African Crop Science Journal, Vol. 20, No. 1, pp. 31 - 37
Printed in Uganda. 
ISSN 1021-9730/2012 $4.00


# GRAIN-FILLING, CHLOROPHYLL CONTENT IN RELATION WITH GRAIN YIELD COMPONENT OF DURUM WHEAT IN A MEDITERRANEAN ENVIRONMENT

A. GUENDOUZ and K. MAAMARI
University Ferhat ABBAS, Setif, Department of Agronomy, Algeria
**Corresponding author's email address:** guendouz.ali@gmail.com

*(Received 4 September, 2011; accepted 2 February, .2012)*

## ABSTRACT

Durum wheat (*Triticum durum* Desf.) is one of the more widely cultivated crops in the Mediterranean basin, where drought is the main abiotic stress limiting its production. This study was conducted on the experimental site of station ITGC in Sétif, Algeria to determine the duration and velocity of filling and its relationships with yield components and chlorophyll content of ten durum wheat genotypes. The SPAD-502 was used to measure the amount of chlorophyll (Chl) in the leaf, which is related to leaf greenness, by transmitting light from light emitting diodes (LED) through a leaf at wavelengths of 650 and 940 nm. Grain yield was negatively correlated with number of days to heading (DH) and positively with velocity of filling. The beginning of active phase of grain filling corresponded to the beginning of the degradation of chlorophyll content. The velocity of grain filling was negatively correlated to the number of days to heading (DH). Changes in photosynthesis most closely paralleled changes in chlorophyll content. All these changes occurred during the period of grain filling.

*Key Words*: *Triticum durum*, velocity of filling

## RÉSUMÉ

Le blé dur (*Triticum durum* Desf.) est l'une des cultures les plus largement cultivées dans le basin méditeranéen où la sécheresse constitue une contrainte abiotique majeur à sa production. Cette étude était conduite sur le site expérimental de la station ITGC au Sétif, Algérie, pour déterminer la durée de la vélocité du remplissage et ses relations avec les composants du rendement et le contenu en chlorophylle de dix génotypes de blé dur. Le SPAD-502 était utilisé pour mesurer la quantité de la chlorophylle (Chl) dans la feuille en relation avec la verdure, en transmettant la lumiére des diodes émettrices de la lumiére (LED) à travers une feuille à des longueurs d'onde de 650 et 940 nm. Le rendement en grain était négativement corrélé avec le nombre de jours au *heading* (DH) et positivement corrélé avec la vélocité de remplissage. Le début de la phase active du remplissage de grains correspondait au début de la dégradation du contenu en chlorophylle. La vélocité du remplissage de grains était négativement corrélé avec le nombre des jours au *heading* (DH). Les changements en photosynthèse étaient paralléles en rapport avec les changements en contenu chlorophyllien. Tous ces changements étaient apparus durant la période du remplissage de grains

*Mots Clés: Triticum durum*, vélocité du remplissage

## INTRODUCTION

Durum wheat (*Triticum durum* Desf.) is one of the more widely cultivated crops in the Mediterranean basin, where drought is the main abiotic stress limiting its production (Royo *et al.*, 1998). Durum wheat is mostly grown under rainfed conditions, where drought and heat stress usually constrain yield during the grain filling period (Simane *et al.*, 1993).

The main effect of high temperatures during grain filling is to cause reduction of individual kernel mass (Wardlaw *et al*., 1980). Seed or grain filling, the final process associated with yield performance, is a crucial determinant of grain yield in cereal crops. Grain development of field crops is initially slow, but eventually enters a linear phase where growth rate is fast and then slows down toward maturity (Yoshida, 1981). In fact grain growth follows a sigmoid curve with a period of low accumulation of dry matter, a linear phase and finally a plateau (Triboi, 1990). The initial phase determines the number of cells of the endosperm; the importance of this phase is explained by the closely relationship between the final dry weight of grain and the number of cells in the endosperm (Macleod and Duffus, 1988).

During the linear phase dry matter is deposited in the cells of the endosperm (Singh and Jenner, 1982). This phase is characterised by two variables for weight of grain, namely, duration and speed of filling. The ripening of the grain is marked by a stop in accumulation of dry matter and a drop in moisture content of grain. Yoshida (1981) suggested that effective grain filling duration, where grain growth is linear, is more important than the duration of ripening from the date of heading to the time when maximum grain weight is attained. This is because most dry grain mass accumulates during the effective grain filling period. However, grain filling patterns frequently demonstrate genotypic variations in many cereal crops. The objective of this study was to determining the duration and velocity of filling and its relationships with yield components and chlorophyll content.

## MATERIALS AND METHODS

**Plant material and growth conditions.** A set of 10 genotypes of durum wheat (*Triticum durum* Desf**.**) (Table 1) were planted on 1 December 2008, in the experimental fields of ITGC, Sétif, Algeria (5°20'E, 36°8'N, 958 m above sea level). Genotypes were grown in a randomised complete block design with four replicates. Plots were 5 m × 6 rows with 0.20 m row spacing, sowing density was adjusted to 300 kernels $m^{-2}$. The soil at the experimental site is a rendzin, mollisol (Calcixeroll USDA) up to 0.6 m in depth. SULFAZOT fertiliser (26% N,12% S,120 kg $ha^{-1}$) was applied at tillage time to all plots. Weeds were removed chemicaly using TOPIC herbicide (0.75 L $ha^{-1}$) and GRANSTAR (15 g $ha^{-1}$). Rainfall during the whole growth cycle was 338.3 mm. During the period of grain filling, rainfall was nil and mean day temperatures varied between 17.2 and 27.8 °C.

**Agronomical and physiological measurements.** The number of days from sowing to heading (DH) was recorded. Five ears of the main shoot of each genotypes were harvested from flowering to physiological maturity, and dried in an oven at 80°C for 48 hr. The number and dry weight of grains were determined. Grain yield and its main components were estimated at harvest. The SPAD-502 was used to measure the amount of chlorophyll (Chl) in the leaf, by transmitting light from light emitting diodes (LED) through a leaf at wavelengths of 650 and 940 nm. SPAD meters have been used to estimate chlorophyll concentrations and infer nitrogen status of leaves of wheat, corn *(Zea mays* L.), and other plants (Wood *et al*., 1993; Blackmer and Schepers, 1995). Chlorophyll content measurements were carried out five times between flowering and the end of senescence on three flag leaves of each genotype. The five dates of assessments were expressed in sums of temperatures after flowering ($\Sigma t_1 - \Sigma t_5$) and the corresponding chlorophyll content values.

**Statistical analysis.** Data were analysed using SAS, version 9 (SAS Institute, 1987). The analysis of variance was performed for agronomical traits.

TABLE 1. Origin of the ten genotypes used in the study in Algeria

| Cultivar | Name | Origin |
|---|---|---|
| 1 | Bousselem | Algeria |
| 2 | Hoggar | Algeria |
| 3 | Oued Zenati | Algeria |
| 4 | Polonicum | Algeria |
| 5 | Waha | Algeria |
| 6 | Altar | Mexico |
| 7 | Dukem | Mexico |
| 8 | Kucuk | Mexico |
| 9 | Mexicali | Mexico |
| 10 | Sooty | Mexico |

Significant means were separated using Student-Newman-Keuls multiplr-range test. Linear correlation analysis was used to determine the relationships between the traits measured.

## RESULTS

Grain growth of all genotypes followed a sigmoid curve (Fig. 1). The duration of grain filling ranged between 20 days for Waha, to 28 days for Polonicum. Velocity of grain filling ranged between 1.14 mg $day^{-1}$ for Oued Zenati to 2 mg $day^{-1}$ for Mexicali (Table 2). Ranking of tested genotypes for all variables is illustrated in Table 3. Degradation of chlorophyll with time (expressed in the amount of temperature accumulated after flowering for each day) in the ten genotypes studied is illustrated in Table 4. Grain yield was not correlated to thousand-kernel weight, biomass and duration of grain filling, but there was a significant positive correlation between velocity of filling and grain yield (r = 0.63) (Table 5). A significant negative correlation was noted between grain yield and number of days to heading (DH) (r = -0.75). There was a negative relationship between duration of grain filling and velocity of filling, the latter variable was negatively correlated with the number of days to heading (DH) (r = -0.76). Thousand-kernel weight was negatively correlated with number of grains per spike and number of grains per m² (r = -0.82, r = -0.9 respectively); but was positively correlated to biomass; biomass was positively correlated to number of grains per spike. A significant positive correlation was found between number of grains per spike and grains per m². There was no significant correlation between chlorophyll content and all variables studied; however,

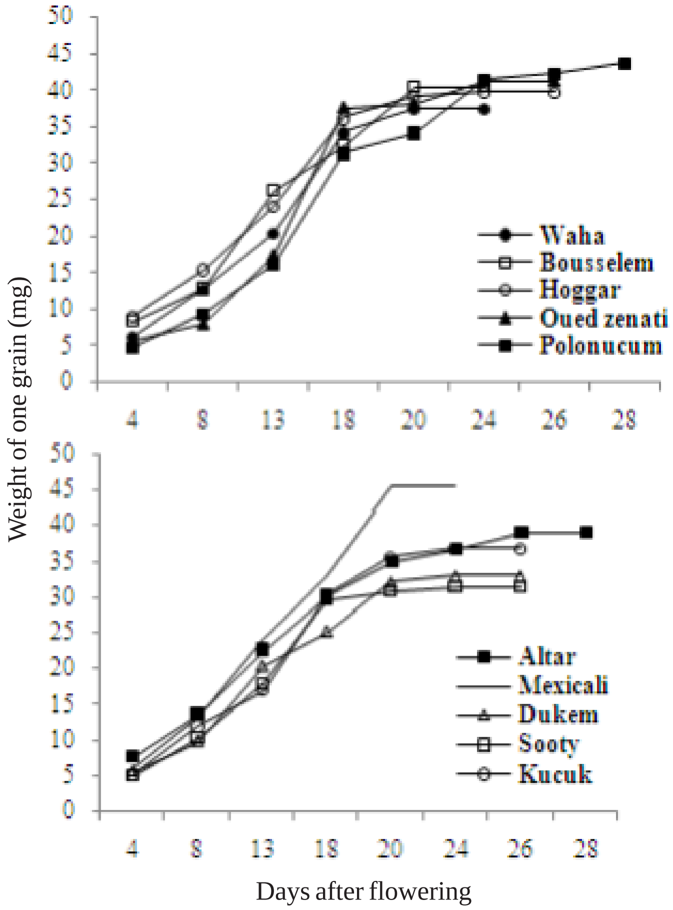


Figure 1. Evolution of grain filling (mg) of the ten genotypes tested in Algeria.

TABLE 2. Duration and velocity of grain filling for the ten genotypes tested in Algeria

| Genotype | DGF | Genotype | DGF | Genotype | VGF | Genotype | VGF |
|---|---|---|---|---|---|---|---|
| Waha | 20.00 | Altar | 26.00 | Waha | 1.27 | Altar | 1.46 |
| Bousselem | 20.00 | Mexicali | 24.00 | Bousselem | 1.82 | Mexicali | 2.00 |
| Hoggar | 26.00 | Dukem | 24.00 | Hoggar | 1.23 | Dukem | 1.37 |
| Oued Zenati | 26.00 | Sooty | 24.00 | Oued Zenati | 1.14 | Sooty | 1.17 |
| Polonicum | 28.00 | Kucuk | 24.00 | Polonicum | 1.26 | Kucuk | 1.38 |

DGF: Duration of grain filling (day); VGF: Velocity of grain filling (mg $day^{-1}$)

TABLE 3. Ranking of tested genotypes for grain yield (GY), biomass (Bio), thousand-kernel weight (TKW), number of grains per m² (NG $m^{-2}$) and number of grains per spike (NG $S^{-1}$)

| Genotype | GY (Qx $ha^{-1}$) | Biom (Qx $ha^{-1}$) | TKW (g) | NG $m^{-2}$ | NG $S^{-1}$ |
|---|---|---|---|---|---|
| OuedZenati | 25.5 (ab) | 91.05(a) | 47.8(e) | 6774.34(a) | 28.41(a) |
| Altar | 29.3 (ac) | 72.87(bca) | 37.7(bcd) | 9564.77(bc) | 35.23(bd) |
| Sooty | 26.5 (ab) | 69.12(c) | 30.2(a) | 10745.6(b) | 39.47(c) |
| Polonicum | 24.6 (ab) | 78.62(abc) | 41.9(d) | 8254.13(ac) | 33.96(bd) |
| Waha | 26.9 (ab) | 77.59(abc) | 28.9(a) | 11386.06(b) | 38.67(dc) |
| Dukem | 22.0 (b) | 62.37(c) | 29.2(a) | 10819.34(b) | 35.15(bd) |
| Mexicali | 31.9 (c) | 86.43(ab) | 35.1(abc) | 11045.47(b) | 35.33(b) |
| Kucuk | 26.5 (ab) | 75.56(abc) | 32.6(ab) | 11560.27(b) | 34.43(b) |
| Hoggar | 29.6 (ac) | 7462(abc) | 34.4(abc) | 11364.31(b) | 35.65(b) |
| Bousselem | 29.8 (ac) | 87.43(ab) | 39.2(cd) | 9687.81(bc) | 29.61(a) |

Means followed by the same latter are not significantly different at P<0.05 (Student-Newman-Keuls multiplr-range test)

TABLE 4. Degradation of chlorophyll content with time (expressed in sums of temperatures after flowering) for the ten genotypes (SPAD unit) in Algeria

| Genotype | Sums of temperatures after flowering (°C) | | | | | Mean |
|---|---|---|---|---|---|---|
| | 148.5 | 188.2 | 271 | 352.8 | 443.8 | |
| Oued Zenati | 47.20 | 44.13 | 38.70 | 07.67 | 5.17 | 28.57 |
| Altar | 50.97 | 45.87 | 37.23 | 06.13 | 5.57 | 29.15 |
| Sooty | 55.87 | 51.27 | 37.10 | 12.63 | 3.53 | 32.08 |
| Polonicum | 50.50 | 45.17 | 36.13 | 16.13 | 2.57 | 30.10 |
| Waha | 52.90 | 45.70 | 33.93 | 09.03 | 5.50 | 29.41 |
| Dukem | 53.60 | 49.63 | 33.33 | 17.80 | 2.50 | 31.37 |
| Mexicali | 53.80 | 51.73 | 45.67 | 06.83 | 4.80 | 32.57 |
| Kucuk | 47.63 | 45.10 | 35.47 | 12.63 | 4.90 | 29.15 |
| Hoggar | 52.83 | 49.30 | 33.20 | 23.73 | 1.83 | 32.18 |
| Bousselem | 47.43 | 45.03 | 42.23 | 14.93 | 1.70 | 30.27 |

TABLE 5. Correlations between agronomical and physiological variables

| | GY | Bio | TKW | NG $S^{-1}$ | NG $m^{-2}$ | VGF | DGF | Chl | DH |
|---|---|---|---|---|---|---|---|---|---|
| GY | 1 | | | | | | | | |
| Bio | 0.47 | 1 | | | | | | | |
| TKW | 0.07 | 0.71* | 1 | | | | | | |
| NG $S^{-1}$ | -0.04 | 0.66* | -0.82** | 1 | | | | | |
| NG $m^{-2}$ | 0.24 | -0.5 | -0.9*** | 0.7* | 1 | | | | |
| VGF | 0.63* | 0.37 | -0,01 | -0.2 | 0.22 | 1 | | | |
| DGF | -0.2 | -0.11 | 0.45 | -0.09 | -0.44 | -0.37 | 1 | | |
| Chl | 0.27 | -0.28 | -0.44 | 0.43 | 0.5 | 0.3 | 0.01 | 1 | |
| DH | -0.75* | -0.03 | 0.34 | -0.21 | -0.51 | -0.76* | 0.48 | 0.39 | 1 |

* $P<0.05$, ** $P<0.01$ and *** $P<0.001$

decline in chlorophyll content with time affected the final grain yield.

## DISCUSSION

Wheat individual grain weight depends on the rate and duration of grain filling. Under environmental stress, e.g. high temperatures after anthesis, grain yield reduceds due to a decline of single grain weight (Porter and Gawith, 1999). During grain filling, grain weight is reduced at a rate of 4 to 8% $°C^{-1}$ (Wardlaw *et al*., 1980). Water stress during grain filling does not affect the number of fertile tillers nor number of grains per $m^2$. Grain weight is, however, reduced (Hochman, 1982) due to a shortening of the grain filling period resulting from accelerated senescence.

A long duration of grain filling is often an indicator of photosynthetic activity optimum, but a high velocity of filling is indicative of water stress (Sofield *et al*., 1977). Gebeyehou *et al.* (1982) found that the duration of filling contributes much more than the velocity in the performance of grain yield. In contrast, Nass and Resier (1975) and Triboi *et al.* (1985) suggested that the effect of velocity on performance of grain yield is more important than the duration of grain filling. This corresponds with the results of our study. The velocity and duration of filling were related negatively but weakly (r = -0.37), i.e. a lower speed of grain filling is not necessarily offset by an increase in duration of filling. While Triboi (1990) found a strong negative correlation between these two components. This strong correlation indicates compensation between these two variables, but this author found that this compensation phenomenon had no effect on the final dry weight of grain.

The significant negative correlation between grain yield and number of days from sowing to heading (DH) confirms that the earliness has played a very important role in stability of durum wheat yield within the dry areas, characterised by excessive temperature and hot winds during the period of grain filling (Sharma and Smith, 1986). The absence of significant correlation between grain yield and thousand-kernel weight was registered previously by Housley *et al.*(1982) and Bruckner and Frohberg (1987). Elhani *et al.* (2007) noted this association in rainfall condition when the water stress was shown during period of grain filling.

Leaf chlorophyll content is often highly correlated with leaf N status, photosynthetic capacity, and RuBP carboxylase activity (Evans, 1983; Seemann *et al*., 1987); a loss in chlorophyll coincides with development of grain filling. Changes in photosynthesis most closely paralleled changes in chlorophyll content considering results obtained with both vegetative and flag leaves.

Other investigators have also reported correlations between loss of Chl and photosynthesis in both wheat and soybeans (Wittenbach, 1979). In addition, Fischer (1983) revealed that radiation use efficiency (RUE) declines during grain filling probably due to sink limitation and/or leaf senescence. In cells, senescence-related changes are first detected in the chloroplast (Dodge 1970) and this means that chlorophyll content. Slafer *et al.* (1996) argue that the lower grain weight observed with increased number of grain per m² is not only due to a lower amount of assimilates per grain but it is the result of an increased number of grains with a lower weight potential coming from more distal florets. Improved biomass and photosynthesis is a major objective for improving the yield potential of wheat (Waddington *et al.*, 1987).

## CONCLUSION

The durum wheat genotype variation in grain filling velocity is responsible for the difference in grain yield and the improvement in grain yield can be achieved by the increasing in velocity of grain filling. The genotypes that flower early can escape the risk of water stress and, thus, establish a potential for wide grain size; but their short vegetative growth could induce a lower fertility spike, the lower speed of grain filling is not necessarily offset by an increase in duration of filling. Changes in photosynthesis most closely paralleles change in chlorophyll content; all these changes occur during the period of grain filling which affects the grain weight.

## REFERENCES

Blackmer, T.M. and Schepers, J.S. 1995. Use of a chlorophyll meter to monitor nitrogen status and schedule fertigation for corn. *Journal of Production Agriculture* 8: 56-60.

Bruckner, P.L. and Frohberg, R.C. 1987. Rate and duration of grain fill in spring wheat. *Crop Science* 27: 451–455.

Dodge, J.D. 1970. Changes in chloroplast fine stucture during the autumnal senescence of *Betula* leaves. *Annales Botanici* 34: 817-824.

Dwuyer, L.M., Tollenaar, M. and Stewart, D.W. 1991. Changes in plant density dependence of leaf photosynthesis of maize (*Zea mays* L.) hybrids, 1959 to 1988. *Canadian Journal of Plant Science* 71 :1-11.

Elhani, S., Martos, V., Rharrabti, Y., Royo, C. and Garcýa del Moral, L.F. 2007. Contribution of main stem and tillers to durum wheat (Triticum turgidum L. var. durum) grain yield and its components grown in Mediterranean environments. *Field Crops Research* 103: 25–35.

Evans, J.T. 1983. Nitrogen and photosynthesis in the flag leaf of wheat. *Plant Physiology* 72: 297–302.

Fischer, R.A. 1983. Wheat. In: Proceeding symposium on potential productivity of field crops under different environments. pp.129-154.

Gebeyehou, G., Knott, D.R. and Baker, R.J. 1982. Relationships among duration of vegetative and grain filling phases, yield components and grain yield in durum wheat cultivars. *Crop Science* 22: 287-290.

Hochman, Z.V.I. 1982. Effect of water stress with phasic development on yield of wheat grown in a semi-arid environment. *Field Crop Reserche* 5: 55-67.

Housley, T.L., Kirleis, A.W., Ohm, H.W. and Patterson, F.L. 1982. Dry matter accumulation in soft red winter wheat seeds. *Crop Science* 22: 290–294.

Macleod, L.C. and Duffus, C.M. 1988. Reduced starch content and sucrose syntheses activity in developing endosperm of barley plants grown at elevated temperature. *Australian Journal of Plant Physiology* 15: 367-75.

Nass, H.G. and Resier, B. 1975. Grain filling period and grain yield relationships in spring wheat. *Canadian Journal of Plant Science* 55: 673-678.

Porter, J.R. and Gawith, M. 1999. Temperature and the growth and development of wheat: A review. *European Journal of Agronomy* 10, 23–36.

Royo, C., Michelena, A., Carrillo, J.M., Garcýa, P., Juan-Aracil, J. and Soler, C. 1998. Spanish durum wheat breeding program. pp. 80–87. In: Nachit, M.M., Baum, M., Porceddu, Monneveux, and Picard, E. (Eds). SEWANA (South Europe, West Asia and North Africa) durum research network. Proceedings of the SEWANA durum network workshop, 20–23 March 1995. ICARDA: Aleppo, Syria.

Seemann, J.R., Sharkey, T.D., Wang, J. and Osmond, C.B. 1987. Environmental effects on photosynthesis, nitrogen-use efficiency, and metabolite pools in leaves of sun and shade plants. *Plant Physiology* 84: 796–802.

Sharma, R.C and Smith, E.L. 1986. Selection for high and low harvest index in three winter population. *Crop Science* 26: 1147-1150.

Simane, B., Struik, P.C., Nachit, M. and Peacock, J.M. 1993. Ontogenic analysis of yield components and yield stability of durum wheat in water-limited environments. *Euphytica* 71: 211–219.

Singh, B.K. and Jenner, C.F. 1982. Association between concentration of organic nutrient in the grain, endosperm cell number and grain dry weight with the ear of wheat. *Australian Journal of Plant Physiology* 10: 227-236.

Slafer, G.A., Calderini, D.F. and Miralles, D.J. 1996. Yield components and compensation in wheat: Opportunities for further increasing yield potential. pp.101-133. In: Reynolds, M.P. Rajaram, S. and McNab, A. (Eds.). Increasing yield potential in wheat: Breaking the Barriers.

Sofield, I., Evans, L.T., Cook, M.G. and Wardlaw, I.F. 1977. Factors influencing the rate and duration of grain filling in wheat. *Australian Journal of Plant Physiology* 4: 785–797.

Triboi, E., Planchon, J. and Magne, J. 1985. Déterminisme du poids moyen du grain chez le blé. Effet sur la variation du rendement. *Comptes rendus de l'Académie d'agriculture de France* 71:871-886.

Triboi, E. 1990. Modelé d'élaboration du poids du grain chez le blé tendre (*Triticum aestivum*) en thell. *Agronomie* 1: 191-200.

Waddington, S.R., Osmanzai, M., Yoshida, M. and Ransom, J.K. 1987. The yield of durum wheats released in Mexico between 1960 and 1984. *Journal of Agricultural Science Cambridge* 108: 469-477.

Wardlaw, I.F., Sofield, I. and Cartwright, P.M. 1980. Factors limiting the rate of dry matter accumulation in the grain of wheat grown at high temperature. *Australian Journal of Plant Physiology* 7: 87- 400.

Wittenbach, V.A. 1979. Ribulose bisphosphate carboxylase and proteolytic activity in wheat leaves from anthesis through senescence. *Plant Physiology* 64: 884-887.

Wood, C.W., Reeves, D.W. and Himelrick, D.G. 1993. Relationships between chlorophyll meter readings and leaf chlorophyll concentration, N status, and crop yield: A review. *Proceedings - Agronomy Society New Zealand* 23: 1-9.

Yoshida, S. 1981. Fundamentals of rice crop science. International Rice Research Institute, Los Banos, Philippines. pp. 59–60.