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THE EFFECT OF GROWTH STRUCTURE ON ORGANIC WINTER WHEAT QUALITY

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Abstract

The effect of inter-row distance and sowing rate on protein content and grain yield of two winter wheat cultivars grown in organic and conventional farming were studied in two growing seasons. The results show that grain grown under organic farming had lower protein content than the conventional one grown in 125 mm inter-row distance. However, when the distance between the rows was increased from 125 mm to 375 mm in organic farming, the concentration of grain protein increased significantly: about 0.5-1.3 % (depending on variety). Widening the row spaces did not decrease grain yield.

Key words: organic farming, winter wheat, growth structure, protein content, cultivation method, yield.

Introduction

It is now clearly established that grain quality is a function of grain composition, principally in proteins /Triboi et al., 2000/. Also, according to Pan et al., (2006) grain nitrogen (N) concentration is one of the main quality parameters of wheat grains.

The ability of wheat flour to form viscoelastic dough which in the oven is transformed into a tasty loaf of bread depends mostly on the nature of its proteins. When flour is mixed with an appropriate amount of water, the proteins hydrate and interact with themselves, and certain carbohydrates and lipids, to form gluten, which after rising and baking, become the structural framework of a loaf of bread. The grain and texture of bread crumb result from the rigid structure that is formed when wet gluten is baked /Bushuk, Bekes, 2002/.

Organic technique of cultivation can have an adverse effect on the technological quality, especially when protein content is an important factor /Moudrý, Prugar, 2002/. Lower protein content limits the possibilities of food and baking processing /Prugar, 1999/. This was confirmed by the similar results of other authors, i. e. Strobel et al. (2001).

Bread flour must have a relatively high protein content, 11.0 % to 13.5 %, depending on the type of bread /Bushuk, Bekes, 2002/. Quantitative variation of protein content depends mainly on the environmental effect (growing season, site, fertilization), less on the genotype. The most important environmental factor affecting protein content

was N supply (fertilization and site) (63 % of total variation). Wheat variety only accounted for 4 % of total variation while growing season did not significantly affect PC /Triboi et al., 2000/. According to Bushuk and Bekes (2002), under normal growing conditions almost 70% of the variation of the protein content is due to variation in soil fertility and climatic conditions. Similar results were published by Petr (2001), who stated that protein content was influenced from 78 % by the intensity of cultivation.

However, in organic farming, where it is not allowed to use fertilizers with fast effect, the lack of nitrogen results in lower accumulation of storage protein /Prugar, 1999/. Storage proteins determine parameters of technological quality /Prugar, Hraška, 1986/. The results of trial of Federal Agency for Agriculture and Food in Fresing showed that if the quantity of N-fertilizers is reduced to half, protein content will be reduced approximately by 1 %.

Recent research has proved that the original idea - that modern cultivars selected under conditions of high N-input are little suited to low-input conditions - was no longer valid. According to Guarda et al. (2004), under organic-farming practices the best results were achieved with modern cultivars with the intrinsic traits capable of ensuring yield and quality at low N-supply even though they maximize their traits at high nitrogen inputs.

In organic farming it is important to use varieties of wheat from group of quality "E"-elite or "A"- high-quality, that are able to keep genetic disposition for high mill and baking quality in different technique of cultivation, also in low-inputs /Petr et al., 1987/.

Quantity and quality of protein complex in grain of wheat can be considerably influenced by the intensity of cultivation, especially N-fertilization, and by variety. For wheat under the system of organic farming not using fertilizers, it is necessary to find another way how to increase gluten protein content in grain to improve food, bakery quality. One of the options should be a different type of growth structure of winter wheat (wider inter-row distances, different sowing rates) than in conventional farming, where it is seeded into narrow drill. Duration and intensity of radiation in the growth strongly influence the creating of grain protein, especially gluten fraction /Petr et al., 1987/.

Also according to Förster et al. (2004), widening of inter-row distances can increase protein content in grain. Results proved that high bakery quality can be reached in this way.

Therefore, basic hypothesis of the experiment comes from this thesis. The objective of this study was to evaluate the effects of different types of growth structure (seed rates, inter-row distances) on protein content in grain and grain yield. In other words to prove opportunity of support synthesis of protein in wheat grain from organic farming by optimisation of growing conditions, especially improvement of light conditions in growth by different type of growth structure.

Material and methods

Experimental site

The trial was conducted in two experimental years 2004/05 and 2005/06 at Experimental station of Department of Crop Production of the Czech University of Agriculture in Prague- Uhříněves. The altitude of the site is 295 m above sea level, the

average of annual temperature is 8.4 °C and annual precipitation is 575 mm. The type of soil is brown soil with high nutrient reserve. Texture class of soil is clay loam. Organic matter content is 1.74-2.12 %.

Table 1. Temperature and precipitation in experimental periods and long term average
1 lentelė. *Bandymų laikotarpio temperatūra, krituliai ir daugiametis vidurkis*

Year Month *Metai Mėnuo*	2004/05		2005/06		Longterm average (°C) *Daugiametis vidurkis*	
	Temperature (°C) *Temperatūra*	Precipitation (mm) *Krituliai*	Temperature (°C) *Temperatūra*	Precipitation (mm) *Krituliai*	Temperature (°C) *Temperatūra*	Precipitation (mm) *Krituliai*
X.	10.0	21	10.2	11.0	8.6	41
XI.	4.7	68.7	3.2	15.7	3.2	34
XII.	0.8	12.6	.0	38.2	-0.5	34
I.	1.8	30.9	-4.8	18.7	-2.1	28
II.	-1.9	47.3	-1.2	30.6	-0.8	27
III.	3.2	14.2	2.3	50.1	3.4	31
IV.	10.7	19.5	9.7	48.4	8.2	46
V.	14.8	52.5	17.2	100.9	13.4	65
VI.	17.9	62.4	18.5	86.8	16.3	74
VII.	19.3	137.8	23.2	12.2	18.2	74
VIII.	17.2	68.5	16.6	117.5	17.5	72

Experimental station in Prague- Uhříněves has certificate for experiments in organic farming. The experiments are carried out according to principles of IFOAM and methodical instruction for organic farming by Ministry of Agriculture of the Czech Republic, without fertilizers and pesticides.

Cultural practices

For the experiments, two varieties of winter wheat (*Triticum aestivum* L.) 'Ludwig' and 'Sulamit' (group of quality "E") were used in different type of growth structure (three inter-row distances and three sowing rates) (Tab.2). Inter-row hoeing by Martinkova hand weeder was used twice in variants with 250 and 375 mm inter-row distance.

Experiments in conventional agriculture were established for comparison, but only with one type of inter-row distance (Table 2), which is commonly used for cereals. 100 kg N ha^{-1} and herbicide were used in conventional treatments.

Table 2. Summary of experimental variants
2 lentelė. *Bandymų variantų apibendrinimas*

Cultivation *Auginimas*	Inter-row distance mm *Tarpueilių atstumas mm*	Seeding rate (seeds m^2) *Sėklos norma (sėklų m^2)*
Organic *Organinė žemdirbystė*	125	200, 300, 400
	250	200, 300, 400
	375	200, 300, 400
Conventional *Įprasta žemdirbystė*	125	200, 300, 400

Analysis of plants

Post harvest analyses were focused on the evaluation of protein content in dry matter (ČSN ISO 1871) by Near Infrared Reflectance Spectroscopy (NIRS) and on the determination of yields from each variants. Differences in protein content and yield were observed between samples from organic and conventional farming and ones from different inter-row distances in organic treatment.

Statistical analysis

Summary statistics and graph were obtained using Microsoft®Excel 2000. Statistical analyses were performed using the ANOVA from the SAS®System for windows (version 8.02). Means were compared using Tukey (HSD) test at the level of significance $\alpha = 0.05$.

Results and discussion

Effect of cultivation treatment on protein content

The greatest differences between organic and conventionally grown grain in individual qualitative parameters are observed only in protein content /Prugar, 1999, Capouchová, 2004/. Organically grown wheat has lower protein content due to the absence of nitrogen fertilizers /Seibel, 1983/.

This fact was also confirmed in our results (Table 3), when protein contents in years' average and varieties were statistically different in grain from organic and conventional treatment (Table 4). Protein content was higher about 1.2 % than in organic grain. Similar results were published by other authors – Brümmer (1997) and Capouchová (2004) who claimed that grain of winter wheat from organic farming has lower protein content approximately about 2-3 % in comparison with conventional grown grain. The differences were more pronounced for variety 'Ludwig' (protein content was higher (about 1.5 %) in conventionally grown grain).

Effect of inter-row distance on protein content

Inter-row distance had statistically confirmative effect on protein content in dry matter of grain from organic treatment (Table 4). Protein content was statistically different in all inter-row distances (125, 250, 375 mm) in organic farming and also in conventional treatment in 125 mm inter-row distance.

Comparing conventional and organic approach (grains grown in 125 mm inter-row distance), organic grown grain showed statistically significant lower protein content: in dry matter about 1.9 % (Figure).

Using wider inter-row distances (250 and 375 mm), in organic farming there was observed about 0.5-1.3 % protein-content-increase (Figure) for Ludwig and Sulamit as well (depending on variety). As a result, both varieties fulfil the basic parameters for food/baking production. Moreover, using 375 mm inter-row distance the protein content was markedly above the limit required by the standard ČSN ISO 1871 (11.5 % protein content). This coincides with results of Hiltbrunner et al. (2005) that show that the concentration of grain protein increased significantly from 11.7 to 12.7 %, when the distance between the rows was increased from 187.5 mm to 375 mm.

Table 3. Protein content in dry matter of grain and grain yields of winter wheat from experimental year 2004/05 and 2005/2006

3 lentelė. *Baltymų kiekis žieminių kviečių grūdų sausoje medžiagoje ir grūdų derlius 2004/05 ir 2005/2006 metais*

Variety *Veislė*	Technique of cultivation *Auginimas*	Inter-row distance (mm) *Tarpueilių atstumas*	Seed rate[1] *Sėklų norma*[1]	2005		2006	
				Protein content (%) *Baltymų kiekis*	Yield[2] *Derlius*[2]	Protein content (%) *Baltymų kiekis*	Yield[2] *Derlius*[2]
'Ludwig'	Conventional	125	200	12.62	7.50	14.10	8.42
	Įprasta	125	300	12.59	7.37	14.15	8.59
	žemdirbystė	125	400	12.07	8.10	14.92	8.91
	Organic	125	200	11.26	4.72	11.88	6.33
	Organinė	125	300	10.60	5.98	11.39	6.93
	žemdirbystė	125	400	10.89	6.82	11.13	6.71
		250	200	11.77	4.87	11.62	5.90
		250	300	11.53	6.10	12.23	6.23
		250	400	11.89	6.37	12.77	6.40
		375	200	12.26	6.30	12.52	6.41
		375	300	12.68	6.60	12.79	6.48
		375	400	12.71	6.41	12.02	6.54
'Sulamit'	Conventional	125	200	12.33	7.18	15.01	7.01
	Įprasta	125	300	12.36	7.60	15.09	7.35
	žemdirbystė	125	400	12.27	8.00	14.70	7.47
	Organic	125	200	11.37	4.28	12.59	4.91
	Organinė	125	300	11.93	5.64	12.79	4.96
	žemdirbystė	125	400	11.45	6.28	12.41	5.54
		250	200	12.39	4.48	13.11	4.55
		250	300	12.15	5.41	12.54	4.79
		250	400	11.78	5.53	13.82	5.11
		375	200	13.60	5.05	13.83	4.57
		375	300	12.82	5.90	14.30	5.11
		375	400	12.24	5.83	13.20	5.14
Source of variation / *Variacijos šaltinis*							
Variety (V) / *Veislė (V)*				1.49	1.24	1.47	1.11
Seed rate (SR) / *Sėklos norma*				1.00	6.69	0.02	0.81
Technique of cultivation (TC) *Auginimas*				6.23 *	1.81 *	3.03	1.16
Inter-row distance (IRD) *Tarpueilių atstumas*				14.31 *	7.18	1.88	13.34 *
V x TC				4.55	43.28	91.53	425.43
V x IRD				11.91	6.3	6.51	34.79
V x TC x IRD				33.61 *	23.73 *	81.53 *	251.86*
TC x IRD				36.38 *	26.71 *	43.66 *	35.60 *
SR x IRD				7.93 *	8.43 *	0.93	7.24 *
SR x TC				2.34	46.79 *	28.34 *	37.20*
SR x V				1.96	5.94	4.71	12.19 *
SR x TC x IRD				23.92 *	31.31 *	25.51 *	22.87 *

[1)] seeds m^{-2} / *sėklų* m^{-2}

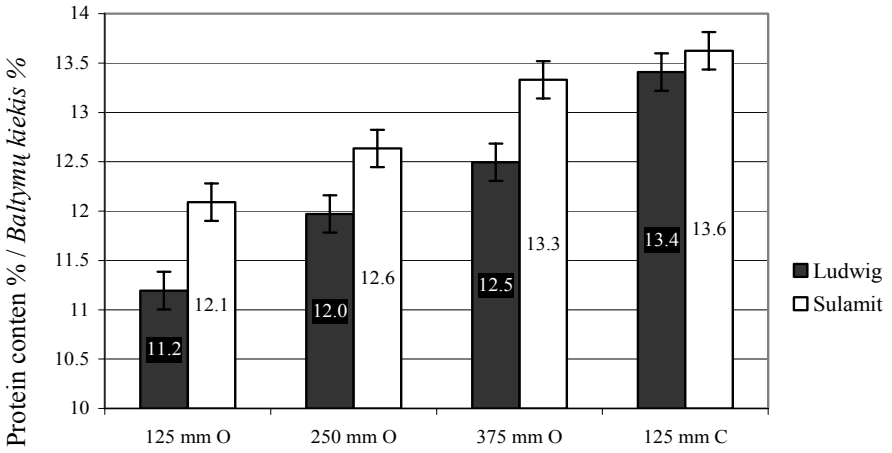
[2)] t ha^{-1}

* signif. difference / *patikimas skirtumas*

Table 4. Statistical evaluation of the effect of technique of cultivation, inter-row distance and seed rate on protein content and yield (in average of years and varieties)
4 lentelė. *Statistinis auginimo būdo, tarpueilių atstumo ir sėklų normos įtakos baltymų kiekiui ir derliui (metų ir veislių vidurkiai) įvertinimas*

Parameters *Rodikliai*	Protein content % *Baltymų kiekis %*	Signif. * *Patik. **	Yield t ha^{-1} *Derlius t ha^{-1}*	Signif. * *Patik. **
Technique of cultivation / *Auginimo būdas*				
Organic / *Organinis*	12.28	a	5.70	a
Conventional / *Įprastas*	13.52	b	7.79	b
$HSD_{0.05}$	0.2353		0.2127	
Inter-row distance (mm) / *Tarpueilių atstumas (mm)*				
125 Organic	11.64	a	5.76	ab
250 Organic	12.30	b	5.48	b
375 Organic	12.91	c	5.86	a
125 Convent.	13.52	d	7.79	c
$HSD_{0.05}$	0.3791		0.3420	
Seed rate (seed m^{-2}) / *Sėklos norma (sėklų m^{-2})*				
200			5.20	a
300			5.85	b
400			6.06	b
$HSD_{0.05}$			0.3035	

* Variants with different letter are statistically significantly different P ≥ 0.05
Variantuose su skirtingomis raidėmis yra statistiškai patikimi skirtumai P ≥ 0,05



N o t e . Vertical lines represent significant differences P ≥ 0.05
P a s t a b a . Vertikalios linijos rodo patikimus skirtumus P ≥ 0,05

Protein content in different inter-row distances and different technique of treatment
Baltymų kiekis grūduose įvairiuose tarpueilių atstumų ir auginimo variantuose

It can be clearly seen from our results that different growth structure (wider inter-row distance) in organic farming stimulates the protein synthesis in grain as stated before by Petr et al. (1987) and Förster et al. (2004). The higher protein content can be explained by better radiation conditions in growth, higher "aeration" of growth that can reduce the assault of fungal diseases which results in longer photosynthetic activity of assimilatory organs of wheat.

Effect of cultivation treatment on yield

Apart from the basic quality, also favourable yield is required for the successful growing of winter wheat in organic farming. Our results showed that the yields from conventional treatment were statistically significantly higher than in organic farming (Table 4). However, the satisfactory yields were reached by grain grown under organic farming (Table 3). Comparing organic and conventional treatment higher differences in yields were observed for variety 'Ludwig' (about 1.95 t ha^{-1}).

Effect of inter-row distance on yield

As mentioned above, the highest statistically significant yield was found for variants under conventional treatment in 125 mm inter-row distance (Table 4). Comparing yields from different inter-row distances (Table 4) in organic farming, the highest yield 5.86 t ha^{-1} was observed for variants from 375 mm inter-row distance. This yield was statistically significantly different from the lowest yield 5.48 t ha^{-1} for variant from 250 mm inter-row distance. It corresponds with results of Hiltbrunner et al. (2005) observation that widening the row space did not decrease grain yield.

Effect of sowing rate on yield

The highest yield was reached with the 400 seeds m^{-2} (Table 4) by both treatments of cultivation. However, differences in averages of sowing rates 300 and 400 seeds m^{-2} in average of two years were not statistically significant (Table 4). Also according to Lloveras et al. (2002), the highest grain yields in each environment were obtained with the highest seeding rates, with plant numbers of between 371 and 508 plants m^{-2}.

The effect of sowing rate on yield was negligible in range 200-400 seeds m^{-2} when using wider inter-row distance in organic farming. In other words, significantly lower sowing rate than commonly used in conventional farming can be used for inter-row distance 250 and 375 mm, respectively. This decrease of sowing rate is independent on grain yield. Similar findings have been published recently by Förster et al. (2004)

Conclusions

Comparing organic and conventional treatment, grain grown in organic farming had statistically significant lower protein content in dry matter of grain: about 1.2 %. The concentration of grain protein increased significantly for about 0.5-1.3 % (depending on variety), when the distance between the rows was increased from 125 mm to 375 mm in organic farming. As a result, both varieties fulfil the basic parameters for food/baking production. Widening the row distance did not decrease grain yield. The effect of sowing rate (in range 200-400 seeds m^{-2}) on yield was negligible in inter-row

distances 250 and 375 mm. For this reason, lower sowing rate than commonly used in conventional farming can be used for wider inter-row distances in organic farming.

The results of this project have proved that widening of inter-row distance increases the protein content in grain. Therefore it can be recommended to achieve higher baking quality of organically grown wheat.

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AUGIMO STRUKTŪROS ĮTAKA ŽIEMINIŲ KVIEČIŲ, UŽAUGINTŲ ORGANINĖJE ŽEMDIRBYSTĖS SISTEMOJE, KOKYBEI

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Santrauka

Tarpueilių pločio ir sėklų normos įtaka baltymų kiekiui ir grūdų derliui tirta dviejose žieminių kviečių veislėse, augintose įprastoje ir organinėje žemdirbystės sistemose, per du vegetacinius periodus. Rezultatai rodo, kad grūdai, užauginti organinėje žemdirbystės sistemoje, turėjo mažiau baltymų, palyginus su grūdais, užaugintais įprastoje žemdirbystės sistemoje su 125 mm pločio tarpueiliais. Tačiau, kai atstumas tarp eilučių buvo padidintas nuo 125 mm iki 375 mm organinėje žemndirbystės sistemoje, grūdų baltymų koncentracija iš esmės padidėjo – apie 0,5-1,3 % (priklausomai nuo veislės). Padidinus atstumą tarp eilučių, grūdų derlius nesumažėjo.

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