The effect of sites and years on the technological quality of winter wheat grain

J. Kučerová

Mendel University of Agriculture and Forestry in Brno, Czech Republic

ABSTRACT

The results of three-year trials (1999 to 2001) conducted with six winter wheat varieties in which was investigated the effect of sites, years and varieties on the final grain yield and technological quality showed statistically significant differences (*LSD*, 95%) among sites in grain yield and these parameters of quality: test volume mass, wet gluten content, sedimentation test, protein content, falling number and flour water absorption capacity. As to the quality, the Žatec site showed itself as generally most suitable, and the Jaroměřice site as the least suitable one. Climate conditions showed a statistically significant effect (*LSD*, 95%) on grain yield and all quality parameters, beside the percentage of complete grains and swelling capacity of gluten and falling number, which were insignificant. The most favourable weather conditions, a lot of precipitation and high temperature in the course of ripening from three years were proved in the year 2000. Among the varieties were statistically significant differences (*LSD*, 95%) in grain yield and these parameters of quality: test volume mass, thousand grain weight, ash content, percentage of complete grains, sedimentation test, protein content, reologic properties of dough and baking tests. From the six varieties the best profits were shown from variety Sulamit (loaf volume 595 ml/100 g of flour), the worst was Semper (loaf volume 543 ml/100 g of flour) and Vlasta (loaf volume 532 ml/100 g of flour). The best grain yield was in 2001 (average of sites 8.84 t/ha) and the variety Semper had the highest grain yield of 9.17 t/ha, that is higher at 13.41% compared with Sulamit (7.94 t/ha).

Keywords: winter wheat; sites; varieties; technological quality

The basic growing goals in all crops include the achievement to produce maximum produce of sufficient quality.

The technological quality of grain is influenced, not only by variety, but also by many external environment factors and growing measures. Prugar and Hraška (1986) published one of the first comprehensive summaries of the effects of different growing factors, years and sites with respect to determining their order of significance in the quality of products, based on results of several investigations.

The importance of various factors for some quality parameters of winter wheat grain was investigated by Vrkoč et al. (1995). They reported that the nutritional and technological quality of grain is determined, by the variety, but also by the site and year, much more than by cultivation measures. Differences between sites and years cannot be removed even by intensive fertilization. The evaluations of the relationships between the sites, variety and quality parameters, based on extensive experimental material (56 wheat varieties), were carried out by Werteker (2003), and to varying extent this topic was studied by other researchers (Johansson et al. 2001, Altenbach et al. 2002).

This study contributes to the evaluation of a site, year and variety importance for some quality parameters in winter wheat grain.

MATERIAL AND METHODS

Variety. The list of varieties used in this study as well as their origin (country, breeder, year of registration and baking quality) are given in Table 1.

Characteristics of the cultivation sites. The selected set of wheat varieties comes from different localities of the Czech Republic. Wheat grain samples used for laboratory evaluation were obtained from variety test stations at the Central Institute for Supervising and Testing (ÚKZÚZ).

Chrlice (site A) – the site is 190 m above the sea level. Type of soil is eutric fluvisol, the sort of soil is loamy (medium). The previous crop in all three years was peas. Nitrogen fertilizing in 2000 and 2001 was 70 kg N/ha, and in the year 1999 was 80 kg N/ha.

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Table 1. The list of varieties country, breeder, year of registration and baking quality

Country of origin	Variety	Breeder	Registration	Baking quality
Czech Republic	Sulamit	a	2000	A
Czech Republic	Nela	b	1998	A
Czech Republic	Vlasta	c	1999	B
Germany	Ebi	d	1997	E
Austria	Ludwig	e	2000	E
Netherlands	Semper	f	1999	C

a – Selgen, a.s., ŠS Stupice; b – Plant Select, s.r.o.; c – Selgen, a.s., ŠS Úhřetice; d – Limagrain-Nickerson GmbH (representative in CR Selgen, a.s.); e – Probstdorfer Saatzucht GmbH (Oseva Pro s.r.o.); f – Cebeco Zaden B.V. (in CZ Cebeco Seeds s.r.o.)
E – elite, A – good quality, B – standard, C – undersirable baking quality

Jaroměřice (site B) – the site is 425 m above the sea level. The soil type is orthic luvisol, sort of soil clayey-loam (heavy). Previous crop during watch period was peas. Nitrogen fertilizing was in all three years 80 kg/ha.

Sedlec (site C) – the site is 300 m above the sea level. The soil type is orthic luvisol haplic chernozem, the sort is loamy soil (medium). The previous crop during the watch period was lucerne. Nitrogen fertilizing in 1999 was 90 kg N/ha and in the following two years 70 kg N/ha.

Žatec (site D) – the site is 285 m above the sea level. The soil type is orthic luvisol haplic chernozem, the sort of soil is clayey – loam (heavy). Previous crop in 1999 was winter wheat and in the other two years peas. Nitrogen fertilizing in 1999 was 140 kg N/ha, in 2000 and 2001 120 kg N/ha.

Characteristics of climatic conditions on the sites and temperature data for 1999–2001 (Kožnarová and Klabzuba 2002)

Site A – average year temperature is +8.8°C, average year sums of precipitation are 512 mm
Site B – average year temperature is +7.8°C, average year sums of precipitation are 487 mm
Site C – average year temperature is +8.2°C, average year sums of precipitation are 501 mm
Site D – average year temperature is +8.3°C, average year sums of precipitation are 451 mm

The course of the weather (temperatures and precipitations) is given in Tables 2 and 3.

Quality parameters and methods. We evaluated 17 characteristics, which represent technological quality (milling and baking) in wheat. The evaluation methods included the common ones for determination of test weight [grain volume mass, (g/l)], thousand grain weight/mass (g), ash content of flour T-550 (%), percentage of complete grains (%), extraction of flour T-550 (%) milling on Chopin mill. From the chemical and physical analytical methods, were used the standard methods of determination of the dry (%), wet gluten content in the whole grain meal (%), gluten swelling (cm^3), protein content (after Kjeldahl) (%), and rapid assessment methods as SDS-test (ml), Zeleny sedimentation test (ml) and falling number (s); furthermore the determination of farinograph parameters: dough development time (min), dough stability (min), softening degree after 12 minutes (FJ), flour water absorption capacity (%) and baking test (Rapid Mix Test)-parameter loaf volume (ml/100 g of flour) were carried out. Analysis of variance of multiple classifications was used for the result evaluation and *LSD* method at 95% for a more detail evaluation. The results were processed in the programme Statgraphics version 4.

RESULTS AND DISCUSSION

The mean values of the examined traits and grain yield for the sites are given in Table 4. The smallest effect was exerted by the site factor that influenced eight quality traits out of sixteen. In regards to technological parameters, the best values were achieved in eleven traits at the Žatec site whereas at the Jaroměřice site the worst values were demonstrated in nine traits (Table 4). As to the quality, the Žatec site showed itself as generally most suitable for wheat growing, and the Jaroměřice site as the least suitable one.

Grain quality was strongly influenced by the year that exerted a statistical influence on fourteen technological traits out of total sixteen (Table 5). The year of 1999 appeared to be the most suitable for the growing of milling wheat with favourable values prevailing in the traits; the year of 2000 seemed to be the least suitable one for this purpose. On the contrary, the year of 2000 produced

Table 2. Percentages of the precipitation normal in the period (April–August), in sites Chrlice (A), Jaroměřice (B), Sedlec (C), Žatec (D) (evaluated according to WHO method, Kožnarová and Klabzuba 2002)

Month	Precipitation normal (mm)				Percentage of precipitation normal											
					1999				2000				2001			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
April	27	31	39	29	50 bn	72 n	25 vbn	88 N	8 ebn	21 vbn	13 ebn	36 vbn	39 vbn	65 n	81 n	52 bn
May	61	59	70	56	25 vbn	55 bn	24 vbn	25 vbn	30 vbn	31 vbn	42 vbn	46 vbn	21 vbn	37 vbn	50 vbn	41 vbn
June	74	68	77	57	48 vbn	47 vbn	50 bn	60 bn	7 ebn	8 ebn	39 vbn	34 vbn	17 ebn	33 vbn	25 vbn	28 vbn
July	86	66	73	77	47 bn	79 n	55 bn	42 bn	67 n	68 n	43 bn	34 vbn	25 vbn	52 bn	74 n	51 bn
August	62	69	77	54	24 vbn	52 bn	10 ebn	37 bn	28 bn	36 bn	15 ebn	38 vbn	60 bn	40 vbn	26 vbn	44 bn

ebn – extraordinary below normal, vbn – very below normal, bn – below normal, n – normal, an – above normal, van – very above normal, ean – extraordinary above normal

Table 3. Deviation of the temperature normal in the period (April–August), in sites Chrlice (A), Jaroměřice (B), Sedlec (C), Žatec (D) (evaluated according to WHO method, Kožnarová and Klabzuba 2002)

Month	Temperature normal (°C)				Deviation of temperature normal (°C)											
					1999				2000				2001			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
April	9.1	8.0	8.4	8.4	1.3 n	1.6 an	1.3 n	1.5 n	3 van	4 van	3.6 van	3.6 van	–2 bn	–0.5 n	0.2 n	–0.6 n
May	14.1	13.0	13.4	13.2	0.5 n	1.1 n	1.2 n	2.5 an	1.1 n	2.8 van	3.1 van	3.8 van	1 n	2.3 an	2.1 an	2.6 van
June	14.6	16.0	16.6	17.0	3.2 ean	0.4 n	–0.9 n	0 n	3.8 ean	2.8 ean	1.9 an	3 ean	0.4 n	–1.2 bn	–1.1 bn	–1 n
July	16.3	18.0	13.4	18.3	3.4 ean	1.4 an	6.2 ean	2.5 van	–0.1 n	–1 n	3.5 ean	–1 n	2.9 ean	1 n	5.9 ean	2.2 van
August	18.1	17.0	18.1	18.1	–0.7 bn	0.5 n	0 n	0.6 n	1.7 van	3.3 ean	2.4 van	2.7 ean	1.3 an	2.5 van	1.8 an	2.2 van

ebn – extraordinary below normal, vbn – very below normal, bn – below normal, n – normal, an – above normal, van – very above normal, ean – extraordinary above normal

Table 4. Mean values of the examined traits and grain yield for sites Chrlice (A), Jaroměřice (B), Sedlec (C), Žatec (D) in 1999–2001

Examined traits			Site				D_{min}
			A	B	C	D	
Milling quality		test volume mass (g/l)	811.4	819.9	804.3	816.7	9.109
		thousand grain weight (g)	47.95	46.85	48.50	46.76	2.308
		ash content (%)	0.579	0.585	0.594	0.564	0.040
		percentage of complete grains (%)	84.8	87.1	85.9	83.5	7.110
		extraction of flower T-550 (%)	59.9	60.2	59.3	60.1	5.696
Baking quality		wet gluten content (%)	29.2	26.0	28.0	32.1	2.716
		gluten swelling (cm^3)	11.7	11.8	11.5	15.2	9.267
		SDS-test (ml)	61.8	56.1	64.6	65.0	4.158
		Zeleny-test (ml)	45.8	43.4	45.9	53.4	5.232
		protein content (% of dry matter)	13.8	13.2	13.5	14.6	0.504
		falling number (s)	322	317	345	370	30.624
	farinograph	dough development time (min)	6.6	4.6	6.5	7.4	2.856
		dough stability (min)	11.8	11.3	12.0	12.9	2.846
		softening degree after 12 minutes (FJ)	42.1	53.4	43.1	32.2	12.380
		flour water absorption capacity (%)	59.4	58.2	59.0	59.3	1.050
		loaf volume (ml/100 g of flour)	570	550	560	570	33.020
Grain yield (t/ha)			8.12	7.39	8.34	8.18	0.651

Table 5. Mean values of the examined traits and grain yield in years 1999–2001

Examined traits			Year			D_{min}
			1999	2000	2001	
Milling quality		test volume mass (g/l)	834.5	800.5	804.3	7.172
		thousand grain weight (g)	48.25	45.13	49.17	1.817
		ash content (%)	0.617	0.545	0.579	0.032
		percentage of complete grains (%)	86.9	81.5	87.5	5.598
		extraction of flower T-550 (%)	76.7	53.0	49.9	4.485
Baking quality		wet gluten content (%)	28.8	31.5	26.1	2.138
		gluten swelling (cm^3)	10.2	16.3	11.1	7.296
		SDS-test (ml)	58.7	65.0	–	2.219
		Zeleny-test (ml)	–	54.6	39.6	2.792
		protein content (% of dry matter)	13.5	15.0	12.9	0.397
		falling number (s)	339	332	344	24.111
	farinograph	dough development time (min)	3.6	10.6	4.6	2.249
		dough stability (min)	6.3	16.4	13.2	2.241
		softening degree after 12 minutes (FJ)	63.8	18.1	46.2	9.747
		flour water absorption capacity (%)	60.6	59.0	57.3	0.826
		loaf volume (ml/100 g of flour)	559	589	538	25.996
Grain yield (t/ha)			8.59	8.17	8.84	0.512

Table 6. Mean values of the examined traits and grain yield for varieties in 1999–2001

Examined traits			Variety						D_{min}
			Ebi	Sulamit	Ludwig	Nela	Vlasta	Semper	
Milling quality		test volume mass (g/l)	826.4	815.3	820.1	806.5	792.2	817.9	12.409
		thousand grain weight (g)	49.07	45.88	50.65	46.76	49.72	43.00	3.144
		ash content (%)	0.578	0.600	0.576	0.511	0.620	0.600	0.054
		percentage of complete grains (%)	88.4	88.0	93.0	85.2	71.9	85.5	9.686
		extraction of flower T-550 (%)	60.1	58.7	58.1	64.7	58.3	59.2	9.308
Baking quality		wet gluten content (%)	28.7	28.5	28.4	30.1	27.6	29.5	3.699
		gluten swelling (cm^3)	11.8	13.3	13.6	18.8	10.8	6.9	12.624
		SDS-test (ml)	68.1	67.3	65.5	61.0	57.5	51.8	5.684
		Zeleny-test (ml)	55.9	57.7	54.1	34.5	42.0	38.5	7.152
		protein content (% of dry matter)	13.9	14.2	14.1	13.8	13.4	13.3	0.686
		falling number (s)	331	354	346	319	343	337	41.719
	farinograph	dough development time (min)	6.0	7.6	8.4	5.2	6.3	4.3	3.891
		dough stability (min)	12.4	14.0	14.3	11.2	11.1	9.4	3.878
		softening degree after 12 minutes (FJ)	44.7	30.8	34.1	47.5	42.3	56.6	16.865
		flour water absorption capacity (%)	59.1	62.6	58.5	55.2	59.4	58.9	1.430
		loaf volume (ml/100 g of flour)	588	595	569	548	532	543	44.982
Grain yield (t/ha)			8.19	7.94	8.59	8.57	8.72	9.17	0.887

unambiguously the best baking quality grain and the best results (Table 5).

From the viewpoint of general technological quality, the most favourable weather conditions were in 2000, a lot of precipitation (Table 2) and high temperature in the course of ripening (Table 3), the least favourable in 2001.

The mean values of the examined traits and grain yield for varieties are given in Table 6. Figures 1–3 show statistically significant differences among varieties.

The statistical analysis implies that the variety significantly influenced twelve traits out of sixteen under the evaluation (Table 6), which is due to the different quality levels of the varieties under investigation (E, A, B, C) and their response to different weather conditions of the year (Tables 2 and 3), in particular. As to **milling quality**, the Ludwig variety and related Ebi variety (both classified in the group E) appeared to be the best ones, the Vlasta variety seemed to be the worst one (three lowest values of five traits, group B). As to **baking quality**, the Sulamit variety (group A) that surpassed the other varieties in six traits (out of eleven) was the best one. The Ludwig and Ebi varieties showed good quality (both allocated in the group E), while the Semper variety (group C) was the worst one (the least favourable), with six worst values of eleven traits, which was designated by ranking it in the lowest category.

Among reliable traits of baking quality of wheat belong both to the sedimentation tests, protein content and reologic properties of dough (Figure 2) that close positive correlations with loaf volume yield (Figure 3), which was demonstrated by many researchers (Schobert and Kuhn 1999, Bojňanská 1996, and others).

From the viewpoint of general technological quality, the best results were achieved by the Sulamit variety (in six traits out of sixteen), followed by Ludwig and Ebi. In terms of quality, Semper ranked the last with seven worst results of sixteen traits under observation (Table 6).

We can state that the results achieved are in compliance with quality classification of the varieties under observation. A dominant influence of the variety over the site was confirmed by Werteker (2003).

The highest **grain yield** was achieved with the Semper variety (9.17 t/ha) of undesirable baking quality (C), the standard Vlasta variety (B) was placed the second, whereas the lowest values were obtained with the elite varieties Sulamit (7.94 t/ha) and Ebi (8.19 t/ha) (E).

Thus, a hypothesis expressed by many authors (e.g. Šíp et al. 2000, Muchová 2003) was confirmed

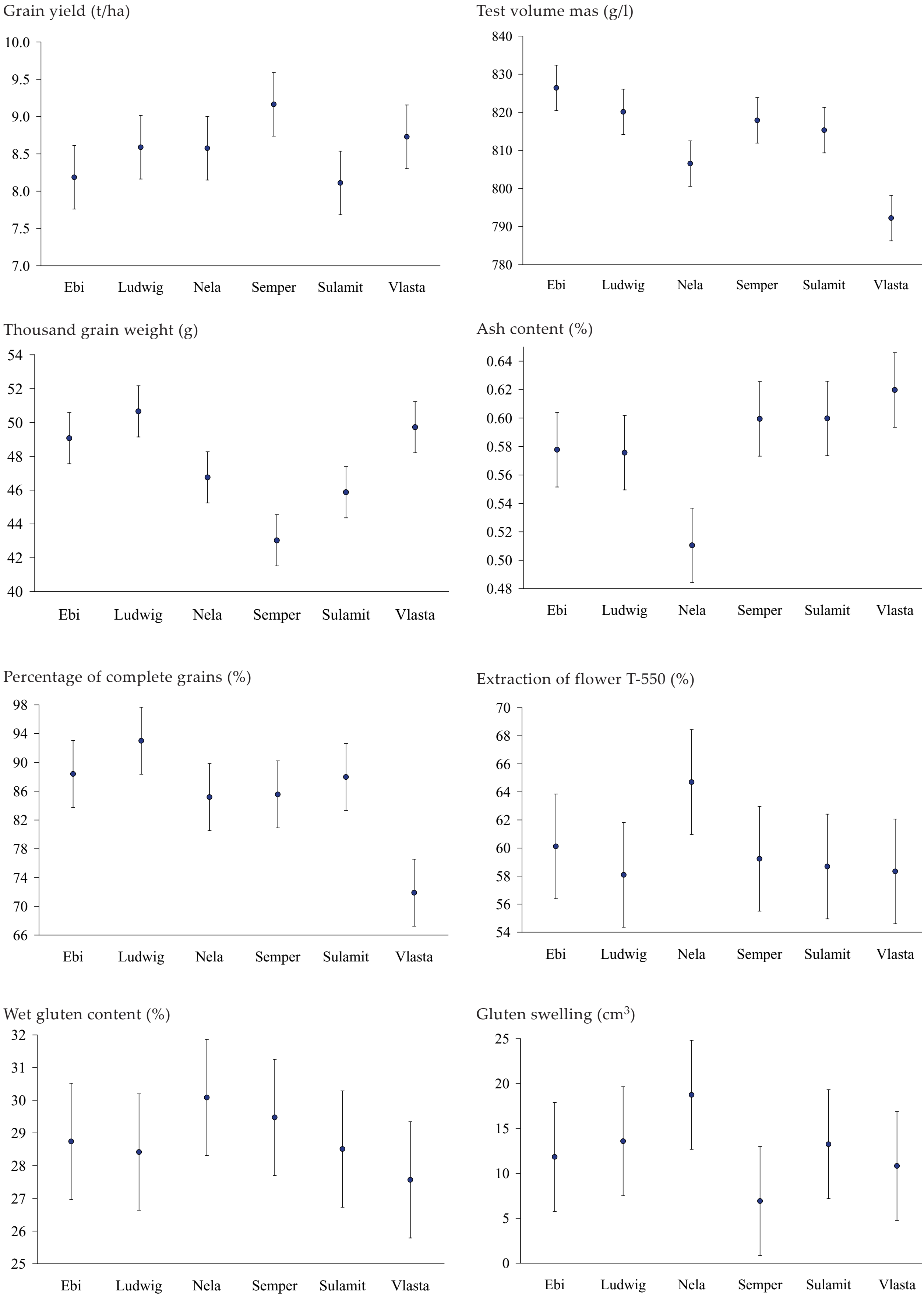

Figure 1. Comparison of grain yield, test volume mass, thousand grain weight, ash content, percentage of complete grains, extraction of flower, wet gluten content, gluten swelling

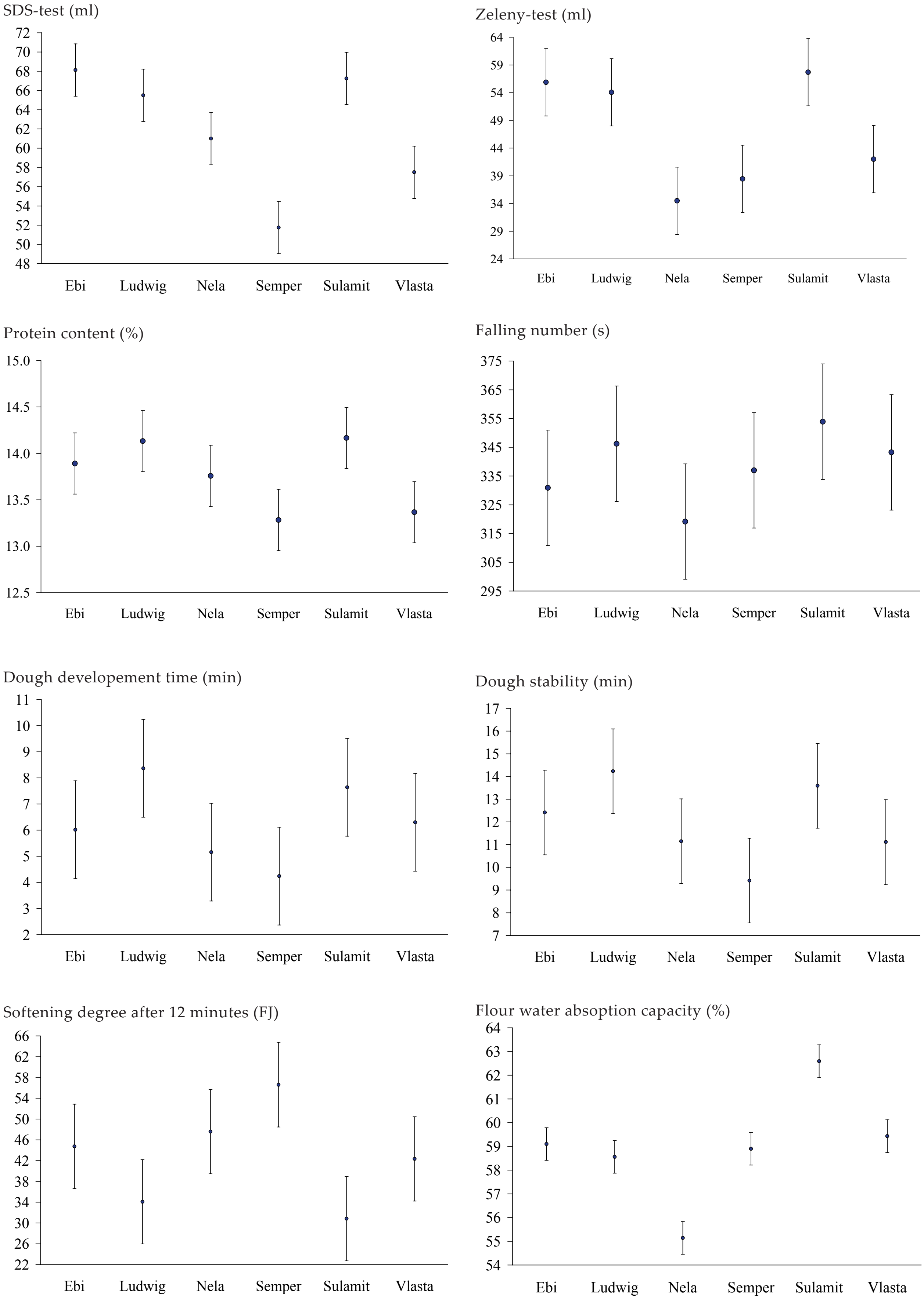

Figure 2. Comparison of SDS-test, Zeleny-test, protein content, Falling number, dough development time, dough stability, softening degree after 12 minutes, flour water absorption capacity

Loaf volume (ml/100 g of flour)

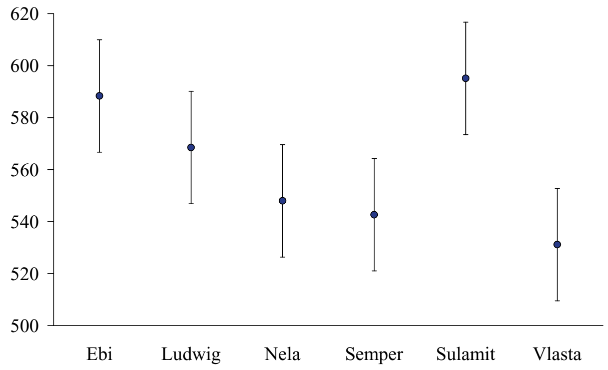

Figure 3. Comparison of loaf volume

saying that high baking quality of grain is negatively correlated with grain yield, and that is why in comparative trials the varieties of B or C class give the highest yield. On the other hand, the E and A varieties provide the highest financial profit to a farmer. There is a very strong negative link between grain yield and crude protein content; therefore it is very difficult to simultaneously increase protein content and grain yield by seed improvement.

The particular findings in this study showed, that the technological quality of wheat is not a simple matter. Therefore, proper studies are necessary to determine all the factors, which affect it.

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ABSTRAKT

Vliv stanovišť a ročníků na technologickou kvalitu zrna ozimé pšenice

Výsledky tříletých pokusů (1999 až 2001) s šesti odrůdami ozimé pšenice, u kterých byl sledován vliv stanoviště, ročníku a odrůdy na výsledný výnos zrna a technologickou jakost, prokázaly statisticky průkazné rozdíly (*LSD*, 95 %) mezi stanovišti u výnosu a u těchto jakostních znaků: objemové hmotnosti, obsahu lepku, sedimentační hodnoty, obsahu bílkovin, čísla poklesu a vaznosti mouky. Pokud se týká jakosti, ukázala se celkově nejvýhodnější stanice Žatec, naopak nejméně výhodné byly Jaroměřice. Podmínky ročníku statisticky průkazně (*LSD*, 95 %) ovlivnily výnos a všechny jakostní znaky kromě podílu plných zrn, bobtnavosti lepku a čísla poklesu. Nejpříznivější povětrnostní podmínky z hlediska jakosti, hodně srážek a vysoká teplota při dozrávání, byly zaznamenány v roce 2000. Mezi odrůdami se statisticky průkazné rozdíly (*LSD*, 95 %) projevily u výnosu a objemové hmotnosti, hmotnosti tisíce zrn, obsahu popela, podílu plných zrn, sedimentační hodnoty, obsahu bílkovin, reologických vlastností těsta a měrného objemu pečiva. Nejlepších výsledků dosáhla odrůda Sulamit (měrný objem 595 ml/100 g mouky), nejnižší pekařskou jakost měla odrůda Semper (měrný objem 543 ml/100 g mouky) a Vlasta (měrný objem 532 ml/100 g mouky). Nejvyšší výnosy dosáhly odrůdy v roce 2001 (průměr stanovišť 8,84 t/ha), přičemž nejpříznivěji se za celé sledované období projevila odrůda Semper (nejnižší jakost), průměr 9,17 t/ha, což je o 13,41 % více než u odrůdy Sulamit (7,94 t/ha).

Klíčová slova: ozimá pšenice; stanoviště; odrůdy; technologická kvalita

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Corresponding author:

Ing. Jindřiška Kučerová, Ph.D., Mendelova zemědělská a lesnická univerzita v Brně, Zemědělská 1, 613 00 Brno, Česká republika
phone: + 420 545 133 194, fax: + 420 545 133 096, e-mail: kucerova@mendelu.cz