SHORT COMMUNICATION

Variability of grain yield components of some new winter wheat genotypes (*Triticum aestivum* L.)

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ABSTRACT

Variability of grain yield components of some new winter wheat genotypes (e.g. Lara, Lenta, Kruna, Fiesta, Perla, and one line of AG-45) was examined. The analysis of grain yield components of these genotypes and the line was undertaken in a two-year research (1997/1998 and 1998/1999) at two different locations. Significant differences among genotypes, locations and research years were established. In the first experimental year (1997/1998) there was a high positive correlation between nearly all components of the grain yield. The most significant correlation was found between the grain number per spike and grain yield. In the second experimental year (1998/1999) the components did not show statistically significant correlation with the grain yield. It seems that the grain yield of examined genotypes depended significantly on the grain number per spike, grain mass per spike, and agroecological conditions during the vegetation period, whereby the potential yield was determined by the interaction among genotypes, location and production year. The biggest differences among examined genotypes of winter wheat were found in the stem height and spike length.

Keywords: *Triticum aestivum* L.; genotype; components grain yield; stem; spike; grain; biological yield; agriculture yield

Selection of a short stem, bigger number of spikes per area unit and grains per spike contributed most to a higher grain yield (Piljnjev 1990, Austin 1994, Hay 1995). Over the years, yield increase was result of stem shortenings accompanied by an adequate increase of a harvest index (Busch and Stuthman 1990). Increase of the harvest index was a result of increased grain number per spike combined with a stable individual grain weight (Hay 1995). Creation of a new and short stem cultivar, a higher grain number per spike with more spikes per area unit, affected the harvest index increase. Plant substances were better reallocated into the grain (Hay 1995) because biological mass remained unchanged or changed only slightly (Austin 1994, Siddique and Whan 1994, Slafer et al. 1994), the grain yield increased, having an identical or a smaller grain mass (Austin 1980). According to Martinčić et al. (1996) grain yield is under big influence of spike properties, and interdependence and correlation between spike length and spikelet number per spike. However, a thousand kernel weight plays a very important role in the possible increase of the grain yield of new wheat genotypes. The previously mentioned authors claim that not all spikelet florets are fertile and the number of fertile florets depends significantly on genotype and ecological factors. The increase of genetic yield potential includes creation of wheat genotypes of the higher grain yield per spike (Drezner 1995). The growth of grain numbers per spike increases the plant need for assimilates which can be met under favourable conditions of photosynthetic activity. If unfavourable conditions appear, an earlier reallocation of assimilates from the vegetative organs into the grain occurs (Johanson and Ruan 1995). Bede et al. (1997) obtained a very significant correlation between the grain number and the grain mass per spike, which led them to conclude that the grain yield from examined genotypes related greatly to the grain number per spike. Bláha and Michalová (1993) found very important correlation between the grain mass per spike and the grain yield of spring wheat varieties. Variations of the grain number per spike explain 90% of the wheat grain yield fluctuation (Fischer 1975). Hrubý (1993) claims that a mass of 1000 grains is strongly influenced by the production year.

MATERIAL AND METHODS

Five new genotypes of winter wheat and one line (Lara, Lenta, Kruna, Fiesta, Perla, and AG-45) were chosen at two different locations (Donji Miholjac and Kutjevo) for the purpose of analysis of the basic grain yield components taken from macro-selection trials in four repetitions and from two vegetation periods (1997/1998 and 1998/1999).

Grain yield components, namely, stem length, spike length, plant mass, spike mass, grain mass per spike, 1000 grain mass, number of spikelets per ear, biological yield and grain yield were determined according to the standard methods and the mean values are shown in Tables 4 and 5.

Table 1. Results of soil analyses of examined locations

Locations	pH (H_2O)	pH (HCl)	Humus (%)	P_2O_5 (mg/100 g soil)	K_2O (mg/100 g soil)
Donji Miholjac	5.70	4.43	1.47	14.67	18.08
Kutjevo	7.10	6.03	1.47	30.56	15.82

Table 2. Climate conditions at Donji Miholjac and Kutjevo location in 1997/1998 and 1998/1999

Month	Year	Average monthly temperature (°C)		Average monthly precipitations (mm/m^2)	
December	1997	–0.3	–0.6	66.7	126.0
	1998	–1.1	–1.1	92.4	114.5
July	1998	20.8	20.3	91.2	147.3
	1999	22.4	22.4	68.5	127.6

The examined wheat genotypes differed in genetic background and several characteristics. In creating the examined genotypes the following cultivars were used as parent components: Žitarka, Slavonia, Njivka, Pitoma, Gemini, OSK. 7-5/3-82, X-87-83 × 3.68/2-81 and GO-3135.

The chosen locations also differed, for example in the height above sea level, chemical composition of the soil, fertilization and climate conditions. The height above sea level of Donji Miholjac is $H = 86$ m which is a low-lying area, while Kutjevo lies in the hilly area and its height above sea level is $H = 236$ m. Differences between locations refer to chemical composition of the soil, climatic conditions and fertilizers, these are shown in Tables 1, 2 and 3.

To determine the grain yield components, 80 plants in four repetitions were sampled from each genotype during the waxen ripening. Number of plants per area unit (stand) was defined by counting the number of spikes in four repetitions, by a randomized block system, and by a square pattern 50 × 50 cm (Table 9).

Influences of genetic specificity and agroecological conditions of locations on the grain yield components were examined by variance analysis and tested by F-test. The significance of the differences between genotypes and localities was determined by the LSD test ($P_{0.05}^{*}$, $P_{0.01}^{**}$). The interrelation of components of the grain yield was determined by multiple regression and correlation analysis.

RESULTS

Before the harvest in 1997/1998, the average stem height of all wheat varieties was 73.20 cm in Donji Miholjac and 69.00 cm in Kutjevo (Table 4). Prior to the harvest, plants were higher in 1998/1999 than in 1997/1998 at both locations. The lower stem height of 1997/1998 and a highly significant correlation with the biological yield ($r = 0.777^{**}$, $P < 0.01$) (Table 6) related to the cultivar specificity and climate conditions during the vegetation period. The genotypes of 1998/1999 had significantly higher stem (Table 5). Stem height did not correlate significantly with the grain yield (Table 7). According, to the variance analysis in 1998/1999 high significant influence of genotype and location was established, while the interaction of location and genotype was not statistically significant (Table 8).

As far as the spike length is regarded in 1997/1998 the variance analysis proved an outstanding dependence of this parameter upon genotype in contrast with location, but the interaction between location and genotype was also highly significant (Table 8). In 1997/1998 according to the correlation between the spike length and grain yield ($r = 0.802^{**}$, $P < 0.01$) (Table 6), it was obvious that the grain yield increased as spike length increased. Significantly longer spike was noticed in the genotypes of 1998/1999 (Table 5), but the spike length did not show statistically significant correlations with other yield components and the grain yield (Table 7). In both experimental years fixed and positive correlations between the plant mass and spike mass were established (Tables 6 and 7). The impact of location was very marked, as well as that of genotype. The interaction between location and genotype was also significant (Table 8).

The influence of genotype on the plant mass in both experimental years was substantial as well as the interaction of location and genotype (Table 8).

As it seems, spike mass in 1997/1998 depended on the genotype while location did not have any impact. The interaction between location and genotype was highly significant (Table 8). The average values of the spike mass were higher in Kutjevo than in to Donji Miholjac (Table 4) with a variability coefficient of 14.05%. In 1998/1999 the spike mass was strongly influenced by location. The interaction of location and genotype was highly significant (Table 8). The average spike mass was bigger in Donji Miholjac than in Kutjevo in 1998/1999 (Table 5) and the variability coefficient was 10.80%.

Table 3. Fertilization (kg/ha) of the locations in 1997/1998 and in 1998/1999

Locations	1997/1998					1998/1999				
	N			P_2O_5	K_2O	N			P_2O_5	K_2O
	b.d.	t.d.	Σ	Σ	Σ	b.d.	t.d.	Σ	Σ	Σ
Donji Miholjac	107	82	189	67.5	52.5	126	68.5	194.5	67.5	52.5
Kutjevo	40	117	157	120	80	121	95	176	120	80

Table 4. Mean values of grain yield components of examined genotypes of winter wheat in Donji Miholjac in 1997/1998

Localities	Genotypes	Mass of plants (g)	Mass of spike (g)	Mass of grains per spike (g)	Number of grains per spike	Number of spikelets per spike	Mass of 1000 grains (g)	Height of stem (cm)	Length of spike (cm)	Biological yield (t/ha)	Yield grain (t/ha)
Donji Miholjac	Lara	4.00	1.99	1.34	30.25	15.75	44.20	73.87	5.49	21.20	7.12
	Lenta	3.80	1.97	1.45	38.50	17.50	37.78	82.39	7.76	24.00	9.20
	Kruna	3.60	1.72	1.17	29.00	15.75	40.98	73.77	5.89	22.72	7.49
	Fiesta	4.40	2.39	1.74	39.75	17.25	43.71	76.60	7.04	24.22	9.52
	AG-45	3.40	1.65	1.18	28.50	16.50	41.99	66.89	6.52	20.15	7.30
	Perla	3.60	2.10	1.57	34.75	17.25	45.57	65.51	6.46	18.96	8.23
	average	3.80	1.97	1.41	33.50	16.70	42.40	73.20	6.52	21.90	8.14
Kutjevo	Lara	3.00	1.71	1.30	31.25	16.00	41.22	63.78	5.30	16.64	7.61
	Lenta	3.64	1.95	1.45	40.75	17.00	35.51	75.60	7.40	23.10	9.17
	Kruna	3.22	1.75	1.20	30.25	15.50	39.36	68.21	5.70	20.69	7.77
	Fiesta	3.72	2.20	1.58	39.25	17.50	41.11	68.24	7.00	20.90	9.06
	AG-45	3.25	1.91	1.45	34.25	16.50	41.87	62.93	6.70	18.93	8.56
	Perla	4.51	2.54	1.79	42.25	17.25	42.41	75.02	7.50	28.709	11.30
	average	3.54	2.01	1.46	36.30	16.70	40.20	69.00	6.60	21.50	8.91

The average grain mass per spike was bigger in Kutjevo than in Donji Miholjac in both experimental years (Tables 4 and 5) and variability coefficient was 9.36%. In both experimental years, the grain mass per spike depended more on genotype (Table 8). Correlation analysis of 1997/1998 showed the expected relationship between the grain mass per spike with the number of grains per spike, number of spikelets per spike, length of spike and of the grain yield (Table 6), but in 1998/1999 correlation was established only with the stem height and grain yield (Table 7).

Variance analysis and the F-test showed a very marked influence of genotype and location on the grain number per spike in 1997/1998. In 1998/1999, the influence of genotype on the grain number per spike was highly significant. According to F-test, the interaction of location and genotype was highly significant in both experimental years (Table 8).

In the both experimental years, the variance analysis and F-test showed highly significant influence of genotype on the spikelets number in the spike (Table 8). The average values of the spikelets number per spike were nearly identical at both locations and in both years (Tables 4 and 5) with a low variability coefficient of 4.76%.

Genotype and location had a strong impact on the mass of 1000 grains in 1997/1998 whereas the interaction of genotype and location was not statistically significant.

Table 5. Mean values of grain yield components of examined genotypes of winter wheat in Kutjevo in 1997/1998

Localities	Genotypes	Mass of plants (g)	Mass of spike (g)	Mass of grains per spike (g)	Number of grains per spike	Number of spikelets per spike	Mass of 1000 grains (g)	Height of stem (cm)	Length of spike (cm)	Biological yield (t/ha)	Yield grain (t/ha)
Donji Miholjac	Lara	3.10	1.51	1.35	42.25	15.50	32.25	85.00	6.65	20.78	9.01
	Lenta	3.42	2.03	1.32	39.25	16.50	33.93	91.75	8.28	25.62	9.08
	Kruna	3.66	1.92	1.25	38.00	15.25	33.02	88.50	7.23	24.40	8.44
	Fiesta	4.00	2.29	1.29	42.50	17.00	30.44	90.25	8.45	22.66	7.32
	AG-45	3.75	2.10	1.27	38.25	17.00	33.47	84.75	8.18	24.51	8.25
	Perla	3.45	2.07	1.13	34.25	16.00	32.93	76.25	8.10	21.14	6.93
	average	3.60	1.98	1.26	39.00	16.20	32.67	86.00	7.81	23.22	8.16
Kutjevo	Lara	3.30	1.83	1.15	32.50	15.00	35.83	85.25	7.53	22.91	7.79
	Lenta	3.90	2.00	1.50	40.50	17.00	37.42	94.50	10.25	25.13	10.34
	Kruna	3.60	2.00	1.23	37.00	15.75	22.52	92.25	8.23	25.39	8.46
	Fiesta	3.60	1.79	1.51	43.00	16.00	35.56	94.00	9.80	18.60	7.86
	AG-45	3.20	1.69	1.20	37.50	15.50	32.00	86.00	9.28	21.92	8.36
	Perla	3.30	1.80	1.34	41.00	15.00	32.90	79.50	8.75	22.44	9.24
	average	3.50	1.85	1.32	38.60	15.70	34.50	88.60	8.79	22.73	8.67

Table 6. Correlation coefficients between grain yield components and grain yield ($P < 0.05^{*}$, $P < 0.01^{**}$) of examined genotypes of winter wheat in 1997/1998 on both locations

	Mass of spike	Mass of grains per spike	Number of grains per spike	Number of spikelets per spike	Mass of 1000 grains	Height of stem	Length of spike	Biological yield	Yield grain
Mass of plant	0.863**	0.738**	0.615*	0.573*	0.274NS	0.669*	0.528NS	0.828**	0.661*
Mass of spike		0.961**	0.817**	0.749**	0.304NS	0.338NS	0.581*	0.649*	0.840**
Mass of grains per spike			0.872**	0.835**	0.268NS	0.278NS	0.645*	0.519NS	0.861**
Number of grains per spike				0.870**	–0.231NS	0.475NS	0.839**	0.601*	0.923**
Number of spikelets per spike					–0.008NS	0.354NS	0.882**	0.509NS	0.822**
Mass of 1000 grains						–0.362NS	–0.343NS	–0.163NS	–0.135NS
Height of stem							0.550NS	0.777**	0.436NS
Length of spike								0.654*	0.802**
Biological yield									0.744**

* significant at 5% level, ** significant at 1% level, NS not significant

In 1998/1999, however, the influence of location on the mass of 1000 grains was highly significant, while the impact of genotype was less expressed. The interaction of the two factors was highly significant (Table 8). The mass of 1000 grains of examined genotypes was on average 42.40 g in Donji Miholjac in 1997/1998 and 40.20 g in Kutjevo (Table 4) with a very low variability coefficient of 6.71%. In 1998/1999, the mass of 1000 grains of examined genotypes was lower on the average in Donji Miholjac than in Kutjevo (Table 5) with a low variability coefficient of 5.61%. In both experimental years, there was no statistically significant correlation between the mass of 1000 grains and other components of the grain yield (Tables 6 and 7).

Genotype had a very strong influence on the biological yield of examined genotypes in both years, but the impact of location was not statistically significant. At the same time, the interaction of location and genotype had a highly significant influence on the biological yield formation (Table 8).

In both experimental years, the grain yield of examined genotypes was strongly influenced by genotype and location. At the same time, a strong interaction between location and genotype was established (Table 8).

DISCUSSION

Component analysis of the grain yield of examined genotypes showed significant differences among genotypes, locations and experimental years. Influenced by genotype and location, the total stem height varied significantly. The spike length is, according to the variance analysis, a marked cultivar specificity influenced strongly by location (Table 8).

Variability among genotypes, locations and experimental years was specially established for the spike mass. Some authors claim that grain mass per spike directly influences yield results (Bláha and Michalová 1993, Drezner 1995, Bede et al. 1997). It is evident for the gen-

Table 7. Correlation coefficients between grain yield components and grain yield ($P < 0.05^{*}$, $P < 0.01^{**}$) of examined genotypes of winter wheat in 1998/1999 on both locations

	Mass of spike	Mass of grains per spike	Number of grains per spike	Number of spikelets per spike	Mass of 1000 grains	Height of stem	Length of spike	Biological yield	Yield grain
Mass of plant	0.857**	0.324NS	0.263NS	0.791**	0.120NS	0.573*	0.329NS	0.459NS	0.111NS
Mass of spike		–0.137NS	–0.107NS	0.683*	–0.191NS	0.204NS	0.173NS	0.460NS	–0.305NS
Mass of grains per spike			0.800NS	0.363NS	0.455NS	0.593*	0.567NS	–0.147NS	0.581**
Number of grains per spike				0.336NS	–0.166NA	0.380NS	0.297NS	–0.256NS	0.357NS
Number of spikelets per spike					0.007NS	0.418NS	0.406NS	0.253NS	0.006NS
Mass of 1000 grains						0.404NS	0.435NS	0.136NS	0.432NS
Height of stem							0.453NS	0.318NS	0.337NS
Length of spike								–0.086NS	0.272NS
Biological yield									0.441NS

* significant at 5% level, ** significant at 1% level, NS not significant

Table 8. Impact of location and genotype on grain yield components of examined genotypes of winter wheat (F-test)

Components yield grain	1997/1998			1998/1999		
	location (L)	genotype (G)	interactions (L × G)	location (L)	genotype (G)	interactions (L × G)
Mass of plant	6.22^{*}	6.87^{**}	7.10^{**}	7.39^{*}	12.07^{**}	5.03^{**}
Mass of spike	3.23^{NS}	19.54^{**}	5.56^{**}	11.91^{**}	7.42^{**}	10.65^{**}
Mass of grains per spike	5.37^{NS}	25.10^{**}	4.13^{**}	5.41^{*}	8.48^{**}	8.64^{**}
Number of grains per spike	13.70^{**}	28.17^{**}	2.63^{**}	4.10^{NS}	4.48^{**}	7.02^{**}
Number of spikelets per ear	2.96^{NS}	13.62^{**}	3.02^{NS}	4.29^{*}	4.41^{**}	3.63^{NS}
Mass of 1000 grains	30.27^{**}	30.24^{**}	3.55^{NS}	12.33^{**}	2.92^{*}	3.86^{**}
Height of stem	18.08^{**}	15.29^{**}	8.62^{**}	23.43^{**}	63.08^{**}	6.02^{NS}
Length of spike	3.98^{NS}	64.21^{**}	5.76^{**}	119.27^{**}	42.12^{**}	3.17^{*}
Biological yield	4.10^{NS}	6.05^{**}	10.37^{**}	4.23^{NS}	21.94^{**}	7.95^{**}
Yield of grain	16.70^{**}	19.73^{**}	7.78^{**}	8.85^{**}	11.46^{**}	8.33^{**}

* significant at 5% level, ** significant at 1% level, ^{NS} not significant

otypes Lenta, Fiesta and Perla. Significant differences in the spike mass became evident among the genotypes in the year 1997/1998 regarding the characteristics of the grain mass per a spike, grain number per a spike, spikelets number per a spike, the grain yield and the spike length. These characteristics became more pronounced due to spike elongation.

In both years, the grain mass per spike was highly dependent on genotype (Table 8). Grain number per spike varied significantly under the influence of genotype and location. The positive correlation (1997/1998) was established between the grain number per spike and the grain mass per spike, on the one hand, and the spike length and grain yield on the other. This implied that by an increase of the grain number per spike, there is also an increase of the individual grain weight and grain yield. According to Fischer (1975), fluctuation of the grain number per spike explains 90% of the grain yield fluctuation. The best grain yields were found in examined genotypes with the highest grain number per spike (Tables 4 and 5). Positive correlation between the grain number per spike and the grain mass per spike was obtained by Bede et al. (1997) who concluded that the grain yield related mostly with the grain number per spike.

In 1997/1998, the biggest number of the spikelets per spike was found in the genotypes Lenta, Fiesta and Perla, which had the biggest grain yield as well (Table 4). High positive correlation between the spikelets number per spike, the spike length and the grain yield is, therefore, understandable (Table 6). In 1998/1999, there was no statistically significant correlation between the spikelet number per spike and components of the grain yield (Table 7).

Table 9. Number of primary wheat off shoots per sq m at growth locations in experimental years

Genotypes	Donji Miholjac		Kutjevo	
	1997/1998	1998/1999	1997/1998	1998/1999
Lara	530	674	597	692
Lenta	637	688	634	687
Kruna	639	680	644	686
Fiesta	551	566	575	520
AG-45	612	647	590	697
Perla	524	615	637	690

Significant variations, among examined genotypes, of the mass of 1000 grains were influenced by genotype and location in both years (Table 8). These variations could be explained by different locations and climate conditions of the crops. According to Hrubý (1993), the mass of 1000 grains is a quantitative characteristic but influenced by ecological factors and other plant characteristics, which affect the grain yield directly or indirectly.

Examined components of the grain yield, stem height, plant mass and spike mass had lower values in the first year but the obtained results were in accordance with the research done by Busch and Stuthman (1990) who claimed that those characteristics influenced the biological growth process. Significant differences in the biological yield among examined genotypes could be the results of climate conditions, which affected the maximum manifestation of genetic potentials. Favourable climate conditions, as a prerequisite for good grain yield, enable better plant development and better utilization of nutrients resulting in high biological yield, but still dependent on genotype and location.

The grain yield of examined genotypes was proportional to biological yield in both years (Tables 4 and 5). In 1997/1998 the grain mass per spike and the grain number per spike were limiting factors for the grain yield because of significant correlation with the grain yield. This research has proved that differences in the grain yield, obtained among examined genotypes, were affected by genotype, whereby a stable interaction between genotype and location determined limitation factors of potential yield. In 1998/1999, the examined genotypes had longer spikes and more grain per spike, which directly influenced the grain yield (Table 5). Grain yield depended mostly on the grain number per spike, the grain mass per spike, and agroecological conditions during the vegetation period. The interaction between genotype and location determined the intensity of potential yield.

The main characteristics of examined genotype and of a line were as follows: Lara had the following properties: short spike, few grains per spike, and a small thousand kernel weight. A better grain yield occurred in case of a thick stand. In both years, the genotype Lara showed better adaptability in Donji Miholjac than in Kutjevo. Unlike Lara and other genotypes, Lenta was characterized by the longest stem, good adaptability, thick stand, the highest biological yield, and high and stable grain yield. The genotype Kruna was with regard to the grain yield and examined components of the grain yield very similar to Lara. The genotype Fiesta had a typical high stem, high sink capacity, which was reflected in longer spikes, higher number of grains per a spike and a higher thousand kernel weight. Even in case of a widely spaced stand, it had high biological yield and high grain yield. The line AG-45 had the lowest stem and high biological yield and grain yield under conditions of a thicker stand. The genotype Perla was the most stable genotype concerning the most important components of the grain yield, but it had poorer adaptability in Donji Miholjac than in Kutjevo.

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ABSTRAKT

Variabilita složek výnosu zrna u vybraných nových genotypů ozimé pšenice (*Triticum aestivum* L.)

Sledovali jsme variabilitu složek výnosu zrna u vybraných nových genotypů pšenice (Lara, Lenta, Kruna, Fiesta, Perla a jedna linie AG-45). Rozbor složek výnosu zrna u těchto genotypů a linie AG-45 jsme realizovali během dvouletého výzkumu (1997/1998 a 1998/1999) na dvou odlišných lokalitách. Zjistili jsme významné rozdíly mezi jenotlivými genotypy, lokalitami a ročníky. V prvním pokusném roce (1997/1998) existovala vysoce kladná korelace téměř mezi všemi složkami výnosu zrna. Nejvýznamnější korelaci jsme zaznamenali mezi počtem zrn na klas a výnosem zrna. V druhém pokusném roce (1998/1999) jednotlivé složky nevykazovaly statisticky významnou korelaci s výnosem zrna. Výnos zrna u sledovaných genotypů byl významně závislý na počtu zrn na klas, na hmotnosti zrn v klasu a na agroekologických podmínkách během vegetačního období, přičemž výši potenciálního výnosu určovaly interakce mezi genotypy, lokalitou a ročníkem. Největší rozdíly mezi sledovanými genotypy ozimé pšenice jsme zaznamenali u výšky stébla a délky klasu.

Klíčová slova: *Triticum aestivum* L.; genotyp; složky výnosu zrna; stéblo; klas; zrno; biologický výnos; zemědělský výnos

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