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OBSERVED DURATION AND AVERAGE AND MAXIMUM GRAIN FILLING RATES IN WHEAT GENOTYPES OF DIFFERENT EARLINESS

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Grain yields of wheat (*Triticum aestivum* L.) are influenced partly by final grain dry weight, which is largely determined by the rate and duration of the grain filling process. A study was undertaken to compare the observed final grain dry weight of five groups of wheat genotypes differing in earliness (extra early, medium early, medium late, late and a control group of high yielding NS cultivars) with the observed duration and average and maximum rates of grain filling in two different environments. Correlation coefficients were used to determine which grain filling parameter had more influence on final grain dry weight. In an environment common for our country (2002), final grain dry weight was strongly positively correlated with the average and maximum rates and strongly negatively correlated with the duration of grain filling. The medium late and control groups had the highest final grain dry weights. Correlations between final grain dry weight and the duration and average rate of grain filling were positive in an unfavorable environment (2001). The NS cultivars and extra early genotypes had the highest final grain dry weights. The rate and duration of grain filling are usually negatively correlated. The influence of grain filling parameters on final grain dry weight

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is not the same in different environments, so the ability of the genotype to compensate for the low grain filling rate with grain fill prolongation in unfavorable environments might be more important. The observed average grain filling rate is probably more important as a parameter for describing these processes than the maximum one.

Key words: wheat, grain filling duration, grain filling rate

INTRODUCTION

Grain yield of wheat (*Triticum aestivum* L.) is a complex trait determined by number of grains per unit area and grain weight (CALDERINI and REYNOLDS, 2000). Potential number of grains is determined in early stages of plant development (SIDDIQUE *et al*., 1989) and the yield in after anthesis period depends on grain weight (WHAN *et al*., 1996), which is a result of grain filling process. Grain filling can be described by two parameters: duration and rate (MOU *et al*., 1994).

The most conspicuous environmental factor affecting grain weight is temperature (CALDERINI *et al*., 2001), as in the period preceding anthesis (KOBILJSKI and DENČIĆ, 1998), as during the grain filling (WARDLAW and MONCUR, 1995). The link between grain filling parameters (rate and duration) is generally accepted as inverse (HOUSLEY *et al*., 1982): faster accumulation of temperature units reduces grain filling duration and increases grain filling rate (JOHNSON and KANEMASU, 1983). Above certain temperature threshold rapid dry matter accumulation cannot compensate for negative effects of reduced grain filling duration, which results in lighter grains at maturity (AL KHATIB and PAULSEN, 1984).

Genetic variability among wheat cultivars exists for both duration and rate of grain filling (DARROCH and BAKER, 1990). However, opinions about relative importance of grain filling parameters for grain weight are separated. Several authors (eg. BRUCKNER and FROHBERG, 1987) found significant correlation between grain weight and rate of grain filling. On the other hand, others (eg. SPIERTZ *et al*., 1971) reported positive associations between grain filling duration and grain weight. GEBEYEHOU *et al*. (1982) found positive connections between both grain filling parameters and grain yield. Different attitudes are probably connected with different environments in which the trials were conducted.

Quadratic (BRUCKNER and FROHBERG, 1987) and cubic (GEBEYEHOU *et al*., 1982) equation, linear regression (VAN SANFORD 1985) and multivariate analysis of nonlinear regression estimated parameters (DARROCH and BAKER, 1990) were more or less effective statistical methods used in efforts to describe grain filling. In attempt to get the most realistic picture about situation in field, we decided to use observed final grain dry weight and observed rate and duration of grain filling.

A study was undertaken to compare the observed final grain dry weight of five groups of wheat genotypes differing in earliness with the observed duration and average and maximum rates of grain filling.

MATERIALS AND METHODS

The trial was conducted at the experimental field Rimski Šančevi, Institute of Field and Vegetable Crops, Novi Sad, in 2001 and 2002. The plot areas were 5m^2, sown in a four replications. The standard agrotechnic procedures were applied. Rimski Šančevi meteorological station data vere used. Analysed genotypes were selected in five groups: extra early (Vrn 7, Vrn 8, Vrn 9), medium early (Lerma Rojo, Inia 66, Argentina 80/5216), medium late (Bankut 1205, Phoenix, Odeska 51), late (F 54 70, Purdue 5392, Stepnjačka 30) and control group of high yielding NS cultivars (Pobeda, Renesansa, Evropa 90, Sonata).

Sampling was initiated 14 days after anthesis and continued at 7 days intervals in first 3 weeks, and approximately 2 days intervals after, until maturity (13% moisture in grain). Random samples of 20 spikes per plot were harvested on each sampling date, selected in four replications. 10 grains from the middle of each of the 20 spikes were removed and oven dried at 80^{o}C for 24h. The grains were weighed before and after drying.

Observed final grain dry weight (M), observed maximum grain filling rate (IN_{max}), observed average grain filling rate (IN_{sr}) and observed duration of grain filling (D) were analysed. Grain filling rate was calculated as ratio of final grain dry weight and grain filling duration and it is expressed in mg dry matter $^oC^{-1}$ grain^{-1}. Instead of time units, accumulated growing degree days (gdd) from anthesis were used. Gdd were calculated as a summ of daily degree days (T_n), which was determined by: $T_n = \{(T_{max} + T_{min})/2\}T_b$, where T_{max} and T_{min} are maximum and minimum daily temperatures, and T_b is the base temperature (0^{o}C). Below the base temperature plants are unable to develop (DUGUID and BRÛLÉ BABEL, 1994).

The data were first analysed by ANOVA to establish if there are differences between genotypes considering analysed traits. Correlation coefficients (HADŽIVUKOVIĆ, 1991) were used to determine which grain filling parameter had more influence on final grain dry weight.

RESULTS AND DISCUSSION

Analysis of variance conducted on individual trials showed significant group differences for all observed grain filling parameters in both environments. Combined ANOVA of two trials indicated significant differences between groups, environments and significant group/environment interactions for all parameters. The only exception was nonsignificant group/environment interaction for D.

Table 1. Sum of temperatures (°C), average daily temperature (°C) and sum of precipitation (mm) in May and June in 2001 and 2002 (Rimski Šančevi meteorological station)

Year	2001	2002
Sum of temperatures	1098.5	1245
Average daily temperature	18	20.4
Sum of precipitation	308	114

The trials were conducted in two very different environments, which causes great deal of different connections between analysed traits: in 2001 grain filling process was interrupted by low temperatures and unusual high sum of precipitation. We can mark this year as environment unfavorable for grain filling. The weather conditions in next year were common for our region (Table 1).

Correlation coefficients were used to determine which grain filling parameter had more influence on final grain dry weight. In unfavorable environment correlations between final grain dry weight and the duration and average rate of grain filling were positive. Extra early genotypes and NS cultivars had the highest final grain dry weights, and the grains of late genotypes were the lightest. In an environment common for our region final grain dry weight was positively correlated with the average and maximum rates and negatively correlated with the duration of grain filling. The highest final grain dry weights had the medium late and control group, and the lighest grains had extra early genotypes. Regardless of environments, rate and duration of grain filling are negatively correlated, similar to results obtained by several authors (eg. KOBILJSKI *et al*., 2000). Correlation coefficients of maximum and average grain filling rate are positive (Figure 1).

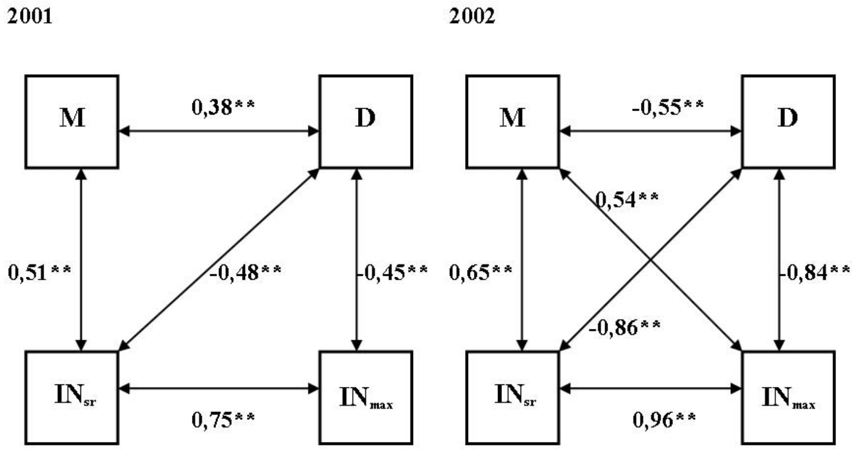

Figure 1. Correlation coefficients between observed final grain dry weight (M), grain filling duration (D), maximum grain filling rate (INmax) and average grain filling rate (INsr) for all analysed genotypes in 2001 and 2002 (** significant at 0,01 level of probability)

Early anthesis enable long grain filling. In the first year of experiment all genotypes, regardless of earliness, had enough time to fill the grains, and the process was not suddenly terminated. Unusually high sum of precipitation and low temperatures interrupted grain filling and causes its low rates. High grain weights of extra early genotypes in regard to others were connected with long grain filling duration and, on the other hand, decreased influence of grain filling rate. Nevertheless, the same grain weights achieved NS cultivars, with shorter duration and very high rates of grain filling. In our conditions extra earliness is not recommended: extra early genotypes are the only group whose grain filling rate was not increased in the next season by shorter grain filling caused by rapid accumulation of thermal units (Table 2).

Table 2. Observed final grain dry weight M (mg), maximum grain filling rate INmax (mg dm °C-1 grain-1), average grain filling rate INsr (mg dm °C-1 grain-1) and grain filling duration (gdd) in four groups of genotypes of different earliness and control group of high yielding NS cultivars

Environments	Groups	M	IN_{max}	IN_{sr}	D
2001					
	extra early	40.7	0.0624	0.0508	971
	medium early	35.7	0.0606	0.0457	985
	medium late	36.1	0.0761	0.0553	898.5
	late	34.1	0.0694	0.0529	900.5
	NS cultivars	40.6	0.0733	0.0572	909
2002					
	extra early	37.8	0.0624	0.053	855.5
	medium early	41.3	0.0705	0.0599	837
	medium late	47.9	0.083	0.0719	789.5
	late	39.1	0.08	0.0675	790
	NS cultivars	47.9	0.0809	0.0721	782

It seems that the average grain filling rate is more important parameter for describing grain filling than the maximum one. Average grain filling rate was positively correlated with final grain dry weight in both environments. Also, the genotype Bankut 1205 had the highest maximum and the lowest average grain filling rate in group of medium late genotypes in both environments, contrary to usual positive link of those two parameters. It is probably connected with sudden leaf area loss and results in lightest grains in group. In addition, control group had the highest average grain filling rate in both environments and the lowest difference between maximum and average grain filling rate in group of genotypes with short dry matter accumulation (medium late, late, NS cultivars) (Table 2). This indicated that, for high final grain dry weight, besides high grain filling rate, of great significance is the graduation of dry matter accumulation.

Because of importance of avoiding terminal dry and temperature stress, and need to provide enough time for grain filling, medium earliness is in our environment recommended for achievement of high grain dry weight. This indicates relatively short grain filling with high rate.

The influence of grain filling parameters on final grain dry weight is not the same in different environments, so the ability of the genotype to compensate for the low grain filling rate with grain fill prolongation in unfavorable environments might be more important. This ability is noticed only in case of medium early genotype Lerma Rojo.

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EKSPERIMENTALNO UTVRĐENA DUŽINA TRAJANJA, PROSEČNI I MAKSIMALNI INTENZITET NALIVANJA ZRNA GENOTIPOVA PŠENICE RAZLIČITE RANOSTASNOSTI

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I z v o d

Prinos zrna pšenice (*Triticum aestivum* L.) je delom uslovljen krajnjom masom suvog zrelog zrna, koja je u velikoj meri određena intenzitetom i dužinom trajanja procesa nalivanja zrna. Cilj istraživanja je poređenje eksperimentalno utvrđene krajnje mase suvog zrelog zrna 5 grupa genotipova pšenice različite ranostasnosti (ekstra rane, srednje rane, srednje kasne, kasne i kontrolna grupa najprinosnijih NS sorti) sa eksperimentalno utvrđenim prosečnim i maksimalnim intenzitetom, te dužinom trajanja nalivanja zrna u različim uslovima sredine. Korelacioni koeficijenti su upotrebljeni u pokušaju da se odredi koji parametar nalivanja zrna ima veći uticaj na krajnju masu suvog zrelog zrna. U kod nas uobičajenim uslovima sredine (2002.) je krajnja masa suvog zrelog zrna bila u jakim pozitivnim vezama sa prosečnim i maksimalnim intenzitetom i u jakoj negativnoj vezi sa dužinom trajanja nalivanja zrna. Najveće krajnje mase suvih zrelih zrna postigli su srednje kasni i genotipovi kontrolne grupe. Korelacije između krajnje mase suvog zrelog zrna i dužine trajanja, te prosečnog intenziteta nalivanja zrna su bile značajno pozitivne u nepovoljnim uslovima sredine (2001.). Novosadske sorte i ekstra rani genotipovi su imali najveće mase suvih zrelih zrna. Intenzitet i dužina trajanja nalivanja zrna su obično u negativnoj korelaciji. Uticaj parametara nalivanja zrna na krajnju masu suvog zrelog zrna nije jednak u različitim uslovima sredine, tako da bi mogla biti bitnija sposobnost genotipa da u nepovoljnim uslovima sredine niske intenzitete nalivanja zrna nadomesti produženjem akumulacije suve materije. Za opisivanje ovih procesa bi prosečni intenzitet nalivanja zrna mogao biti važniji parametar od maksimalnog.

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