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Original article

# Agronomical and Physiological Behavior of Durum Wheat (*Triticum durum* Desf.) Genotypes Under Semi-Arid Conditions

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**Abstract**

In the semi-arid high plains of Algeria, water stress is one of the most significant factors restricting wheat production. This study aims at analyzing water stress effect on durum wheat behavior with a particular focus on relationships between some agronomical and physiological traits. Ten genotypes were tested under rain-fed and full-irrigated conditions in semi-arid climate of Eastern Algeria. The experiment was led down in a randomized complete block design at the experimental field of Natural and Life Sciences Faculty of Sétif1 University. Yield and its components, leaf relative water content, leaf specific weight, grain-filling rate and duration and leaf chlorophyll content were measured. Significant genotypic and environmental variations were observed for major measured traits. Water stress significantly decreased the potential yield by 28%. A significant and strong correlation was observed between agronomical and physiological characteristics. In both stress and non stress conditions, grain yield was positively and significantly associated with: Chlorophyll content (r = 0.893), relative water content (r = 0.956) and grain filling duration (r = 0.853). Wheat productivity was highly associated with high photosynthetic activities, good water status and long grain filling duration. This finding suggests using these traits as tools for screening durum wheat tolerance to water stress.

**Keywords:** Chlorophyll content, Tolerance, Wheat, Water stress, Yield.

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## INTRODUCTION

Durum wheat (*Triticum durum* Desf.) is an important food staple for a large part of humanity and it is cultivated over vast climatic conditions. Durum wheat is an important cereal crop of Algeria and based on area and production it ranks first in cereals. In Sétif province, durum wheat is the most important crop. According to the recent agricultural statistics of Algeria, durum wheat was grown on a total area of 1343 thousands ha, with a total production of 2407 thousand tones and grains yield 1793 kg/ha in Algeria. In Sétif province, it was grown on a total area of 104 thousand ha, with a total production of 148 thousand tones and average grains yield of 1419 kg/ha (Anonymous, 2018).

In the Mediterranean region, durum wheat is generally grown under rain-fed conditions, characterized by low and unpredictable rainfall and a large water stress impact. In this area, water stress is one of the most important factors limiting durum wheat yield. Drought and heat during the grain filling period, nutrient deficiencies, soil problems, diseases, and pests are the main yield constraints (Royo et al., 2009). The ability of a cultivar to produce high and satisfactory yield over a wide range of stress and non-stress environments is very important (Kiliç and Yağbasanlar, 2010).

Hence, selection for drought resistance and production of tolerant cultivars with high yield potential is the main objective of breeding programs. Analysis of agronomical and morpho-physiological traits is useful for studying of plant adaptations to environmental stresses such as water deficit. Knowledge of the relationship of yield in wheat with its components and morpho-physiological traits associated with drought tolerance can be of great assistance to the plant breeder in making selections. The identification of physiological traits responsible for drought tolerance should be considered in the breeding program, because grain yield and drought resistance are controlled at independent genetic loci (Morgan, 1984).

Drought has an effect on the physiological parameters of vegetation, such as chlorophyll content, photosynthetic parameters, biomass and yield (Katerji et al., 2009 ; Ali et al., 2018). Therefore, drought affects the growth of wheat differently at different growth stages. By restricting photosynthesis, drought affects the yield of wheat (Zhao et al., 2020). The primary consideration when using any drought-tolerance indicator in breeding programmes must be whether drought-tolerant cultivars have the potential to transfer these traits to their progeny (Van Heerden and de Villiers, 1996).

Leaf relative water content (RWC) is an important indicator of water status in plants; it reflects the balance between water supply to the leaf tissue and transpiration rate (Lugojan and Ciulca 2011). The ability of certain cultivars to maintain RWC levels for longer periods of time may be the result of higher cell wall strengh or the ability to minimize mechanical damage to the cells (Irigoyen, et al., 1992). It may also indicate a higher level of osmoregulating capacity (Rodriguez-Maribona et aI., 1992).

Leaf is the most important part of photosynthetic apparatus and it has the main role in produce organic matter in plants. Leaf characteristics as well as chloroplasts pigments content, leaf area and dry matter weight have the great influence on yield of cultivated plants (Bojović1 and Stojanović, 2006). Leaf specific weight (LSW), defined as the mass of tissue per unit area has been foud to be an important physiological parameter as it indicates the relative thikness of leaves. Greater LSW provides more photosynthetic potential per unit area of leaf and hence it is frenquently been considered as correlated with photosynthesis in several plant species (Sarkar, et al., 2003).

Leaf chlorophyll content is important factor to determine the photosynthesis rate and dry matter production (Ghosh et al., 2004). Highchlorophyll content is a desirable characteristic because it indicates a low degree of photoinhibition of photosynthetic apparatus, therefore reducing carbohydrate losses for grain growth (Farquhar et al., 1989). According to Iturbe et al., (1998) water stress condition caused reduction in chlorophyll content.

Wiegand and Cuellar (1981) suggest that the grain-filling rate is determined mostly by genetic factors and the grain-filling duration by environmental factors. Many studies in wheat and barley have determined the influence of the vegetative and grain-filling periods on grain yield (Nass and Reiser 1975; Wiegand and Cuellar 1981; Gebeyehou et al. 1982; Knott and Gebeyehou 1987).

The objective of this study was to investigate the genotypic effects for tolerance to water stress in durum wheat using some agronomical and physiological traits.

## MATERIALS and METHODS

### Experimental Design

Ten durum wheat cultivars (Table 1) were tested under rain-fed and irrigation conditions, during the cropping season 2015/2016 at the Experimental Farm of Sétif 1 University (36°9′6"N & 5°21′57"E), in the East Algerian height plains. Total precipitation was recorded as 330 mm in the 2015/2016 growing season. In irrigation treatment and based on the results of soil moisture content, the first irrigation (50 mm) was performed at tillering. The second irrigation (50 mm) was applied at stem elongation and the third irrigation was applied at flowering stage (50 mm).

The experiment was led down for each condition in a randomized complete block design with 3 replications. Each elementary plot was made four rows (2.5 m long) and the first middle row was used for destructive sampling, while observations were taken from the second middle row. The cultivars were hand sown on 15 November 2015. The seeding rates for both experiments were 300 seeds per $m^2$. At sowing, 100 kg/ha of triple super phosphate (46%) were applied in autumn and 100 kg/h of urea (46%) were broadcasted at tillering. Weeds were controlled manually. Grain yield and its components were recorded after harvesting the crop at maturity.

**Table 1**. Names and origins of durum wheat genotypes used in the experiment.

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

**Leaf Chlorophyll Content**

Chlorophyll content of the flag leaf was estimated by using a hand-held meter (SPAD 502 Minolta, Spectrum Technologicals Inc., Plainfield, IL). In each environment, three replications chlorophyll meter readings (arbitrary absorbance or SPAD units) were taken at the abbatial slide of 10 flag leaves during the heading stage.

**Leaf Relative Water Content (RWC) and Leaf Specific Weight (LSW)**

Measures of RWC and LSW were performed at the heading stage. The RWC is determined from a sample of 10 flag leaves. Flag leaves are weighed to determine their fresh weight (FW), then they are trapped in vials containing distilled water and they put on in darkness. After 4 hours: the leaves are come out and dried with blotting paper and then weighed to obtain turgid weight (TW). Then, the leaves are placed in an oven at 65 °C for 16 hours. After this time, leaves, one last time, were reweighed to obtain their dry weight (DW). The RWC was calculated from the formula given by the method of Barrs and Weartherly (1962):

$$RWC\ (\%) = (FW - DW) / (TW - DW) \times 100$$

For leaf specific weight, ten flag leaves were removed and cut them at the base. Leaf area (LA) was calculated by the formula:

$$LA\ (cm^2) = 0.606\ (L \times l)$$

Where: L is the average length, l the average width and 0.606 is the regression coefficient of the surface estimated from the weight of paper that deduced by the product (Lx l). Then, the leaves were dried at 85 °C for 48 hours and then weighed to obtain dry weight (DW). Density (LSW) was calculated from the formula given by Sakar et al., (2003):

$$LSW\ (mg / cm^2) = DW / LA$$

**Grain filling**

At anthesis until the maturity, 10 plants in each plot were sampled every two days. Then, the dry weight of the ten grains of the central spikelets was measured. Grain filling rate (GFR) was calculated as the value of the slope of the regression line of grain dry weight evolution (Triboi, 1990). The grain filling duration (GFD) was calculated as the ratio of final grain weight to mean grain filling rate (Bahlouli et al., 2008).

**Data analysis**

Data were subjected to analyze of variance using the SAS statistical analysis package (version 9.2; SAS Institute, Cary, NC, USA). Differences among environments and genotypes were examined for statistical significance using the least significant difference (LSD) test at ($p < 0.001$) significance levels.

## RESULTS and DISCUSSION

Analysis of variance (Table 2) indicated that environmental and genotypic effects were shown highly significant ($p < 0.001$) for all measured traits. As well, the interaction effect of environment*genotype (E*G) was highly significant for leaf specific weight and grain filling duration. These results indicated high genetic variation for major of characteristics.

**Table 2.** Combined analysis of variance for measured traits.

| Source of Variation | Df | Mean of Square | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | GY | NS/m$^2$ | NG/S | TKW | CC | RWC | LSW | GFR | GFD |
| Environment (E) | 1 | 39.4* | 18727* | 243* | 105* | 28.98* | 872* | 58.03* | 0.33* | 327* |
| Genotype (G) | 9 | 4.14* | 11249* | 59.5* | 123* | 64.89* | 109* | 8.12* | 0.19* | 63* |
| E*G | 9 | 0.47 | 1467 | 26.7* | 2.91 | 0.66 | 5.05 | 2.42* | 0.02 | 20.3* |
| CV % | | 11.54 | 12.46 | 7.70 | 4.19 | 1.76 | 3.75 | 12.2 | 11.82 | 5.77 |

* : significant at 1 ‰, Grain yield (GY), no. spike m-2 (NS/m²), no. grains spike-1 (NG/S), 1000-kernel weight (TKW), chlorophyll content (CC), relative water content (RWC), leaf specific weight (LSW), grain filling rate (GFR) and grain filling duration (GFD).

Among the different approaches, and according to Blum (1988), the identification of high potential genotypes under optimum and deficit water environments has been a principal breeding approach for durum and bread wheat. Our results showed that water stress decreased significantly grain yield. In rain-fed and full-irrigated conditions, the average of grain yield for all genotypes was 4.16 and 5.78 t/h respectively (Table 3). So, water stress reduced the genotype potential for grain yield by 28%.

Under rain-fed condition, grain yield ranged from 2.49 t/h for Oued Zenati to 5.25 t/h for Bousselem with an average of 4.16 t/h overall genotypes. Under optimum condition, grain yield ranged from 4.42 t/h for Oued Zenati to 7.67 t/h for Bousselem with a mean of 5.78 t/h overall genotypes (Table 3).

Under genotypes, most sensitive genotypes were Oued Zenati, and Polonicum, whose reduction in yield potential varies from 44 to 50%. On the other hand, Altar, Sooty, Dukem, Kucuk and Mexicali showed better tolerance to water stress. The reduction in their yield potential has fluctuated between 21 and 23%. Finally, Waha, Hoggar and Bousselem, have shown moderate tolerance to water stress.

Our results indicated that the reduction in yield potential is the result of a reduction in grain yield components, with an average reduction of 5% for the 1000-kernel weight, 9% for the no. grains spike$^{-1}$ and 9% for the no. spike m$^{-2}$ (Table 3).

**Table 3.** Genotypes ranking for grain yield and its component under rain-fed (RF) and full-irrigated (FI) conditions.

| **Genotypes** | **GY (t/h)** | | **NS/m$^2$** | | **NG/S** | | **TKW (g)** | |
|---|---|---|---|---|---|---|---|---|
| | RF | FI | RF | FI | RF | FI | RF | FI |
| Oued Zenati | 2,49 $^{a}$ | 4,42 $^{c}$ | 303 $^{c}$ | 323 | 29,63 $^{d}$ | 40,13 $^{bc}$ | 55,05 $^{ab}$ | 60,10 $^{ab}$ |
| Altar | 4,35 $^{b}$ | 5,32 $^{bc}$ | 343 $^{abc}$ | 407 | 33,60 $^{bcd}$ | 35,60 $^{bc}$ | 57,66 $^{ab}$ | 59,01 $^{ab}$ |
| Sooty | 4,55 $^{b}$ | 5,79 $^{b}$ | 413 $^{ab}$ | 383 | 40,47 $^{a}$ | 43,33 $^{ab}$ | 48,63 $^{cd}$ | 52,08 $^{c}$ |
| Polonicum | 2,63 $^{a}$ | 5,25 $^{bc}$ | 343 $^{abc}$ | 357 | 38,93 $^{ab}$ | 35,67 $^{bc}$ | 54,16 $^{ab}$ | 58,65 $^{ab}$ |
| Waha | 4,37 $^{b}$ | 5,84 $^{b}$ | 417 $^{ab}$ | 427 | 35,00 $^{abcd}$ | 42,27 $^{abc}$ | 52,97 $^{bc}$ | 55,36 $^{bc}$ |
| Dukem | 4,47 $^{b}$ | 5,64 $^{b}$ | 363 $^{abc}$ | 420 | 37,13 $^{ab}$ | 46,67 $^{a}$ | 44,42 $^{d}$ | 45,50 $^{d}$ |
| Mexicali | 4,21 $^{b}$ | 5,48 $^{b}$ | 330 $^{bc}$ | 390 | 33,80 $^{bcd}$ | 39,00 $^{abc}$ | 55,94 $^{ab}$ | 57,06 $^{abc}$ |
| Kucuk | 4,50 $^{b}$ | 5,78 $^{b}$ | 407 $^{ab}$ | 460 | 31,13 $^{cd}$ | 35,07 $^{bc}$ | 53,59 $^{bc}$ | 56,61 $^{abc}$ |
| Hoggar | 4,77 $^{b}$ | 6,59 $^{ab}$ | 427 $^{a}$ | 467 | 36,33 $^{abc}$ | 37,67 $^{bc}$ | 57,77 $^{ab}$ | 59,45 $^{ab}$ |
| Bousselem | 5,25 $^{b}$ | 7,67 $^{a}$ | 403 $^{ab}$ | 470 | 33,00 $^{bcd}$ | 33,87 $^{c}$ | 58,72 $^{a}$ | 61,55 $^{a}$ |
| **Mean** | 4,16 $^{b}$ | 5,78 $^{a}$ | 375$^{b}$ | 410 | 34,90$^{b}$ | 38,93$^{a}$ | 53,89$^{b}$ | 56,54$^{a}$ |
| **LSD$_{1\%}$** | 1,31 | 1,30 | 89,11 | 132,54 | 5,95 | 7,37 | 5,01 | 6,07 |
| **Reduction** | 28% | | 9% | | 10% | | 5% | |

Grain yield (GY), no. spike m$^{-2}$ (NS/m²), no. grains spike$^{-}$1 (NG/S), 1000-kernel weight (TKW).

Leaf relative water content (RWC) has also been proposed as a more important indicator of water status than other water potential parameters under drought stress Dhanda and Sethi, (2002). Alizadeh, (2002), reported that leaf relative water content is one of the best growth biochemical indicators of stress intensity. Our results revealed that environments and genotypes significantly ($p < 0.001$) affected leaf relative water content (Table 2). In full watered condition and rain-fed condition, average RWC was 74.8% and 67.2% respectively. In stressed condition, Bousselem (73.4%) and Oued Zenati (56.7%) had the highest and the lowest RWC respectively. The same results were obtained in favourable environment, were RWC of Bousselem and Oued Zenati showed 80.8 and 66.7% respectively (Figure 1A). In other hand, Sooty and Hoggar had medium values of RWC. Many authors mentioned that plants having high or medium yield, should be of high leaf RWC. Matin et al., (1989), studying barley, reported that drought tolerant cultivars usually maintained higher leaf RWC under the stress.

Leaf specific weight (LSW) is reported to be related to drought tolerance in several crops and has been suggested as a selection criterion for breeding programmes targeting low rainfall areas (Talwar et al., 2011). In this study, LSW differs significantly among the genotypes under both environments. In water stress conditions, LSW fluctuated between 5.2 and 10.2 mg/cm$^2$, with an average of 8.24 mg/cm$^2$ and between 5.1 and 7.4 mg/cm$^2$ in full-irrigated conditions with an average of 6.9 mg/cm$^2$ (Figure 1B). There was significant increase in LSW under rain-fed conditions as compared to full-irrigated conditions. So, water stress increased genotype leaf specific weight by 22%. The range of increase in LSW under stress conditions as compared to that under non-stress conditions was 1 to 35 %. The maximum increase in LSW was recorded in Sooty (35%), Dukem (35%) and Bousselem (32%) and minimum in Oued Zenati (1%) and Polonicum (1%). Ben-Amar et al., (2020) conducted an experiment on 11 durum wheat (Triticum durum Desf.) genotypes and observed that SLW significantly differed among stress and non stress conditions. But they observed that SLW increased significantly under non stres as compared to stress conditions. In rabi sorghum genotupes, Talwar et al., (2011) rapported that specific leaf weight increased significantly under un-irrigated as compared to irrigated conditions in all the genotypes suggesting increase in leaf thickness under moisture stress conditions.

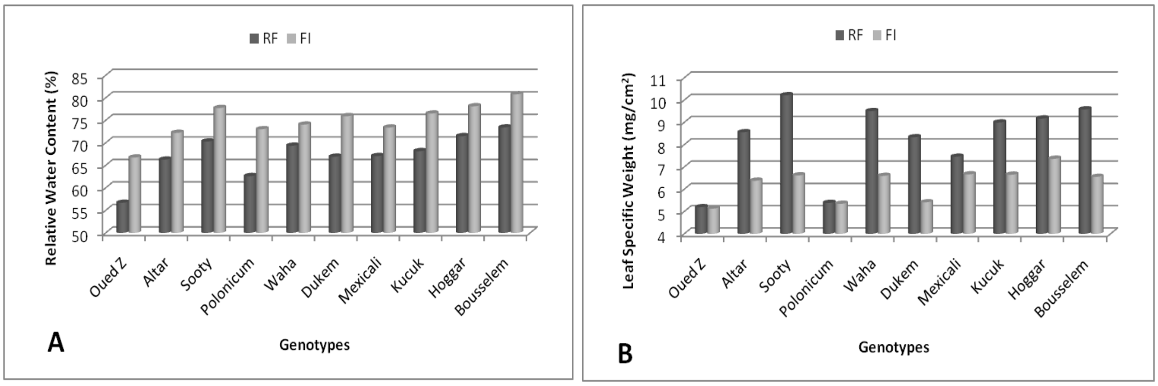


**Figure 1.** Mean of leaf relative water content (A) and leaf specific weight (B) under rain-fed and full irrigated conditions.

The results of measuring chlorophyll contents (CC) in the flag leaf of ten wheat genotypes in rain-fed and full watered conditions are presented in Figure 2. The lowest chlorophyll content in all genotypes was recorded on rain-fed conditions (average values of 60.2). The greatest chlorophyll content was measured in the leaf of genotypes that grew on the well-watered conditions (average values of 61.6). In the stressed environment, Oued Zenati (56) and Polonicum (56.5) recorded the lowest values of CC and Bousselem (65.4), Hoggar (63.5) and Mexicali (62.8) showed the greatest values of CC. In favorable environments, these same genotypes showed the same ranks. There was a significant increase in CC under full-irrigated conditions as compared to rain-fed conditions. So, irrigation increased genotype leaf CC by 22%. The range of increase in CC under non-stress conditions as compared to that under stress conditions was 0 to 4 %. These findings are in agreement with Araus et al., (1998) who reported that drought treatment caused a 20% reduction in leaf chlorophyll content. Decrease in the chlorophyll content under drought stress was also observed by Sayar et al. (2008) in durum wheat and by Lonbani and Arzani (2011) in triticale and wheat.

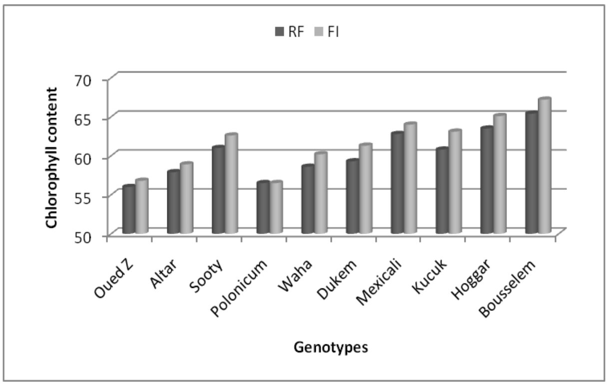


**Figure 2.** Mean of flag leaf chlorophyll content under rain-fed and full irrigated conditions.

On all genotypes, a high grain filling rate (1.51 mg/g/d) and low grain filling duration (29.6 days) were observed in stressful water conditions. At the opposite, we recorded 16% of increases in grain filling duration and 10% of reduction in grain filling rate in favorable conditions. At the genotype level, Oued Zenati and Polonicum showed high values of grain filling rate and low values of grain filling duration, at both environments, favorable and unfavorable (Figure 3). On the other hand, Bousselem was characterized by low values of grain filling rate and duration at both environments, favorable and unfavorable.

The range of increase in GFR under stress conditions as compared to that under non-stress conditions was -5 to 38 %. The maximum increase in GFR was recorded in Waha (18%), Hoggar (16%) and Bousselem (15%) and minimum in Sooty (-5%) and Dukem (-1%). At the opposite, the range of increase in GFD under non-stress conditions as compared to that under stress conditions was -3 to 30%. The maximum increase in GFD was recorded in Waha (30%) and Bousselem (30%) and minimum in Oued Zenati (1%) and Dukem (5%).

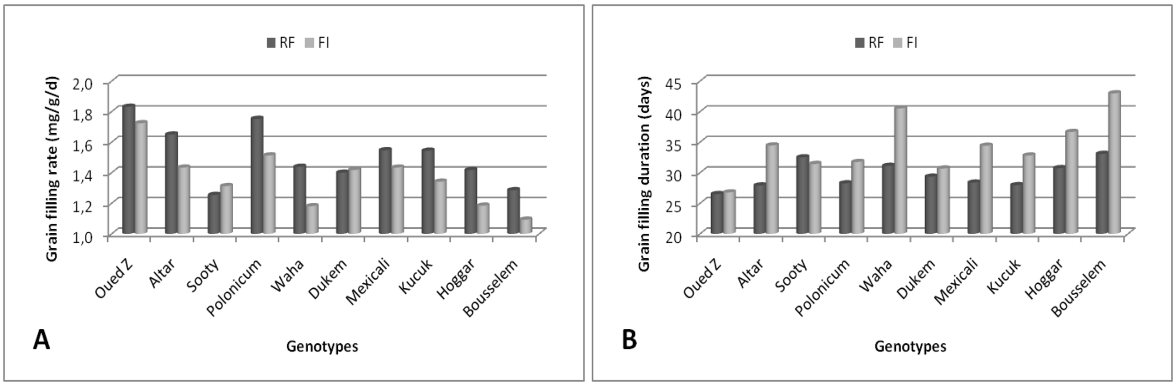


**Figure 3.** Mean of grain filling rate (A) and duration (B) under rain-fed and full irrigated conditions.

In the present study, grain yield was significantly and positively correlated with: number of spikes per m2 (r = 0.885) and relative water content (r = 0.956) (Figure 4). These results are in accordance with results obtained in field experiments. In their study with winter wheat, Tahara, et al., (1990) mentioned a positive relationship between grain yield and RWC measured during anthesis and mid-grain filling, as the high-yield selections maintained a significantly higher RWC than the low-yield selections. Also, correlation coefficients showed strongly positive relation between grain yield with RWC in bread wheat (Keyvan, 2010) and in lentil (Lens culinaris L.) (Neyestani and Azimzadeh, 2003 ; Azizi-Chakherchaman, et al., 2008).

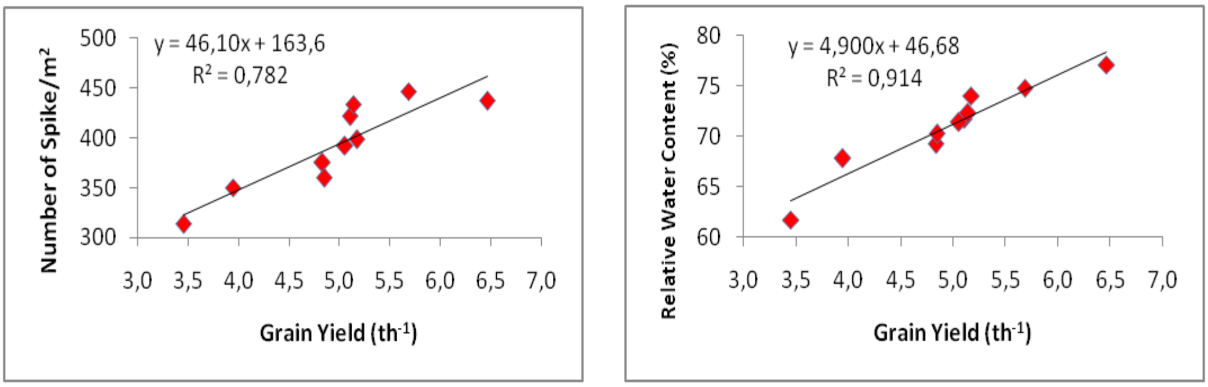


**Figure 4.** Relationship between grain yield and number of spikes per m$^2$ and relative water content.

It is reported that chlorophyll content of resistant cultivar to drought conditions had high chlorophyll content (Keyvan, 2010). Other reports have represented that drought stress did not have effect on chlorophyll concentration (Kulshreshtha et al, 1987). Our results showed that with an increase in the Intensity of drought stress on wheat cultivars, there was a decrease in leaf specific weight, chlorophyll content and grain filling duration. Results of correlation analysis indicated that grain yield was significantly and positively correlated with leaf specific weight (r = 0.856), chlorophyll content (r = 0.893) and grain filling duration (r = 0.853). But with grain filling rate, a significant and negative correlation was observed (Figure 5). The results of this study are in good agreement with the early findings of Kiliç and Yağbasanlar, (2010), when they reported significant and positive correlation between grain yield, chlorophyll content and grain filling period of certain durum wheat genotypes under water stress condition.

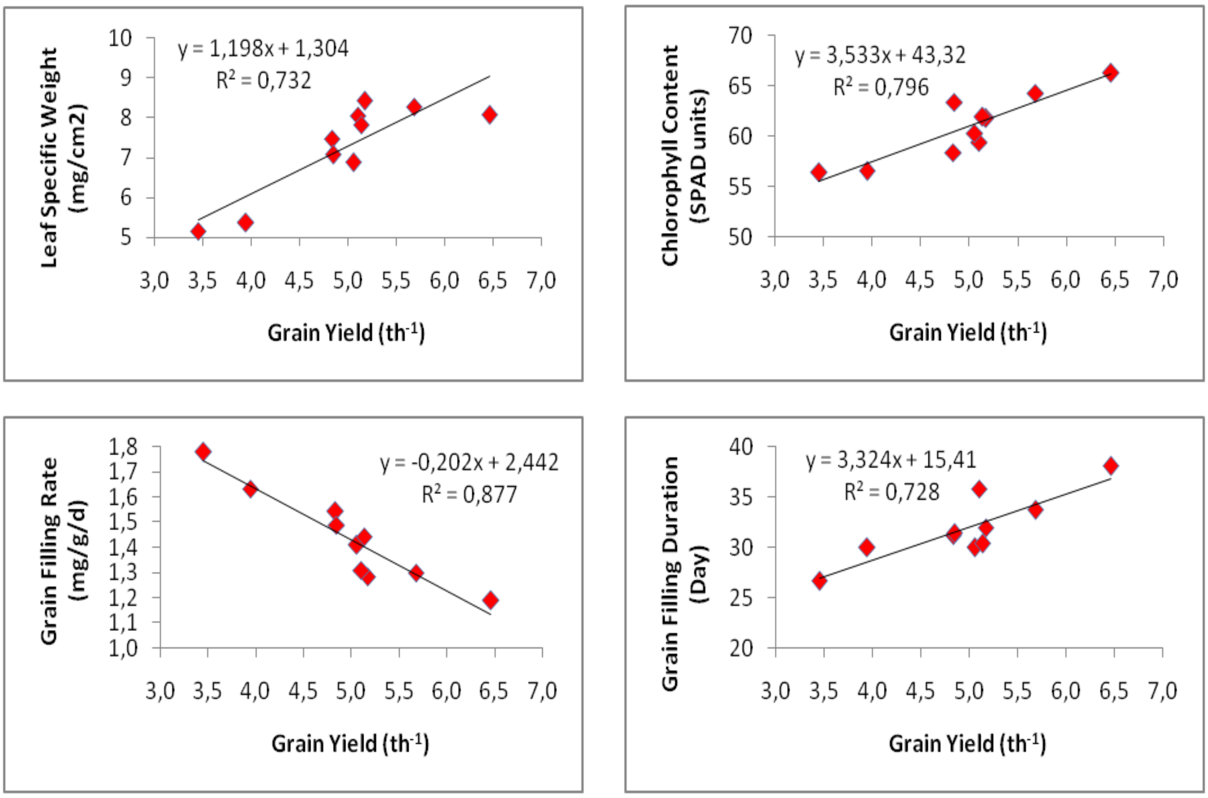


**Figure 5.** Relationship between grain yield, leaf specific weight, chlorophyll content and grain filling.

## Conclusion

Analysis of variability among the traits and the association of particular character in relation to other traits contributing to crop yield would be great importance in planning a successful breeding program (Mary and Gopalan, 2006). The overall result demonstrated that improving water conditions contributed to increasing some agronomical traits such as 1000-kernel weight, number of grains/spike and number of spike/$m^2$. From this study, it is concluded that morpho-physiological traits such: relative water content, leaf specific weight, chlorophyll content content and grain filling rate and duration, can be considered as suitable criteria for the selection of high yielding durum wheat genotypes.

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