Uhříněves in the years 2004–2006 and long-term average of temperatures and precipitation

	2004–2005		2005–2006		Long-term average	
	Average daily temperature (ºC)	Average sum of precipitation (mm)	Average daily temperature (ºC)	Average sum of precipitation (mm)	Average daily temperature (ºC)	Average sum of precipitation (mm)
September	14.1	48	15.8	50	14.0	49
October	8.8	40	10.1	11	8.6	41
November	3.4	36	3.4	18	3.2	34
December	–0.6	35	–0.1	38	–0.5	34
January	2.3	33	–4.6	19	–2.1	28
February	–1.2	44	–1.1	29	–0.8	27
March	3.1	12	2.5	48	3.4	31
April	11.1	18	10.6	47	8.2	46
May	14.7	52	14.2	95	13.4	65
June	17.4	59	18.5	84	16.3	74
July	19.2	132	23.8	12	18.2	74
August	17.4	65	16.8	116	17.5	72

Table 2. Analysis of variance for the grain yield, crude protein content in grain dry matter and Zeleny's sedimentation test (LSD, α = 0.05)

		2005			2006			2005/2006		
		$\bar{x}$	D_{min}	Signifi-cance	$\bar{x}$	D_{min}	Signifi-cance	$\bar{x}$	D_{min}	Signifi-cance
Grain yield										
Variety	Ludwig	6.02	0.38	A	6.32	0.41	A	6.19	0.30	A
	Sulamit	5.38		B	4.93		B	5.15		B
Row spacing (mm)	125	5.62	0.46	AB	5.66	0.49	A	5.67	0.37	AB
	250	5.46		A	5.50		A	5.48		A
	375	6.02		B	5.71		A	5.86		B
Sowing rate (germinating grains per m^2)	200	4.95	0.46	A	5.21	0.51	A	5.11	0.39	A
	300	5.94		B	5.75		AB	5.84		B
	400	6.21		B	5.91		B	6.06		B
Year	2005							5.69	0.28	A
	2006							5.64		A
Crude protein content										
Variety	Ludwig	10.73	0.37	A	11.13	0.59	A	10.93	0.33	A
	Sulamit	11.19		B	12.21		B	11.70		B
Row spacing (mm)	125	10.25	0.46	A	11.21	0.71	A	10.73	0.40	A
	250	10.92		B	11.68		AB	11.30		B
	375	11.72		C	12.11		B	11.92		C
Sowing rate (germinating grains per m^2)	200	11.11	0.42	A	11.77	0.74	A	11.44	0.45	A
	300	10.95		A	11.67		A	11.31		A
	400	10.83		A	11.56		A	11.20		A
Year	2005							10.96	0.32	A
	2006							11,67		B
Sedimentation test Zeleny										
Variety	Ludwig	40.94	3.78	A	40.66	2.38	A	40.83	2.21	A
	Sulamit	48.94		B	49.30		B	49.08		B
Row spacing (mm)	125	41.75	4.63	A	44.98	2.85	AB	43.33	2.68	A
	250	43.67		A	43.29		A	43.48		A
	375	49.42		A	46.67		B	48.04		B
Sowing rate (germinating grains per m^2)	200	47.42	4.82	A	45.40	2.92	A	46.38	2.72	A
	300	44.08		A	44.67		A	44.38		A
	400	43.33		A	44.88		A	44.10		A
Year	2005							44.94	2.19	A
	2006							44.95		A

$\bar{x}$ – average values of grain yields ($t.ha^{-1}$), crude protein content in grain dry matter (%) and sedimentation Zeleny's test (ml), D_{min} – minimum significant difference, differences between average values denoted by the same letters are not statistically significant

Table 3. Effects of different factors (variety, row spacing, sowing rate, year) on yields, crude protein content in grain dry matter and Zeleny's sedimentation test (ANOVA, calculated values of testing criterion *F*)

	2005					
	Grain yield		Crude protein content		Zeleny's test	
	F	%	*F*	%	*F*	%
Variety	1.85*	22.87	0.95*	12.37	288.00**	53.76
Row spacing	0.98^{n}	12.11	6.49**	84.50	191.03**	35.66
Sowing rate	5.26**	65.02	0.24^{n}	3.13	56.69^{n}	10.58
	2006					
Variety	8.23**	82.88	3.58**	48.38	315.53**	89.80
Row spacing	0.15^{n}	1.51	3.69**	49.86	34.17^{n}	9.72
Sowing rate	1.55*	15.61	0.13^{n}	1.76	1.67^{n}	0.48
	2005/2006					
Variety	9.50**	58.35	4.97**	27.22	601.45**	74.26
Row spacing	0.88^{n}	5.41	8.76**	47.97	171.73**	21.20
Sowing rate	5.87**	36.06	0.29^{n}	1.59	36.50^{n}	4.51
Year	0.03^{n}	0.18	4.24**	23.22	0.20^{n}	0.03

** statistical significance α = 0.01, * statistical significance α = 0.05, n = statistically insignificant

Table 4. The content of different elements in dry matter of above-ground biomass of plants (samples of plants taken on 29 April, 2005 and on 28 April, 2006 – shooting)

		Content of different elements in dry matter of above-ground part of biomass of plants (%)				
		N	P	K	Ca	Mg
Variety	Ludwig	4.67	0.46	3.87	0.69	0.14
	Sulamit	4.76	0.45	3.93	0.65	0.13
Row spacing (mm)	125	4.30	0.43	3.62	0.65	0.13
	250	4.93	0.47	3.98	0.62	0.14
	370	4.92	0.47	4.10	0.68	0.14
Sowing rate (germinating grains per m^2)	200	4.82	0.47	3.92	0.68	0.14
	300	4.68	0.45	3.86	0.65	0.13
	400	4.64	0.45	3.91	0.68	0.14
Year	2005	4.70	0.47	3.80	0.62	0.15
	2006	4.73	0.44	4.00	0.73	0.12

rate. Row spacing did not affect the yield statistically significantly and the effect of years was also insignificant. Detailed similar evaluation of significance of differences between different varieties, sowing rates and rows using LSD test is documented by the effect of variety on the grain yield in different experimental years and in average of both the years as well. Row spacing affected grain yields in 2006 insignificantly; in 2005, on the contrary, the effect of row spacing was significant. In both years the highest yield was found at the widest rows (375 mm). The highest yield in both experimental years was recorded at the highest sowing rate (400 germinating grains per m^2); the difference between sowing rates 300 and 400 germinating seeds per m^2, however, was statistically insignificant (Table 2).

In cultivation in wider row spacing, particularly 375 mm, a strong competition between plants and reduction of the cumber of plants during vegetation are manifested. So, it can be said that in congruency with conclusions made by Förster et al. (2004), in wheat cultivation in wider row spacings lower sowing rates can be applied (approximately 300 grains per m^2) than are usually applied in wheat cultivation in traditional narrow row spacings, without significant impact of this reduction of sowing rate on the grain yield.

REFERENCES

BUSHUK, W. – BEKES, F.: Contribution of protein to flour quality. In: Proc. of the ICC Conf. Novel Raw Materials, Technologies and Products – New Challenge for the Quality Control, Budapest, c: pp. 14–19.

FÖRSTER, CH. – WILMERSDORF, G. – LUTZ, C. – MÜLLER, E.: Praxiseinführung des Anbaukonzeptes Weite Reihe für eine umweltgerechte Getreideproduktion unter besonderer Berücksichtigung des Qualitätsaspektes bei Backweizen. Final report of research project of Institut für Pflanzenbau und

Pflanzenzüchtung, Universität Giessen, 2004 (http://www.agranet.de/6222.php).
HILTBRUNNER, J. – LIEDGENS, M. – STAMP, P. – STREIT, B.: Effects of row spacing and liquid manure on directly drilled winter wheat in organic farming. Europ. J. Agron., *22*, 2005: 441–447.
HUBÍK, K.: The effect of fertilization and the year on the quality of food wheat. Rostl. Výr., *41*, 1995: 521–527. (In Czech)
KADAR, R. – MOLDOVAN, V.: Achievement by breeding of winter wheat varieties with improved bread-making duality. Cereal Res. Commun., *31*, 2003: 89–95.
MATUZ, J.: Inheritance of SDS sedimentation volume of flour in crosses of winter wheat. Cereal Res. Commun., *26*, 1998: 203–210.
PETR, J. et al.: Weather and yields. Praha, SZN 1987. 368 pp. (In Czech)
PETR, J. sen. – PETR, J. jun. – ŠKEŘÍK, J. – HORČIČKA, P.: Quality of wheat from different growing systems. Scientia Agric. Bohem., *29*, 1998: 161–182.
PRUGAR, J.: The quality of plant products from ecological agriculture. Stud. Inform. ÚZPI, 1999, 5 (Plant production). 79 pp. (In Czech)
TRIBOI, E. – ABAD, A. – MICHELENA, A. – LLOVERAS, J. – OLLIER, J. L. – DANIEL, C.: Environmental effects on the quality of two wheat genotypes: I. quantitative and qualitative variation of storage proteins. Eur. J. Agron., *13*, 2000: 47–64.
ZHAO, C. J. – LIU, L.Y. – WANG, J. H. – HUANG, W. J. – SONG, X. Y. – LI, C. J.: Predicting grain protein content of winter wheat using remote sensing data based on nitrogen status and water stress. Int. J. Applied Earth Observation and Geoinformation, *7*, 2005: 1–9.

Received for publication on July 2, 2007
Accepted for publication on October 31, 2007

CAPOUCHOVÁ, I. – BICANOVÁ, E. – PETR, J. – KREJČÍŘOVÁ, L. – FAMĚRA, O. (Česká zemědělská univerzita, Fakulta agrobiologie, potravinových a přírodních zdrojů, Praha, Česká republika):

Vliv pěstování ekologické pšenice v širších řádcích na výnos a jakost zrna.

Scientia Agric. Bohem., *39*, 2008: 1–5.

V přesných polních maloparcelkových pokusech s odrůdami ozimé pšenice Ludwig a Sulamit (obě jakostní skupina E – elitní) vedených v ekologickém způsobu pěstování v řepařské oblasti středních Čech v letech 2005 a 2006 jsme prověřovali, zda lze docílit při změně struktury porostu (šířka řádků 125, 250 a 375 mm, výsevky 200, 300 a 400 klíčivých obilek na m^2) zvýšení obsahu N-látek v zrnu a zlepšení pekařské jakosti.

Bylo zjištěno statisticky průkazné zvýšení obsahu N-látek v sušině zrna pšenice o cca 0,6 % při rozšíření meziřádkové vzdálenosti ze 125 mm na 250 mm a o cca 1,2 % při rozšíření meziřádkové vzdálenosti ze 125 mm na 375 mm. Varianty pěstované v širších řádcích tak splnily požadavek na obsah N-látek v sušině zrna pšenice potravinářské pekárenské min. 11,5 %. Pěstování pšenice v širších řádcích přitom nemělo negativní dopad na výnos zrna.

ekologické zemědělství; ozimá pšenice; široké řádky; obsah N-látek; Zelenyho sedimentační test, výnos zrna

Contact Address:

Doc. Ing. Ivana C a p o u c h o v á , CSc., Česká zemědělská univerzita v Praze, Fakulta agrobiologie, potravinových a přírodních zdrojů, katedra rostlinné výroby, Kamýcká 129, 165 21 Praha 6-Suchdol, Česká republika, tel.: +420 224 382 549, fax: +420 224 382 535, e-mail: capouchova@af.czu.cz