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# Breeding Potential of Durum Wheat Landraces from Jordan III. Rate and Duration of Grain Fill

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## ABSTRACT

Grain fill of durum wheat coincides with terminal drought and high temperature stress in the Mediterranean region. Genotypic variation for rate and duration of grain fill was studies in 250 landrace durum wheat genotypes collected in Jordan. A quadratic polynomial was used to describe the relationship between kernel weight and accumulated growing-degree-days from anthesis to maturity. Fitted curves were employed to estimate rate and duration of grain fill. Genotypic differences were found for both traits. Genotypes with high grain filling rate and high kernel weight were identified. Based on grain yield per spike, spikelet fertility, 1000-kernel weight, rate and duration of grain fill, four clusters were identified in this germplasm collection. Correlations between these traits were inconsistent across these clusters, however, rate and duration of grain fill were not correlated across clusters, suggesting that high rate and short duration of grain fill can be combined in one genotype. Canonical discriminant analysis confirmed univariate analysis of variance and resulted in 95% correct classification of genotypes.

## INTRODUCTION

Final grain weight is one of the most important yield components in wheat (*Triticum* spp.). It is determined, to a large extent, by rate and duration of grain fill (Gallagher *et al.*, 1976; Jones *et al.*, 1979). Wheat grown under arid and semiarid Mediterranean environments often undergoes prolonged periods of water and heat stress during grain fill (Acevedo, 1991). Grain yields of durum wheat in Jordan are more closely associated with variation in precipitation than with variation in temperature (Jaradat, unpublished data). After seed number has been determined, cereal grain yields become proportional to kernel weight (Wiegand and Cuellar, 1981), which is a function of the rate and duration of grain fill (Gallagher *et al.*, 1976). Rate of grain fill, which is dependent upon the number of endosperm cells formed during the first two weeks after anthesis (Acevedo, 1991; Lengile and Chevalier, 1992), increasees only moderately with increased temperature, but duration of grain fill has a strong negative response to increasing temperature (Bruckner and Frohberg, 1987; Wiegand and Cuellar, 1981) and a strong positive response to available soil moisture (Bruckner and Frohberg, 1987; Wong and Baker, 1986).

Wiegand and Cuellar (1981) suggested that genetic variability in grain fill rate should be searched for and exploited in wheat improvement programs because genetic factors largely determine grain fill rate and environmental factors largely determine grain fill duration. High rate and short duration of grain fill may contribute to higher kernel weights and yields in cultivars developed for short growing environments (Gebeyehou *et al.*, 1982) and environments prone to sever postanthesis stress (Wiegand and Cuellar, 1981) such like the Mediterranean environment.

Lengthening of the grain fill period through earlier heading and flowering (Acevedo, 1991; Wong and Baker, 1986) and identification and incorporation of drought tolerance traits that would allow photosynthesis and grain growth to continue under drought (Bruckner and Frohberg, 1987) are alternative strategies for achieving higher kernel weights and yields under drought stress. Early maturity is a desirable trait in cereal crops growing under arid and semiarid environments. Because efforts to reduce time to maturity often result in reduced grain yield (Wong and Baker, 1986), a thorough understanding of the developmental aspects of time to maturity may assist in developing early maturing cultivars with acceptable grain yield.

Landrace genotypes of durum wheat from Jordan have been evaluated for five developmental traits (Jaradat, 1991). These included days to booting, days to anthesis, days to heading, and days to maturity. Filling period was estimated as the difference between days to anthesis and days to maturity. Landrace genotypes with different combinations of early, medium and late days to heading, days to maturity and filling period were identified in the Jordanian material. Landrace genotypes with medium-late days to heading and along filling period gave the highest grain yields. A thorough understanding of the grain filling process in these genotypes may be very helpful in attempts to select or to breed for increased grain yields and early maturity in durum wheat under the drough-prone Mediterranean environment.

The objectives of this research were to (1) evaluate genotypic variation for rate and duration of grain fill in a diverse set of landrace genotypes of durum wheat collected from Jordan and (2) examine relationships between estimated grain fill parameters and genotypic productivity.

## MATERIALS AND METHODS

A total of 250 landrace genotypes, representing all possible combinations of early, medium and late days to heading, days to maturity and filling period, were used in this study. The local durum wheat cultivar, Hourani 27, was used as a check. Each landrace genotype was grown on a 1-$m^2$ plot, with two replicates. The local check was planted in every tenth plot. The experiment was conducted at the Research Station of Jordan University of Science and Technology (32.50 N, 36.00 E, 550 m above sea level).

At anthesis, the first 60-70 spikes that extrude anthers from central florets were tagged in each plot. Samples of five tagged spikes were collected twice a week from each plot beginning one week after anthesis and continued past harvest maturity. Each sample was oven dried at 80 C, then hand threshed. Number of spikelets per spike, grain dry weight and kernel number were determined for each spike and the latter two were used to calculate average kernel weight. Number of fertile florets per spikelet were estimated using number of spikelets and number of seed per spike. Accumulated growing-degree-days (GDD) from anthesis was used as a time scale during the grain fill period because the rate of wheat development is determined largely by temperature (Bruckner and Frohberg, 1987; Wiegand and Cuellar, 1981). A base temperature (Tb) of 5 C was used to calculate daily degree-days as follows:

$Tn=(Tmax + Tmin)/2 - Tb$, where Tmax and Tmin are daily maximum and minimum temperature, respectively. For each landrace genotype, the relationship between grain weight and accumulated GDD from anthesis was described by fitting a quadratic polynomial of the form: $W=a+bt+ct^2$, where W is grain weight (mg), t is time in GDD, and a, b and c are regression coefficients (Darroch and Baker, 1990). Rate of grain fill was expressed as mg $kernel^{-1} GDD^{-1}$, and duration of grain fill as accumulated GDD from anthesis to physiological maturity. Time to physiological maturity was defined as the time (in GDD) required for the attainment of maximum dry weight (Darroch and Baker, 1990).

A K-means clustering procedure was employed to cluster the 250 landrace genotypes into a maximum number of clusters significantly different for all measured variables and estimated parameters in this study. Correlation analyses were carried out, for each of 4 clusters identified in the previous step, and were used to examine relationships betweed measured variables and estimated parameters. A canonical discriminant analysis was performed using clusters as the classification criterion, then data was plotted according to the first two functions in this analysis. SAS procedures (SAS Institute, 1985) wereused for statistical analysis.

## RESULTS AND DISCUSSION

The quadratic polynomial used to describe grain growth during the grain filling period, provided an excellent description of grain fill in this germplasm collection.

Table 1. Mean separation among four clusters of durum wheat landrace genotypes, collected from Jordan, for grain yield (g per spike), spikelet fertility (SF), 1000-kernel weight (TKWT, mg), growing degree days (GDD) and rate of grain fill (R, mg $kernel^{-1}$ $GDD^{-1}$).

| Variable | Cluster 1 | Cluster 2 | Cluster 3 | Cluster 4 |
|---|---|---|---|---|
| Number of acc'ns | 91 | 69 | 19 | 71 |
| Grain Yield | 1.62b* | 1.42c | 1.55b | 1.73a |
| Spikelet fertility | 2.01a | 1.68c | 1.89b | 2.02a |
| 1000-kernel weight | 47.1b | 50.1a | 52.2a | 40.7c |
| Predicted 1000-kwt | 48.3 | 51.8 | 50.7 | 43.2 |
| Growing Degree Days | 750c | 789b | 720d | 810a |
| Rate of grain fill ($R \times 10^2$) | 4.7c | 4.9b | 5.3a | 4.2d |

* Cluster means, within each trait, followed by the same letter do not differ significantly (Tukey, 0.05)

Table 2. Pairwise phenotypic correlation coeffecients among 6 traits measured on 4 clusters of durum wheat landrace genotypes from Jordan.

| | R | GDD | FF | TKWT | GY |
|---|---|---|---|---|---|
| R | 1 | .048ns* | .183ns | .694 | .548 |
| | 1 | .005ns | .450 | .365 | .602 |
| GDD | .037ns | 1 | .001ns | .034ns | .015ns |
| | .102ns | 1 | -.061ns | -.081ns | -.023ns |
| SF | -.050ns | .230 | 1 | .154ns | .845 |
| | .387 | .101ns | 1 | .272 | .882 |
| TKWT | .314 | .172ns | .562 | 1 | .517 |
| | .675 | .682 | .448 | 1 | .447 |
| GY | .207 | .331 | .892 | .833 | 1 |
| | .633 | .236 | .873 | .682 | 1 |

* All pairwise correlation coeffecients were highly significant (P<0.001), unless otherwise indicated. Clusters 1&2 above diagonal, clusters 3 & 4 below diagonal. See Table 1 for abbreviations.

Coefficient of determination ($R^2$) values (range 0.87 to 0.95) suggest that kernel weight and GDD data fit the model well. This conclusion is supported by earlier findings by Darroch and Baker (1990). Results of the analysis of variance and mean separation for GDD and rate of grain fill among all 4 clusters suggest that these two parameters were estimated with high precision. Another supporting evidence of this accuracy is the high correlation between actual and predicted 1000-kernel weight (r=0.93; P; see Table 1).

Landrace genotypes in Cluster 3 (n=19) had the fastest rate of GF and the heaviest kernels. Rate of grain fill ranged from .044 mg $kernel^{-1}$ $GDD^{-1}$ in cluster 4 to 0.052 mg $kernel^{-1}$ $GDD^{-1}$ in cluster 3 and averaged 0.047 mg $kernel^{-1}$ $GDD^{-1}$ across landrace genotypes. Duration of grain fill averaged 757 GDD and ranged from 720 in cluster 3 to 810 in cluster 4. These data indicate that substantial genotypic variation exists for both parameters within this germplasm collection. However, longer grain fill period may not be a promissing strategy to increase grain yield under the Mediterranean environment because high temperature during the grain fill period tends to stop grain growth prematurily and force wheat to physiological maturity (Sayed and Ghandourah, 1984; Bruckner and Frohberg, 1987).

Interrelationships between both parameters of grain fill and each of grain wieght/spike (GY), 1000-kernel weight (TKWT) and spikele fertility (SF) were expressed in terms of phenotypic correlations among their mean values (Table 2). Rate and duration of grain fill were not correlated across clusteres, suggesting that there is no genetic barrier to the simultaneous change of both in a breeding program. A supporting evidence was reported by Gebeyehou *et al.* (1982). Grain yield per spike was positively and

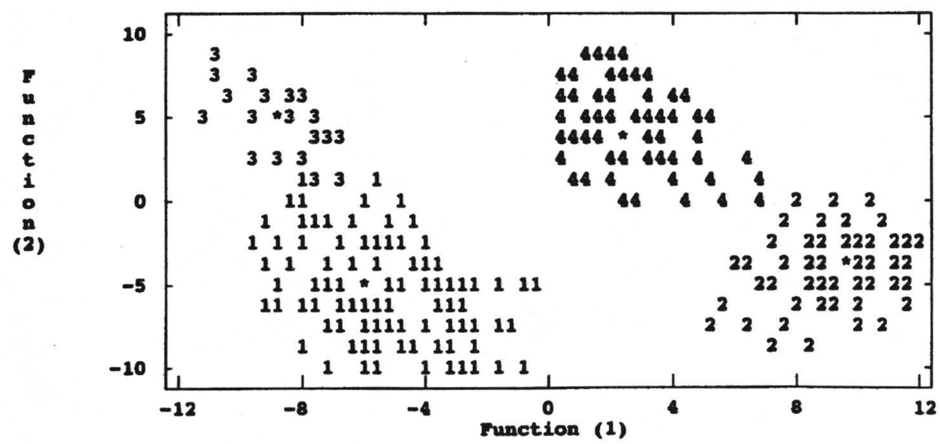


Figure 1. Canonical discrimination analysis of durum wheat landrace genotypes from Jordan (*cluster centroid).

significantly correlated with rate of grain fill in two of the four clusters (Table 2). However, associations of grain yield with 1000-kernel weight and with rate of grain fill were stronger across clusters, thus confirming earlier results in durum (Gebeyehou *et al.*, 1982) and bread wheat (Sayed and Ghandourah, 1984) especially under warm dry conditions, where grain filling duration was significantly correlated with maximum grain weight and with rate of grain filling. It can be postulated that high rate of grain fill with relatively short duration of grain fill appears to be a desirable risk-reducing pattern of grain fill in environments in which the growing season is shortened by terminal stress (Bruckner and Frohberg, 1987). Moreover, selection for higher rate of grain fill and kernel weight without lengthening grain fill duration could be possible. Rate, but not duration of grain fill, was positively and significantly correlated with 1000-kernel weight; however, the intensity of this association varied among clusters (Table 2). This finding confirms results obtained by Bruckner and Frohberg (1987) where rate, but not duration, of grain fill was closely associated with kernel weight, and by May and van Sanford (1992) where kernel growth rate was significantly correlated with effective filling period (r=-0.35; P) in one breeding population, but not in another (r=-0.03; ns).

Canonical discriminant analysis produced a reduced dimension model to effectively indicate measured differences among clusters. It resulted in satisfactory discrimination (95% correct classifiacation) between clusters (Fig. 1). This analysis was based on grain yield per spike, spikelet fertility, 1000-kernel weight, duration and rate of grain fill. The first function was mainly associated with spikelet fertility, 1000-kernel weight and duration of grain fill, and explained 72% of total variance. The second function was mainly correlated with rate of grain fill and grain yield per spike and explained 24% of total variance.

Genetic variation exists in this germplasm collection for both rate and duration of grain fill. These results suggest that kernel weight can be improved simply because it was more closely associated with rate of grain fill than with duration of grain fill. Genotypes with high yield potential, high rate, and short duration of grain fill can be developed or selected from this germplasm collection.

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