THE EFFECT OF VARIETY AND AGROECOLOGICAL FACTORS ON THE YIELD AND QUALITY OF WINTER WHEAT

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The effect of variety, cultivation locality, year and intensity of cultivation on the grain yield and selected parameters of technological quality was studied in experiments conducted with eight varieties of winter wheat cultivated during three years on four experimental sites in sugar-beet-, cereal- and potato-growing regions at two intensities of cultivation – basic and increased (compared to basic intensity of increased nitrogen doses of 40 kg N.ha^{-1}, use of fungicide and growth regulator). The measured values were evaluated statistically by analysis of variance of multiple classification for the purpose to determine the degree of influencing of evaluated parameters by variety and studied agroecological factors and correlation analysis with a goal to study correlations among different parameters. Results of analysis of variance showed prevailing influence by genotype in viscoelastic properties of gluten, assessed by Zeleny's test and Gluten Index, followed by the content of starch and ash, in Falling Number, amylographic maximum and yield of flours obtained during milling on the laboratory mill Bühler. The predominant effect of locality was found in the content of crude protein and wet gluten, bulk density was most affected by the year and grain yield by cultivation locality and intensity. Correlation analysis showed a lot of statistically significant, positive as well as negative relationships among studied parameters. Relatively close positive correlation between Gluten Index and Zeleny's test together with significant, positive correlation between the content of crude protein and wet gluten, as well as by very close positive dependence between Falling Number and amylographic maximum. Correlation coefficients between the content of starch and crude protein, wet gluten, Zeleny's test and Gluten Index were statistically significant, negative but reached relatively low values. Negative, statistically significant, though not very close correlations were found between bulk density and the content of proteins and wet gluten. The yield of flours was not in significant correlation with any other evaluated parameter. Statistically significant, positive correlation was found between the grain yield and starch content. Correlations between grain yield and parameters characterising amount and quality of proteins were negative and mostly on the limit of statistical significance.

winter wheat; variety; cultivation locality; intensity of cultivation; year; yield; technological quality

INTRODUCTION

Winter wheat is the most important and most widespread cereal crop of the Czech Republic. Based on the requirements of customers – producers, orientation towards reaching the quality of wheat by the way of final exploitation has gained ground more and more in recent year.

Criteria to assess the technological quality of the grain of wheat varieties for different trends of exploitation are the subject of many studies. In principle, however, they decide upon the grain quality by the traits predicating the content and viscoelastic properties of gluten proteins. Assessment of weight and grain hardness, flour yield, water-absorptive capacity, content of mineral substances and viscosity (activity of hydrolytic enzymes) can be added to it (Branlard et al., 1991; Šíp et al., 2000).

Traits of technological quality of grain are influenced by both variety and conditions of a site and year, and cultivation practices (Hubík, 1995). Information on the effect of varieties and different agroecological factors on parameters of technological quality of wheat grain and at the same time the knowledge of correlations among different quality traits are therefore one of prerequisites of a correct selection of utility direction, the choice of the most suitable wheat variety with regard to local agroecological conditions and hence also reaching the cultivation success.

The aim of this study was to evaluate the effect of variety, cultivation locality, year and intensity of cultivation on selected parameters of technological quality of winter wheat and the grain yield and to assess correlations among the studied parameters.

MATERIAL AND METHODS

The principle of solution consisted in qualitative analyses of grain samples in a collection of selected winter wheat varieties (Hana, Samanta – quality grade A; Siria, Šárka – quality grade B; Contra, Estica, Samara, Versailles – quality grade C) cultivated in soil-climatic conditions of sugar-beet-, cereal- and potato-growing regions at the variety testing stations of the Central Institute for Supervising and Testing in Agriculture (ÚKZÚZ) Domanínek, Lípa and Chrastava and at the breeding station Stupice (characteristics of experimental sites are in Table 1).

The experiments were established at experimental sites according to the principles valid for conduction of the State Variety Trials in the Czech Republic – using the methods of randomized blocks, in four replications, the size of experimental plot approximately 15 m^2. The experiments were conducted in two intensities of cultivation – basic and increased. The basic intensity of cultivation: dressing (active against stinking smut, dwarf smut), the total dose of nitrogen in connection with a forecrop and locality ranging from 90 to 110 kg $N.ha^{-1}$, (divided into two doses – regeneration and production ones), no morphoregulator, no fungicide. Increased intensity of cultivation: dressing (active against dwarf smut, stinking smut), the total dose of nitrogen since 1998 increased against the basic intensity of cultivation by 40 kg $N.ha^{-1}$ (this 40 kg $N.ha^{-1}$ applied about 14–20 days after production dose), morphoregulator (applied as needed at the start of shooting), fungicide against diseases of stem heels (as needed) and against leaf and spike diseases (the first treatment to phase DC.35, the second at the beginning of heading to the time before flowering). Three-year results are summed in the study (1997–1999).

The yield was determined after the harvests from experiments and about 3 kg of grain sample were taken from each replication for laboratory evaluation. Evaluation of the quality of cereals was done in the laboratory at the Czech University of Agriculture in Prague. Bulk density was determined in grain samples – the Czechoslovak Standard (ČSN) ISO 7971. Part of grain was ground on the laboratory mill with mesh sieve of 0.8 mm and the obtained groats was used for the following analyses: groats moisture – ČSN 56 0512-7; the content of crude protein ČSN ISO 1871; wet gluten content ČSN ISO 5531 – the device Glutomatic 2200 was used to determine it; Gluten Index was determined simultaneously with it; Falling Number ČSN ISO 3093 – Falling Number 1400 was used; starch content ČSN 56 0512-16 – after Ewers; ash content ČSN ISO 2171; amylographic evaluation – amylograph Brabender was used. The remaining part of grain was milled on the laboratory mill Bühler (type MLU-202). Weights of different flour passages were used to calculate the yield of break and reduction flours and the total yield of flours. The flour obtained after sieving was used to determine sedimentation index after Zeleny (ČSN ISO 5529).

Results of the qualitative analyses and yield results were statistically evaluated by the method of analysis of variance of multiple classification (ANOVA) in the program SAS 6.12/1996, with expression of parameter Fisher's distribution (F). More detailed evaluation of differences among averages was done by the method after Tukey on the level of significance $\alpha = 0.05$. Correlation among different studied parameters was evaluated by correlation analysis in the program SAS 6.12/1996 with expressed statistical significance of correlation coefficients on the level of significance $\alpha = 0.05$.

RESULTS AND DISCUSSION

The results obtained document predominant effect of different agroecological conditions of studied experimental sites on the content of crude protein and wet gluten in grain dry matter of evaluated wheat samples – the most marked differences were recorded at the locality Stupice in fertile sugar-beet-growing region and the other localities in cereal- and potato-growing regions (Tables 2 and 3). As reported Shannon and Garwood (1984), production of saccharides in grain prevails to the exclusion of proteins under lower temperatures, typical for less fertile regions. Raised temperature supports, however, total accumulation of proteins and saccharides, intensity of breathing is increasing relatively more at higher temperatures than the supply of saccharides and ratio of proteins in starch is growing in favour of proteins. Mariani et al. (1995), who studied in Italy 21 varieties of hard wheat on different localities, reported that site conditions the most affected the content of crude protein in their experiments. Šíp et al. (2000) and Prugar, Hraška (1986), too, found a marked effect of the site on the content of crude protein on the basis of their experiments carried out with seven winter wheat varieties from two experimental localities in sugar-beet- and potato-growing regions.

The effect of variety on the content of crude protein and wet gluten was statistically significant. Simultaneously with it, varieties from quality grade A Hana and Samanta reached much higher content of crude protein and wet gluten in all cases than the varieties from quality grades B and C (Table 3). Significant effect of varieties,

Table 1. Brief characteristics of experimental sites

Experimental locality	Growing region	Altitude (m)	Average annual temperature (°C)	Average annual sum of precipitation (mm)	Great soil group and texture	Average production potential of soils (points)
Domanínek[1)]	B	565	6.4	565	HPg-ph	47
Lípa[1)]	B	505	7.7	632	HPg-ph	55
Chrastava[1)]	O	346	7.1	798	Hmi-h	63
Stupice[2)]	Ř	295	8.4	575	HM-jh	84

Legend: [1)] – variety testing stations of ÚKZÚZ, [2)] – breeding station at Stupice
Growing regions: B – potato, O – cereal, Ř – sugar-beet
Great soil groups: HPg – acid stagnosol (stagno-gleyic cambisol), Hmi – luvisol (albic), HM – typical luvisol
Soil textures: ph – sandy loam, h – loam, jh – clay loam

Table 2. Calculated values of testing criterion *F* for three-year results of studied quality parameters and grain yield of winter wheat

Quality parameter / factor	Crude protein content	Wet gluten content	Zeleny's test	Gluten Index	Starch content	Falling Number	Amylographic maximum	Ash content	Yield of break flours	Yield of reduction flours	Total yield of flours	Bulk density	Grain yield
Locality	4335.85**	3618.99**	298.70**	506.73**	40.35**	218.03**	744.52**	57.99**	1361.80**	1294.53**	940.15**	194.32**	524.30**
Variety	3796.57**	3201.16**	357.03**	672.15**	80.67**	249.50**	763.17**	32.17**	2098.00**	2443.38**	1997.30**	214.78**	72.52*
Year	3253.35**	2707.42**	66.60*	101.11*	67.83**	185.89**	727.19**	52.25**	307.73*	93.30 ns	81.60 ns	258.04**	50.18 ns
Intensity of cultivation	2948.73**	2022.47**	20.28 ns	9.18 ns	15.43*	59.20*	275.79*	12.35*	106.24 ns	52.40 ns	41.40 ns	64.35*	172.81*

** statistical significance = 0.01, * statistical significance = 0.05, ns – statistically insignificant

Table 3. Analysis of variance for three-year results of evaluation of quality parameters of winter wheat grain (crude protein content, wet gluten content, Zeleny's test, Gluten Index) (Tukey, $\alpha = 0.05$)

Quality parameter / factor		Crude protein content (%)			Wet gluten content (%)			Sedimentation test by Zeleny (ml)			Gluten Index		
		$\bar{x}$	D_{min}	significance	$\bar{x}$	D_{min}	significance	$\bar{x}$	D_{min}	significance	$\bar{x}$	D_{min}	significance
Locality	Stupice	12.01		a	30.72		a	32.35		a	65.36		a
	Domanínek	10.39	0.01	b	25.64	0.04	b	23.00	0.24	b	59.13	0.37	b
	Lípa	11.16		c	28.04		c	25.58		c	58.71		c
	Chrastava	11.36		d	25.83		d	26.21		d	64.88		d
Variety	Hana	12.26		a	31.13		a	34.79		a	75.34		a
	Samanta	11.72		b	28.94		b	32.13		b	79.63		b
	Siria	11.19		c	26.53		c	27.13		c	70.13		c
	Šárka	11.28	0.02	d	27.33	0.06	d	27.33	0.39	c	76.42	0.90	d
	Samara	10.79		e	26.72		e	19.46		d	43.88		e
	Versailles	10.82		f	26.13		f	25.83		e	47.55		f
	Contra	10.67		g	26.27		g	21.75		f	48.96		g
	Estica	11.11		h	27.40		h	25.88		e	54.29		h
Year	1997	11.93		a	28.53		a	28.09		a	67.85		a
	1998	10.97	0.01	b	28.76	0.03	b	25.23	0.19	b	53.52	0.58	b
	1999	10.80		c	25.39		c	27.03		c	64.69		c
Intensity of cultivation	basic	10.76	0.01	a	26.56	0.02	a	26.40	0.14	a	60.08	0.30	a
	increased	11.70		b	28.55		b	27.18		b	63.95		b

Differences among average values denoted by identical letters are not significant
$\bar{x}$ – average values of studied grain parameters
D_{min} – minimal significant difference

Table 4. Correlation between studied quality parameters and yield of winter wheat grain

Intensity of cultivation	Quality parameter	Crude protein content	Wet gluten content	Zeleny's test	Gluten Index	Starch content	Falling Number	Amylograph	Ash content	Grain yield	Bulk density	Yield of break flours	Yield of reduction flours	Total yield of flours
Basic	Crude protein content	1												
Increased														
Basic	Gluten content	0.60*	1											
Increased		0.62*												
Basic	Zeleny's test	0.35*	0.36*	1										
Increased		0.38*	0.37*											
Basic	Gluten Index	0.29*	0.30*	0.70*	1									
Increased		0.30*	0.32*	0.73*										
Basic	Starch content	–0.22*	–0.23*	–0.35*	–0.19*	1								
Increased		–0.20*	–0.17*	–0.28*	–0.18*									
Basic	Falling number	–0.11	–0.13	0.04	–0.08	–0.11	1							
Increased		–0.08	–0.10	–0.02	–0.04	–0.08								
Basic	Amylograph	–0.17*	–0.16*	–0.08	–0.10	–0.06	0.94*	1						
Increased		–0.15	–0.08	–0.06	–0.08	–0.04	0.92*							
Basic	Ash content	–0.08	–0.10	0.05	–0.06	–0.08	0.02	–0.03	1					
Increased		–0.02	–0.04	0.02	–0.04	–0.09	0.03	0.02						
Basic	Grain yield	–0.21*	–0.12	–0.18*	–0.11	0.23*	0.09	0.05	0.05	1				
Increased		–0.19*	–0.15	–0.19*	–0.08	0.22*	0.11	0.10	0.07					
Basic	Bulk density	–0.22*	–0.19*	–0.14	–0.13	0.16*	0.07	0.02	0.06	0.20*	1			
Increased		–0.27*	–0.21*	–0.15	–0.16*	0.17*	–0.05	0.04	0.08	0.19*				
Basic	Yield of break flours	0.10	0.08	–0.05	0.01	–0.02	0.03	0.06	0.07	–0.02	–0.02	1		
Increased		–0.12	–0.09	0.02	–0.04	–0.04	0.01	0.05	0.10	–0.06	0.08			
Basic	Yield of reduction flours	0.04	0.02	0.03	0.02	0.05	0.12	0.08	0.08	0.05	0.05	–0.28*	1	
Increased		–0.03	0.05	0.10	–0.04	0.07	0.09	0.10	0.11	0.07	0.10	–0.24*		
Basic	Total yield of flours	–0.06	–0.08	0.05	0.08	0.03	–0.10	0.04	0.10	0.09	0.11	–0.16*	0.35*	1
Increased		–0.08	–0.11	–0.10	–0.06	0.01	0.06	0.03	0.12	0.05	0.07	–0.18*	0.32*	

* Correlation coefficient statistically significant on the level of significance $\alpha = 0.05$

ranked among various quality grades on the content of crude protein, was reported also by B e r g t h a l l e r et al. (1997).

Moreover, it followed from Table 2 that the content of crude protein and wet gluten was rather affected by the variety more than by intensity of cultivation and the year, but less than by cultivation locality. After P e t r (2001) the content of crude protein in wheat was affected by the variety out of 22% (the content of wet gluten out of 28%) and cultivation conditions out of 78% (the content of wet gluten out of 76%). Š í p et al. (2000) came to similar conclusions – the effect of variety on the content of proteins was rather statistically significant in their experiments, but lower compared with the effect of experimental site.

The results of the studies written by H u b í k (1995), V r k o č et al. (1995) and Š í p et al. (2000) document that intensity of cultivation, particularly by the use of different doses of N fertilizers can be affected by the content of crude protein and wet gluten in grain wheat in a significant way.

There is a little information on the effect of application of fungicides and growth regulators on the content of crude protein and wet gluten. Literary data on the effect of growth regulators as affected the quality traits of grain, are not homogenous and are s product of the varieties used, cultivated under different conditions (Š í p et al., 2000). As recorded C l a r k (1993) a weak reduction of the content of proteins with insignificant effect on the other indicators of grain quality can be expected after application of growth regulator. On the other hand, M a et al. (1994) reported that application of growth regulator could have a positive effect on the content of proteins. On the basis of their results C l a r e et al. (1990) stated that they did not find a marked effect of application of fungicide on the quality of grain indicators, though thanks to the destruction of leaf area at strong attack by diseases, indirect effect of this treatment on the yield as well as traits of grain quality is highly probable.

It followed from our results that the effect of increased intensity of cultivation characterised by the application of fungicide and growth regulator and since 1998 also by raised total dose of N by 40 kg of $N.ha^{-1}$ compared with the basic intensity on the content of crude protein and wet gluten was statistically significant and was manifested by higher content of crude protein and wet gluten at elevated intensity of cultivation. In total, intensity of cultivation affected the content of crude protein as well as wet gluten least of all studied factors (Table 2) in our experiments.

It is evident from Table 4 that positive, statistically significant correlation between the content of crude protein and wet gluten ($r = 0.60^{*}$ in basic and $r = 0.62^{*}$ was found in increased intensity of cultivation); correlations between the content of crude protein, wet gluten and indicators characterising the quality of protein complex (Zeleny's test and Gluten Index) were also statistically significant, positive, but correlation coefficients reached lower values. Statistically significant, negative correlations were recorded between the content of crude protein, wet gluten and starch (Table 4).

The quality of protein grain complex affected the possibilities of exploitation of wheat in a decisive way. Both Zeleny's sedimentation test and Gluten Index can be characterised as fast, simple methods, on whose basis viscoelastic properties of gluten proteins can be assessed.

It followed from the results obtained that the effect of variety on the values of Zeleny's sedimentation test and Gluten Index was more conspicuous than the effect of the other studied factors (Table 2). Results in Table 3 document it that varieties from quality grade A Hana and Samanta reached higher values of Zeleny's test and Gluten Index than varieties from quality grade B and particularly from quality grade C and were statistically different from them. The varieties Samara and Contra reached the lowest values of Zeleny's test as well as Gluten Index.

These data indicate relatively high genetic interdependence in viscoelastic properties of wheat proteins. L u k o w, M c V e t t y (1991), H u b í k (1995) and O n d r e j č á k, M u c h o v á (2002) came to identical conclusion on the basis of their results.

Cultivation locality affected the values of Zeleny's test and Gluten Index less than the variety, but more than the year (Table 2). Š í p et al. (2000) report a significant influence of the site on the values of Zeleny's test, and V r k o č et al. (1995) and C u r i c et al. (2001) mentioned a significant effect of cultivation conditions on Gluten Index. The effect of intensity of cultivation on Zeleny's test and Gluten Index was lowest in our experiments of all studied factors (Table 2).

It followed from Table 4 that relative close positive correlation was found between Gluten Index and Zeleny's test ($r = 0.70^{*}$ in basic and $r = 0.73^{*}$ in higher intensity of cultivation. C u b a d d a et al. (1992) and M a n e v et al. (1996) found a highly significant positive correlation between Gluten Index and sedimentation test. In their opinion Gluten Index has a good capacity to determine characteristics of the quality of wheat gluten (strength and weakness of flour and groats).

The content of starch in wheat grain is in inverse relationship to the content of proteins. Therefore, high-protein wheat cultivars are marked by lower starch content. This generally known fact was presented by many authors (B e r g t h a l l e r et al., 1997; C a p o u c h o v á et al., 2002) and our results from these experiments confirmed this, even though differences in the starch content in wheat grain dry matter among evaluated localities, varieties, years and intensities of cultivation were much lower than in indicators characterising amount and quality of proteins.

The effect of cultivation locality on the content of grain starch and flours produced in laboratory was statistically significant in some cases, in other cases it was insignificant. The content of starch from localities with less favourable soil-climatic conditions (Domanínek, Lípa) was always statistically significantly different from the localities with better conditions (Stupice, Chrastava) (Table 5).

The prerequisite of Petr et al. (2001) was confirmed that in colder, less fertile conditions of potato- or cereal-growing region will reach higher starch content with respect to lower bioenergic potential of these regions, because plants need less energy for starch production than for production of proteins.

The effect of variety on the starch content was more marked than the effect of cultivation locality (Table 2). It has been also proved by the results from Table 5 – varieties from quality grade A Hana and Samanta but also Šárka from quality grade B reached lower starch content than varieties from quality grade C and were statistically significant different from them. The variety Contra reached the highest starch content in grain and flour in all three evaluated years. Bergthaller et al. (1994), Petr et al. (2001), Capouchová et al. (2002) also mentioned significant effect of variety on the starch content.

It followed from the results presented in Table 5 that the experimental year 1999 was statistically significantly different in the starch content of grain from experimental years 1997 and 1998. It was probably caused by cooler and moister weather in the period of grain production and ripening in 1999. Starch synthesis is carried out prevailingly to the exclusion of crude protein under such conditions. Marked influence of the year on the starch content is confirmed by the results presented in Table 2.

In our case intensity of cultivation did not affect the starch content too much. Though differences between basic and increased intensity of cultivation were statistically significant (Table 5), based on the values presented in Table 2, intensity of cultivation affected the content of grain starch least of all studied factors.

Correlation coefficients characterising relationship between the content of starch and crude protein, wet gluten, Zeleny's sedimentation test and Gluten Index were statistically significant, negative, but reached relatively low values. Negative correlation between the content of starch and Zeleny's test was showed as the most significant. Correlations between the content of starch and the other studied quality indicators were mostly statistically insignificant (Table 4).

Falling Number and the values obtained from amylographic evaluation of grain (particularly the values of amylographic maximum) characterise the damage of endosperm caused by hydrolytic enzymes with consequence of changes of technological quality of grain.

The variety influenced most markedly Falling Number together with amylographic maximum of all studied factors (Table 2). The variety Samanta reached lowest values of Falling Number and amylographic maximum, the highest values were found in the variety Contra (Table 5).

After Hubík (1995) and Horčička et al. (2000) the effect of variety on Falling Number is dominant. Peltonen-Sainio, Peltonen (1993) and Trethowan (1995) report also high heritability in Falling Number and lower affecting by interactions of genotype with medium.

We found significant, statistically significant differences in Falling Number and amylographic maximum of grain among different localities (Table 5). Unlike previous quality indicators (content of crude protein, wet gluten, Zeleny's sedimentation test, Gluten Index), it was not confirmed that in warmer, more fertile conditions of sugar-beet-growing region (the locality Stupice) higher values of Falling Number and amylographic maximum were reached compared with localities in less fertile conditions of cereal- and potato-growing regions (Table 5).

The effect of the year on Falling Number and amylographic maximum was statistically significant, but lower than the effect of variety and cultivation localities (Table 2). Intensity of cultivation affected Falling Number and amylographic maximum least of all studied factors (Table 2). After Vrkoč et al. (1995), too, Falling Number is almost not influenced by intensity of cultivation.

Highly significant positive dependence between Falling Number and amylographic maximum of grain ($r = 0.94^*$ in basic and $r = 0.92^*$ in increased intensity of cultivation) is evident from the values of correlation coefficients (Table 4). Statistically significant relationships were not found in majority of cases among Falling Number, amylographic maximum and the other studied quality indicators.

Differences in the ash content in wheat grain between evaluated localities, varieties, years and intensities of cultivation were very small, despite it, in majority of cases they were statistically significant. After Table 2 the ash content was most affected by variety and year, least by intensity of cultivation.

Bulk density was influenced statistically significantly by the year (Table 6), and as it followed from Table 2, most of all studied factors. Our results coincide in it with the conclusions made by McGuire, Blackwood (1990) and Hubík (1995) who also present prevailing effect of the year on the bulk density.

Variety and year also affected the bulk density statistically significantly and relatively conspicuously (Tabs 2 and 6). On the other side, Hubík (1995) report according to his results that significant effect of variety on bulk density was not recorded. The effect of intensity of cultivation on bulk density was lowest of all studied factors (Table 2).

In addition, Hubík (1995) reports that he found statistically significant negative correlations between bulk density, content of proteins and wet gluten. Schuler et al. (1995) found significant negative correlation between bulk density and protein content in wheat grain. Preston et al. (1995) also found highly significant negative correlation between bulk density and content of proteins in grain in samples of Canadian wheat varieties from harvest of 1989–1991. In their opinion it shows that grains with high content of proteins have less rounded shape and on the basis of that in highly-protein wheat cultivars lower content of endosperm and lower yield of flours can be expected.

Table 5. Analysis of variance for three-year results of evaluation of quality parameters of winter wheat grain (starch content, Falling Number, amylographic maximum, ash content) (Tukey, $\alpha = 0.05$)

Quality parameter / factor		Starch content (%)			Falling Number (s)			Amylographic maximum (A.J.)			Ash content (%)		
		$\bar{x}$	D_{min}	significance	$\bar{x}$	D_{min}	significance	$\bar{x}$	D_{min}	significance	$\bar{x}$	D_{min}	significance
Locality	Stupice	65.22		a	279.06		a	640.78		a	1,60		a
	Domanínek	66.58	0.38	b	292.94	1.12	b	732.08	2.95	b	1,64	0,01	b
	Lípa	66.39		b	288.68		c	707.60		c	1,69		c
	Chrastava	65.49		a	313.26		d	808.13		d	1,74		d
Variety	Hana	64.02		a	309.09		a	791.25		a	1,65		a
	Samanta	65.17		b	305.96		b	751.98		b	1,66		b
	Siria	67.14		ce	284.57		c	674.58		c	1,64		c
	Šárka	64.33	0.64	a	294.11	1.87	d	732.08	4.93	d	1,63	0,01	d
	Samara	65.85		d	266.83		e	594.79		e	1,67		e
	Versailles	66.52		c	287.25		f	680.42		f	1,67		e
	Contra	67.74		e	323.97		g	911.25		g	1,63		d
	Estica	66.57		c	276.08		h	640.83		h	1,69		f
Year	1997	65.31		a	279.76		a	658.40		a	1.67		a
	1998	65.56	0.30	a	294.32	0.89	b	727.34	2.33	b	1.60	0.01	b
	1999	66.59		b	306.38		c	780.70		c	1.72		c
Intensity of cultivation	basic	66.12	0.21	a	294.65	2.60	a	700.89	1.59	a	1.66	0.01	a
	increased	65.71		b	292.32		a	743.41		b	1.69		b

Differences among average values denoted by identical letters are not significant

$\bar{x}$ – average values of studied grain parameters

D_{min} – minimal significant difference

Table 6. Analysis of variance for three-year results of evaluation of quality parameters (yield of flours, bulk density) and yield of winter wheat grain (Tukey, $\alpha = 0.05$)

Quality parameter / factor		Yield of break flours (%)			Yield of reduction flours (%)			Total yield of flours (%)			Bulk density ($kg.hl^{-1}$)			Grain yield ($t.ha^{-1}$)		
		$\bar{x}$	D_{min}	significance	$\bar{x}$	D_{min}	significance	$\bar{x}$	D_{min}	significance	$\bar{x}$	D_{min}	significance	$\bar{x}$	D_{min}	significance
Locality	Stupice	19.82		a	46.89		a	66.71		a	76.88		a	5.29		a
	Domanínek	21.01	0.11	b	42.71	0.26	b	63.78	0.17	b	75.91	0.16	b	9.41	6.69	b
	Lípa	20.09		c	44.08		c	64.20		c	76.74		a	7.73		c
	Chrastava	20.47		d	43.24		d	63.70		d	77.03		c	0.02		d
Variety	Hana	21.50		a	44.67		a	66.17		a	75.87		a	6.89		a
	Samanta	21.04		b	41.08		b	62.12		b	75.80		a	6.96		b
	Siria	19.94		c	47.73		c	67.67		c	76.15		b	7.04		c
	Šárka	20.10	0.08	d	36.35	0.09	d	56.28	0.45	d	77.00	0.20	c	7.56	0.04	d
	Samara	20.14		d	43.42		e	63.56		e	77.14		c	7.37		e
	Versailles	20.00		c	49.57		f	69.56		f	77.08		c	7.48		f
	Contra	21.73		e	42.41		g	64.14		g	77.67		d	7.47		f
	Estica	18.34		f	48.83		h	67.17		h	76.52		e	7.48		f
Year	1997	20.30		a	43.89		a	64.25		a	76.76		a	7.26		a
	1998	20.19	0.20	a	45.21	0.22	b	65.40	0.20	b	77.33	0.22	b	7.01	0.02	b
	1999	20.55		b	43.59		c	64.14		a	75.84		c	7.57		c
Intensity of cultivation	basic	20.35	0.03	a	44.27	0.24	a	64.63	0.22	a	76.02	0.11	a	6.77	0.01	a
	increased	20.34		b	44.18		a	64.51		a	77.25		b	7.79		b

Differences among average values denoted by identical letters are not significant

$\bar{x}$ – average values of studied grain parameters

D_{min} – minimal significant difference

Statistically significant, negative, though not close correlations between bulk density, content of proteins and wet gluten ($r = -0.22^*$ to -0.27^*) followed also from our results (Table 4). We found negative correlations also between bulk density and Gluten Index and between bulk density and Zeleny's sedimentation test, however, correlation coefficients were all statistically insignificant. Statistically significant, positive, though not high correlation coefficients were found between bulk density and starch content. Correlations between bulk density and yield of flours were statistically insignificant.

Grinding of wheat sample on laboratory milling automatic machine Bühler (type MLU-202) makes possible to judge suitability of wheat for milling purposes. Grain should have been full, rather slightly rounded with smooth shells (seed vessel and episperm) and shallow longitudinal line (Petr, Louda, 1998). There is a little information on the effect of varieties, sites, cultivation measurements on yield of flours is available in special literature. Statistically significant and unambiguously dominant effect of variety on yield of flours produced in laboratory (Tables 2 and 6) is evident. The highest total yield of flours (69.56%) and simultaneously with it the highest yield of reduction flours (obtained during milling on plain rolls) (49.57%) was reached by the variety Versailles. High yield of reduction flours was found also in the varieties Estica (48.83%) and Siria (47.73%). Furthermore, these varieties reached high total yield of flours (67.17% and 67.67%). On the other hand, yield of break flours (obtained during milling on knurled rollers) was lowest in them (18.34% and 19.94%). The highest yield of break flours was recorded, on the contrary, in varieties Contra (21.73 %), Hana (21.50%) and Samanta (21.04%), in which yield of reduction flours and total yield of flours were on lower level. The variety Šárka was significantly different from remaining evaluated varieties that reached average yield of break flours but strongly below-average yield of reduction flours (only 36.35 %) and strongly below-average total yield of flours (56.28%).

Cultivation locality participated in yield of flours statistically significantly (Table 6) and as it follows from Table 2, relatively significantly – the effect of locality on yield of flours was rather lower than the effect of variety, but significantly lower than the year and intensity of cultivation. The highest yield of break flours was found at Domanínek, the lowest one at Stupice. The highest yield of reduction flours was found, on the contrary, at Stupice, the lowest at Domanínek and identical result was recorded also in case of total yield of flours.

Moreover, it followed from our results that the effect of the year on yield of flours was in some cases statistically significant, in other cases statistically insignificant (Table 6), but in all cases relatively low what can be seen by results presented in Table 2. Then intensity of cultivation affected yield of flours less of all studied factors – the effect of cultivation on yield of flours was statistically insignificant.

It followed from evaluation of relationships of yield of flours and remaining studied indicators of technological quality (Table 4) that the yield of flours did not correlate significantly with any other studied quality trait. Statistically negative correlations between yield of break and reduction flours ($r = -0.28^*$ in basic and $r = -0.24^*$ in increased intensity of cultivation) were found and statistically significant positive correlations between total yield of flours and yield of reduction flours ($r = 0.35^*$ in basic and $r = 0.32^*$ in increased yield of cultivation). At the same time by the results of Bona et al. (2002) who studied 80 samples of different wheat varieties from two harvests in Hungary, the relationship between yield of flours and other indicators of technological quality of wheat was very unambiguous and majority of found correlations was statistically insignificant. As it has been mentioned above, there were found no statistical significant correlations even between yield of flours and bulk density, what is often considered a certain indicator of yield of flours. We meet in it with the results obtained by Schuler et al. (1995) who tested 24 wheat varieties cultivated in six different regions with different conditions of environment and did not find statistically significant correlations between the yield of flours and bulk density, and also the conclusions made by Posner, Hibbs (1997) according to them there is an incorrect prerequisite that bulk density has to have relationship to yield of flours.

Based on the results found, it can be assumed that there is a certain relationship between the yield of flours and grain hardness. Though gain hardness was not studied within this work, but if we start from opinions that grain hardness is the question of variety above all (Prugar, Hraška, 1986; Eliasson, Larsson, 1993; Finney, 1994 and others), new results of Faměra, Hrušková (2003) can be considered. They evaluated grain hardness in the collection of wheat varieties registered in the Czech Republic by the method PSI and they found that from the varieties included in our study, the varieties Versailles and Estica are marked by hard grain and the varieties Šárka, Contra and Samanta have soft grain. It is evident that soft varieties are characterised by higher yield of break and lower yield of reduction flours; it is vice versa in hard varieties. This opinion has been confirmed by the conclusions made by Finney (1994), who found in soft wheat varieties of break flours from the mill Allis-Chalmers significantly the higher yield than in hard varieties of wheat and in hard wheat varieties.

The results obtained (Table 6) document a significant effect of different agroecological conditions fully convincingly as affected the yield of grain of evaluated wheat varieties.

Differences in the grain yield among different localities were statistically significant; simultaneously the most important differences were recorded among localities at Stupice (sugar-beet-growing region) and Domanínek (potato-growing region). At the same time, the dominant effect of cultivation locality on the grain yield is apparent from Table 2. Highly significant effect of a site on wheat grain yield was also reported by Hubík (1995), Peltonen (1995) and Šíp et al. (2000).

The grain yield was influenced by variety in majority of cases statistically significantly, but it is apparent from Table 6 that the differences among different evaluated varieties were far from being so distinct as among different localities. Results from Table 2 also prove lower effect of variety on the grain yield in our experiments. The effect of the year on the grain yield was lowest of all studied factors.

Intensity of cultivation was applied in the grain yield statistically significantly (Table 6) and as it follows from Table 2, also relatively considerably. Many authors mentioned substantial growth of yield at increased intensity of cultivation. Based on their results, Šíp et al. (2000) referred to that application of growth regulator in combination with N dressing compared with untreated control was manifested by significant increase of yield, the effect of application of the growth regulators themselves, nevertheless, was not so remarkable. Clark (1993) and Puppala et al. (1998) found a distinct effect of treatment with fungicide on the grain yield owing to prevention of destruction of leaf area at strong attack with diseases.

It followed from Table 4 that statistically significant, though not very close negative correlations were found between the grain yield, content of crude protein and Zeleny's sedimentation test together with negative, but statistically insignificant correlation between grain yield and content of wet gluten and statistically significant positive correlation between the grain yield, the starch content and bulk density. Negative correlations between the grain yield and the protein content were also reported by Branlard et al. (1991). Moreover, they also mention a negative correlation between the grain yield and sedimentation test.

On the other side, Šíp et al. (2000) based on their results from evaluation of seven winter wheat varieties from two cultivation localities in two years and eight treatment variants during the vegetation gave that correlations between the content of grain proteins and grain yield were insignificant in five assessed varieties. In remaining two varieties (Vlasta and Sirie) they were significant and positive. Ortiz-Monasterio et al. (1997) stated that drop in the protein content does not occur in modern short-stem wheat varieties under conditions of optimal N nutrition at high grain yield. Positive correlations between the protein content and grain yield testify raised N translocation into grain and most likely also more efficient exploitation of this nutrition, what belongs to very important breeding aims (Pena, 1996).

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CAPOUCHOVÁ, I. – PETR, J. (Česká zemědělská univerzita, Agronomická fakulta, Praha, Česká republika):

Vliv odrůdy a agroekologických faktorů na výnos a jakost ozimé pšenice.

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Vliv odrůdy, pěstitelské lokality, ročníku a intenzity pěstování na výnos zrna a ukazatele technologické jakosti (obsah N-látek, mokrého lepku, Zelenyho sedimentační test, Gluten Index, obsah škrobu, číslo poklesu, amylografické maximum, obsah popela, objemová hmotnost, výtěžnost laboratorně vyrobených mouk) byl studován v pokusech s osmi odrůdami ozimé pšenice z jakostních skupin A, B, C, pěstovanými v průběhu tří let na čtyřech pokusných stanovištích v řepařské, obilnářské a bramborářské oblasti při dvou intenzitách pěstování – základní a zvýšené (oproti základní intenzitě navýšení dávky N o 40 kg $N.ha^{-1}$, užití fungicidu a regulátoru růstu). Naměřené hodnoty byly statisticky vyhodnoceny analýzou variance vícenásobného třídění za účelem vymezení míry ovlivnění hodnocených parametrů odrůdou a sledovanými agroekologickými faktory a korelační analýzou za účelem studia vzájemných vztahů mezi jednotlivými parametry.

Výsledky analýzy variance ukázaly převažující ovlivnění genotypem u viskoelastických vlastností lepku, posuzovaných na základě Zelenyho testu a Gluten Indexu, dále u obsahu škrobu a popela, u čísla poklesu, amylografického maxima a výtěžnosti mouk získaných při mletí na laboratorním mlýnu Bühler. Převažující vliv lokality byl zjištěn na obsah N-látek a mokrého lepku, objemová hmotnost byla nejvíce ovlivněna ročníkem a výnos zrna pěstitelskou lokalitou a intenzitou pěstování.

Korelační analýza ukázala řadu statisticky průkazných, pozitivních i negativních vztahů mezi sledovanými parametry. Byla zjištěna poměrně těsná pozitivní korelace mezi Gluten Indexem a Zelenyho testem ($r = 0{,}70^*$ u základní a $r = 0{,}73^*$ u zvýšené intenzity pěstování) a rovněž průkazná, pozitivní korelace mezi obsahem N-látek a mokrého lepku ($r = 0{,}60^*$ u základní a $r = 0{,}62^*$ u zvýšené intenzity pěstování) a dále velmi těsná pozitivní závislost mezi číslem poklesu a amylografickým maximem ($r = 0{,}94^*$ u základní a $r = 0{,}92^*$ u zvýšené intenzity pěstování). Korelační koeficienty mezi obsahem škrobu a obsahem N-látek, mokrého lepku, Zelenyho testem a Gluten Indexem byly statisticky průkazné, záporné, ale dosahovaly relativně nízkých hodnot. Záporné, statisticky průkazné, i když ne příliš těsné korelace jsme zjistili mezi objemovou hmotností a obsahem bílkovin a mokrého lepku ($r = -0{,}22^*$ až $r = -0{,}27^*$). Výtěžnost mouk nekorelovala statisticky průkazně s žádným dalším hodnoceným parametrem. Statisticky průkazná kladná korelace ($r = 0{,}23^*$ u základní a $r = 0{,}22^*$ u zvýšené intenzity pěstování) byla zjištěna mezi výnosem zrna a obsahem škrobu. Korelace mezi výnosem zrna a ukazateli charakterizujícími množství a kvalitu bílkovin byly záporné a většinou na hranici statistické průkaznosti.

ozimá pšenice; odrůdy; pěstitelské lokality; intenzita pěstování; ročníky; výnos; technologická jakost

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