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GRAIN FILLING PARAMETERS AND YIELD COMPONENTS IN WHEAT

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Grain yield of wheat (*Triticum aestivum* L.) is influenced by number of grains per unit area and grain weight, which is result of grain filling duration and rate. The aim of the study was to investigate the relationships between grain filling parameters in 4 wheat genotypes of different earliness and yield components. Nonlinear regression estimated and observed parameters were analyzed. Rang of estimated parameters corresponds to rang of observed parameters. Stepwise MANOVA indicated that the final grain dry weight, rate and duration of grain filling were important parameters in differentiating among cultivar grain filling curves. The yield was positively correlated with number of grains/m^2, grain weight and grain filling rate, and negatively correlated with grain filling duration. Correlation between grain weight and rate of grain filling was positive. Grain filling duration was negatively correlated with grain filling rate and number of grains/m^2. The highest yield on three year average had medium late Mironovska 808, by the highest grain weight

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and grain filling rate and optimal number of grains/m^2 and grain filling duration.

Key words: wheat, grain filling, yield components

INTRODUCTION

Grain yield of wheat (*Triticum aestivum* L.) depends on two components which are formed during successive stages of the plant ontogeny. The potential number of grains is determined from initiation of floral development to anthesis (FISCHER, 1985), while the final grain weight can be expressed as a function of grain filling duration and rate (MOU *et al.*, 1994). Grain yield can be improved by understanding the interrelationships among yield components, yield, and duration of individual phenological stages and rate of dry matter accumulation.

Although several authors found, besides genotypic, significant influence of environmental factors on grain filling parameters (GEBEYEHOU *et al.*, 1982, BRUCKNER and FROHBERG, 1987), genetic variability is detected for both grain filling duration and rate (HUNT *et al.*, 1991, DARROCH and BAKER, 1995) and can be utilized for breeding. Temperature is the most important environmental factor affecting grain filling parameters and grain weight (CALDERINI *et al.*, 2001).

Genotype adaptability on certain environmental conditions depends a lot of the anthesis date. Genetic control of this trait is complex and depends of *Vrn*, *Ppd* and *earliness per se* genes (WORLAND, 1996).

The study was undertaken to investigate the influence of grain filling parameters on yield components and yield in four wheat genotypes differing in earliness.

MATERIAL AND METHOD

Four wheat genotypes differing in earliness were used in this study: extra early Vrn 6, medium early Saitama 27, medium late Mironovska 808 and late Elkorn. The trial was conducted in three years (2000, 2001 and 2002) at the experimental field Rimski Šančevi, Research Institute of Field and Vegetable Crops, Novi Sad. The standard agrotechnic procedures were applied and the plot areas were 5m^2, sown in four replications. Rimski Šančevi meteorological station data (temperature, precipitation) were used.

Random samples of 20 spikes per plot were harvested and selected in four replications. 10 grains from the middle of spikes were removed, oven dried at 80^{o}C for 24h and weighed. Sampling started 14 days after anthesis and continued at 7 to 2 days intervals until maturity. Accumulated growing degree days (GDD) from anthesis were used instead time units and were calculated as a sum of average daily temperatures (DUGUID and BRÛLÉ BABEL, 1994).

The data from each plot were fitted by nonlinear regression to a logistic curve (DARROCH and BAKER, 1990) and parameters W (estimated final grain dry weight, mg), R (estimated maximum grain filling rate, mgGDD^{-1}) and T (estimated grain filling duration, GDD) were calculated. The data were analyzed by stepwise MANOVA method described by KEULS and GARRETSEN (1982) in order to determine which of the estimated parameters is the most important in characterizing the grain filling curves.

The following observed traits were first analyzed by ANOVA: final grain dry weight (M, mg), average grain filling rate (IN, mgGDD^{-1}), grain filling duration (D, GDD), number of grains/m^2 (NG) and yield (Y, kg/m^2). IN was expressed as a ratio of M and D. LSD test values and correlation coefficients were calculated.

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RESULTS AND DISCUSSION

Combined ANOVA of three trials indicated significant differences between genotypes and environments regarding all analyzed observed and nonlinear regression estimated parameters (Table 1.). Genotype/environment interactions were also significant, except for number of grains/m^2 and yield.

Table 1. *Three year average values of estimated final grain dry weight (W, mg), estimated max grain filling rate (R, mgGDD^{-1}), estimated grain filling duration (T, GDD), observed final grain dry weight (M, mg), observed average grain filling rate (IN, mgGDD^{-1}), observed grain filling duration (D, GDD), number of grains/m^2 (NG) and yield (Y, kg/m^2) in four wheat genotypes of different earliness*

Genotype	W	R	T	NG
Vrn 6	40,4 a	0,1092 a	639 a	24884 a
Saitama 27	33,3 b	0,1187 ab	535 b	34889 b
Mironovska 808	48,8 c	0,1372 b	600 ac	29819 ab
Elkorn	45,2 d	0,1243 ab	577,5 bc	29018 ab
Mean	41,9	0,1224	588	29652
	M	IN	D	Y
Vrn 6	40,2 a	0,0451 a	901 a	1,01 a
Saitama 27	32 b	0,0429 a	763 b	1,12 ab
Mironovska 808	47,6 c	0,0597 b	802 b	1,42 b
Elkorn	41,9 a	0,0538 b	788,5 b	1,2 ab
Mean	40,4	0,0504	813,5	1,19

a – e Values within columns followed by the same letter do not differ significantly at the 0.05 level of probability according to LSD test

The growing season of 2000 was warm and dry. Sum of temperatures in May and June was 1214.5^{o}C and sum of precipitations for the same period was only 67 mm. May and June of 2001 were cooler (sum of temperatures was 1098.5^{o}C) and extremely wetter (308 mm) compared with 2000 and 2002. It caused an interruption of grain filling and we marked this environment as unfavorable. Weather conditions during grain filling period were common for our region in 2002. Sum of precipitation was 114 mm and sum of temperatures was 1245°C.

The logistic curve provided a good fit to the grain filling data in all cases. The smallest R^2 value was 0.79, and for 40 of 48 curves R^2 values exceeded 0.91. For each environment was used the method of stepwise MANOVA in order to determine the smallest set of estimated variables that contribute information to genotypic grain filling curves. All three variables (W, R, T) are found to be important in differentiating among genotype grain filling curves in all environments. Variable with the smallest λ value in 2000 and 2002 was the final grain dry weight, and maximum grain filling rate was the most important variable in unfavorable 2001 (Table 2.). The highest significance of R in 2001 is probably caused by delayed maturity. All genotypes had enough time to fill the grains, which increased the significance of differences among grain filling rates.

Both estimated and observed grain filling parameters had similar ranking between genotypes, but the logistic equation overestimated the final grain dry weight and underestimated the duration of grain filling (Table 1.), which is probably a consequence of the differences in the measurement methods. Similar results are reported by DUGUID and BRÛLÉ BABEL (1994).

Table 2. *Determination of the smallest set of estimated variables (final grain dry weight (W), maximum rate (R) and duration (T) of grain filling) required to completely characterize the grain filling curves in four wheat genotypes of different earliness*

environment	cond. set	λ	df	F	final set
2000	W	0,047042	3,12	81,03**	
	T \ W	0,025105	3,11	19,47**	
	R \ WT	0,422523	3,10	4,56*	W, T, R
2001	R	0,172209	3,12	19,23**	
	W \ R	0,460905	3,11	12,54**	
	T \ RW	0,371529	3,10	5,64*	R, W, T
2002	W	0,007807	3,12	508,37**	
	R \ W	0,539388	3,11	1,33 ns	
	T \ W	0,298962	3,11	3,04 ns	
	RT \ W	0,011912	6,20	249,12**	W, R, T

cond. set – conditional set, λ – Wilks' λ criterion, df – degrees of freedom, ns, *, ** - insignificant and significant at the 0,05 and 0,01 level of probability, respectively

Correlation coefficients were calculated for observed parameters in order to determine interrelationships among grain filling parameters, yield components and yield. Yield was positively correlated with final grain dry weight, number of grains/m^2 and grain filling rate. Negative correlation of yield and grain filling duration is probably caused by negative link between number of grains/m^2 and duration of dry matter accumulation. Final grain dry weight was positively correlated with grain filling rate, and rate and duration of dry matter accumulation were in negative correlation (Table 3.), similar to results obtained by several authors (e.g. CALDERINI and REYNOLDS, 200; KOBILJSKI *et al.*, 2000).

Table 3. *Correlation coefficients between observed final grain dry weight (M), observed average grain filling rate (IN), observed grain filling duration (D), number of grains/m^2 (NG) and yield (Y) in four wheat genotypes (three year average)*

	IN	D	NG	Y
M	0,88 **	-0,10 ns	-0,17 ns	0,45 **
IN		-0,55 **	0,06 ns	0,57 **
D			-0,42 **	-0,41 **
NG				0,79 **

ns, ** - insignificant and significant at the 0,01 level of probability, respectively

The highest yield on three year average had medium late cultivar Mironovska 808, with the highest final grain dry weight and grain filling rate, optimal number of grains/m^2 and optimal grain filling duration (Table 1.). Yields of medium early Saitama 27 and late Elkorn did not differ significantly, which implies, considering their significant differences in yield components and grain filling parameters, various possibilities for achievement of high yields. High grain filling rate is recommendable because of his strong positive influence on final grain dry weight, but not necessary, since lighter grains can be compensated by more grains/m^2. Similar results reported KOBILJSKI *et al.* (2000). Balanced relations among yield components and grain filling parameters are much more important than their high values.

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PARAMETRI NALIVANJA ZRNA I KOMPONENTE PRINOSA PŠENICE

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I z v o d

Prinos pšenice (*Triticum aestivum* L.) određuju broj zrna po jedinici površine i masa zrna, koja je rezultat dužine i intenziteta nalivanja zrna. Ogled je izveden u cilju ispitivanja veza parametara nalivanja zrna 4 genotipa pšenice različitog vremena stasavanja i komponenti prinosa. Analizirani su nelinearnom regresijom procenjeni i eksperimentalno utvrđeni parametri nalivanja zrna. Rang procenjenih odgovara rangu eksperimentalno utvrđenih parametara. Stepwise MANOVA-om su kao značajni parametri koji uslovljavaju razlike među krivama nalivanja zrna analiziranih genotipova izdvojeni masa zrna, intenzitet i dužina nalivanja zrna. Zabeležena je pozitivna korelacija prinosa i broja zrna/m^2, mase zrna i intenziteta nalivanja zrna, kao i negativna korelacija sa dužinom nalivanja zrna. Između mase zrna i intenziteta nalivanja zrna je utvrđena pozitivna korelacija. Dužina nalivanja zrna je bila u negativnoj korelaciji sa intenzitetom nalivanja zrna i brojem zrna/m^2. Najveći prinos je u trogodišnjem proseku ostvarila srednje kasna Mironovska 808, sa najvećim intenzitetom nalivanja i masom zrna i optimalnim brojem zrna/m^2 i dužinom nalivanja zrna.

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