Water Use Efficiency and Flag Leaf Photosynthetic in Response to Water Deficit of Durum Wheat (*Triticum durum* Desf)

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**Abstract:** The knowledge of the physiological characters implied in the processes of the adaptation plants to the abiotic constraints constitutes a decisive stage of fight against the drought. Six varieties of durum wheat (*Triticum durum*) were used in this study: four local varieties characterized by a low potential production (Djenah khetafa, Belioum, Rabouia and Guem gomur kham) and two introduced varieties with a high production potential (Viron and Gta dur). Pot experiments were carried out in a greenhouse. The plants were subjected to different rates of water supply (100, 80, 60, 40 and 12% of field capacity). At the anthesis stage, some physiological parameters such as net photosynthesis, transpiration, water use efficiency, stomatal resistance and the rate of chlorophyll were recorded on the flag leaf. The results revealed highly significant varietal differences to the whole of parameters measured. The results showed that water stress, in all the varieties decreased the chlorophyll rate, while increased the stomatal resistance, which involves a fall in the photosynthetic activity and therefore a decrease in the production of the dry mass. Yet, under the same conditions of water stress, the introduced varieties have a good capacity of adaptation compared with the local varieties. Nonetheless, variety Belioum is confirmed as the most productive in parallel with the other local varieties. In the conditions of this study, positive correlations were reported between the net photosynthesis and the production of the dry mass.

**Key words:** *Triticum durum* Desf · Water stress · Net photosynthesis · WUE · Stomatal resistance

**INTRODUCTION**

Drought is one of the main factors which limit productivity all over the world [1]. In such conditions, it sounds more essential to select varieties with a fair yield in dryness conditions rather than searching for high yield potential varieties in adequate water supply conditions. But in order to limit the variations of the production due to environmental variability, many research studies were carried out to identify the morphological [2], physiological [3], biochemical [4] and genetic characters [5] due to the mechanisms of the adaptation of species to the lack of the water and can serve as selection criteria to assist in and accelerate such breeding programmes [6].

In the Mediterranean basin, which is considered as one of the major centres of plant diversity in the world, the rare precipitation is in part or totally the factor that limits production. Actually, the region is characterised by a dry climate, hot in summer and cold in winter [7]. Durum wheat is the most widely grown cereal species in this region and it holds about 45% of durum wheat cultures in the world [8]. These crops are widely cultivated under rainfall conditions [9], with variable intermittent moisture stress and terminal moisture stress of various lengths [10]. In Algeria, cereals hold 60% of the cultivated lands; unfortunately, the production is still very low. The adverse climatic variations, bearing particularly severe and steady water stress often along with extreme heat by the end of the season, result in a high variability of the production of these crops [11]. There are a large number of local varieties of wheat in Algeria. They have been selected since long before 1961 until date [12]. They are rather poorly exploited and are quite neglected because of their low potential of productivity. However,
we are nowpressed to consider actions to be taken as well as research programmes to preserve and promote these cultivars for the conservation of this genetic heritage. It is necessary to also have some insight into the physiological mechanisms underlying these crop responses [13].

Besides, it is admitted that losses of water resulting from the atmospheric challenges are regulated by the stomata [14]in the leaves. The fall in productivity of the plants in unfavourable environmental conditions is caused by the fact that they downsize their foliar area when they reduce their growth; this results in a decrease of the photosynthetic capacity of the whole plant [15].

The purpose of this study is to quantify the effects of water stress on some growth and physiological characters. The aim is to establish simple criteria that will serve to identify the physiological mechanisms that describe tolerance to drought of the Durum wheat varieties for a better management of the improvement programmes and to optimally exploit natural resources.

MATERIALS AND METHODS

Plant Material and Growing Conditions: Six varieties of Durum wheat (Triticum durum, Desf.) Local and introduced released by the Technical Institute Crop El Khroub Constantine 'ITGC' are the subject of this present study (Table 1). These cultivars are characterized by contrasting agricultural productivity. Ten seeds are germinating in Petri dishes. After germination, seedlings are transplanted into plastic pots with mixture of (Clay Soil / sand 3:1). The pots are arranged randomly (total randomization) in green house with an average temperature of 36-75±10°C and relative humidity of 47-55±8%. After plant emergence, pots were irrigated at field capacity and weighed every day, until flowering stage. At this stage five different water regimes were imposed. They consisted of 100 (control), 80, 60, 40 and 12% of field capacity (F. C), each treatment was replicated three times.

<table>
<thead>
<tr>
<th>Varieties</th>
<th>Code</th>
<th>Origin</th>
</tr>
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<tbody>
<tr>
<td>Beltoumi</td>
<td>BEL</td>
<td>Algeria</td>
</tr>
<tr>
<td>Djenah Khetaifa</td>
<td>D. K</td>
<td>ITGC Algeria</td>
</tr>
<tr>
<td>Guergoum K’khem</td>
<td>G. G. R</td>
<td>ITGC Tiaret</td>
</tr>
<tr>
<td>GTA dar</td>
<td>GTA</td>
<td>CIMMYT (Mexico)</td>
</tr>
<tr>
<td>Hoggar Ex : Vitron</td>
<td>VIT</td>
<td>Introduce Spain Selection : ITGC / TIARET 1989</td>
</tr>
</tbody>
</table>

Measurement of Chlorophyll (Unit SPAD): The rate of chlorophyll in the leaves is determined by using a chlorophyll meter, (model MINOLTA type SPAD). Before any measure, the device must be set (number of signal tower) and size (N = 0). In this protocol the rate of chlorophyll is estimated per unit SPAD.

The Dry Mass g (MS): Ten plants are valued at random, cleaned and placed in an oven for dehydration at 80°C for 48 h. The plants are taken separately and weighing of each plant is noted. The average weighed of ten plants is chosen.

Water Use Efficiency (WUE) (μmolCO₂/ mmolH₂O·s): The efficiency of water use is estimated at the sheet. Defined as the ratio of Net photosynthesis to Transpiration (PN / T) of net CO₂ assimilation (PN) per unit of water transpired (T) per sheet [16].

Statistical Analysis: The interpretation of results is achieved by the program Statistical 7. Comparing average results is tested by an analysis of the ANOVA. The separation of homogeneous groups based on the smallest significant amplitude (PPAS) observed among several medium is made by test-NEWMAN KEULS the significance at the level of 5% and 1%. Similarly, Dagnelie [17, 18] determination of correlation coefficients and linear regression was performed by XLSTAT 2009 programm, to identify the relationships among the variables.

RESULTS AND DISCUSSION

The results show that net photosynthesis and transpiration fall significantly (p < 0.01) with the intensity of water stress in all varieties studied (Table 2). The values obtained in net photosynthesis differ from one variety to another (Fig. 1). For each water regime there were significant differences across genotypes for almost all traits. At the most stressed water treatment (12% F. C) recorded the lowest values of Net photosynthesis. However the introduced genotype GTA dar showed
the highest value of Net assimilation (27.78 umolCO₂ M⁻² S⁻¹), compared to the local variety (Djenah Khetaifa (10.90 umolCO₂ M⁻² S⁻¹), Which showed the lowest rate of the flag leaf photosynthesis and the most affected by this level of water supply. At the same level of severe stress the interaction was highly significant between genotype x water regime (p < 0.001) with regard to this parameter (Table 2).

The decline in photosynthetic activity among plant under several stressed was cited by other studies as one of the major causes of reduced growth and productivity [19, 20]. This decrease can be influenced by stomatal effects that result in low diffusion and CO₂ fixation [21] and/or non-stomatal effects. They are distinguished by a slightly increased effectiveness of primary activities of photosynthesis, limiting operating PSI protein and / or alteration of the photosynthetic apparatus [22]. This suggests that water stress can have an inhibiting effect on various physiological processes involved in the plant function [23]. Therefore, diminution can lead to a closure of stomata limiting the internal CO₂ concentration [24], which is expressed by a decline in photosynthetic activity.

In this study, stomatal resistance developed by the six varieties studied is also significantly affected by the water deficit (p<0.05). The differences was observed due the installation of water stress and stomatal resistance increases as the stress becomes more severe (12% F. C). Belioumi was the genotype showing the highest value (250 m² s. mol⁻¹) compared to other cultivars, followed by the introduced variety GTA dur, enregestrug an smaller increase of this trait (Fig. 2).

In this concern, Sarda et al. [25] reported that Durum wheat under drought condition, seems to be favor the first strategy is to enable the closure of stomata and limit the intensity of transpiration by plants. The maintaining of satisfactory photosynthetic activity by the local variety (Belioumi) against the applied water stress in our study, despite the decrease in internal CO₂ concentration due to the closure of stomata, can result by the establishment of the non stomatic mechanisms as a means of adaptation to limit the water loss [22, 26, 27]. In addition, for all different varieties studied measuring transpiration presents a significant genotypic variability, the differences are highly significant (p < 0.01). The values recorded at the well watered condition (100% F. C), vary from 12.07 to 42.03 mmolH₂Om⁻²s⁻¹ at the local variety Djenah Khetaifa and variety introduced GTA dur, respectively. Under different levels of water stress applied, tested genotypes showed significant decreases compared with control plants (100% F. C) (Table 3). Also, under progressive drought we detected an important decrease of this trait (for about 50%) among cultivars Djenah Khetaifa and Belioumi. These results are consistent with findings of Zhao Hui et al. [28].
Table 3: Effect of water stress on Transpiration rate (T) (mmol H2O m-2 s-1) of six Durum wheat genotypes

<table>
<thead>
<tr>
<th>Genotypes</th>
<th>T</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
</tr>
</thead>
<tbody>
<tr>
<td>DK</td>
<td>12, 07±0, 71c</td>
<td>11, 80±4, 7c</td>
<td>10, 65±0, 32 c</td>
<td>6, 69±7, 4a</td>
<td>5, 46±1, 50 a</td>
</tr>
<tr>
<td>GGR</td>
<td>17, 16±0, 59 cd</td>
<td>16, 13±4, 04cd</td>
<td>14, 48±1, 34cd</td>
<td>8, 04±1, 16 b</td>
<td>6, 49±0, 82 a</td>
</tr>
<tr>
<td>RAH</td>
<td>20, 13±1, 02 e</td>
<td>19, 64±8, 54 cd</td>
<td>20, 47±1, 73 c</td>
<td>12, 14±1, 72 c</td>
<td>7, 79±4, 45b</td>
</tr>
<tr>
<td>BEL</td>
<td>30, 43±1, 7f</td>
<td>28, 53±2, 15 e</td>
<td>18, 05±5, 87cd</td>
<td>10, 84±1, 62 c</td>
<td>9, 86±1, 11b</td>
</tr>
<tr>
<td>V1T</td>
<td>35, 39±10, 25g</td>
<td>30, 62±1, 00 f</td>
<td>29, 26±4, 66 e</td>
<td>12, 58±2, 07c</td>
<td>10, 92±1, 24c</td>
</tr>
<tr>
<td>GTA</td>
<td>42, 03±9, 59h</td>
<td>30, 84±4, 90g</td>
<td>28, 59±1, 04c</td>
<td>20, 64±1, 5e</td>
<td>12, 13±1, 69c</td>
</tr>
</tbody>
</table>

*Water regime: T: Control, S1 80%, S2 60%, S3 40% and S4 12% of field capacity
a, b, c d,..., Homogenes Groups obtained by Newman keuls test at 5%

Fig. 2: Variation of Stomatal Resistance (Rs) (m2.s.mol-1) of six Durum wheat genotypes during water deficit levels (100, 80, 60, 40 and 12% F.C).

Generally, the reduction of the transpiration reflects the effect of the drought that can be translated, according to the adaptive strategy of the species or the variety, by the morphological modifications to increase the absorption of water and / or decrease the transpiration. These modifications affect the aerial parts as the underground parts of the plant [29].

The variation of the rate of chlorophyll, under different levels of water stress provides information about the behavior of varieties towards the water efficiency. The chlorophyll rate of the local varieties Djenah Khetaifa and Guemgoum Rkhem dropped under severe water regime (12%), respectively, in contrast, the introduced varieties Vitron and GTA dur, were characterized by the highest rates ranging from 17.07 to 16.88 ( U. SPAD), respectively (Fig. 3). These results confirm the observations of GU et al. [30], showed that the lack of water leads to a drop of chlorophyll in the leaves. The relathionship between this parameter and the Net photosynthesis is very high (r = 0.92) regardless of the water regime (Fig. 4).

In well condition of water supply, dry mass content is significantly higher (p < 0.01) compared to drought conditions (Table 2), it also indicated that the effects of interaction (genotypes x water regime), were highly significant, it means that the different varieties studied varied in their behavior against the drought [31]. Indeed the relationship between the values of PN and the dry mass shows that these two parameters are linearly related (Fig. 5) with significant differences (p < 0.05) at right slope.
of regression (Pearson). According to Newman Keuls test threshold 5% GTA dur variety ranks the first with the largest value of dry mass of about 19.32 g and the last was given by the variety Djenah Khetaifa with 8.15 g. The two parameters are highly, significantly correlated (Pearson correlation between MS and PN is \( r = 0.89 \) with \( p = 0.000 \)). The water promotes the synthesis of plant mass, when stress becomes severe production of dry matter slowed [32]. The efficiency of the water use estimated by the report (PN / T), vary according to genotypes and evolve in a similar way according to applied water regimes. Indeed, under well watered conditions; control (100%), the studied varieties present values of this
parameter, that varied between 1.50 μmol CO₂/mmolH₂O₂, recorded at the variety local Guemgoum R'khem and 1.75 μmolCO₂/mmolH₂O₂ at the variety Djenah Khetaifa. This variability is maintained at the time of the application of water stress and increase with the intensity of this last [33]. So, values recorded under severe stress in this survey (12 % F. C), spread of 1.75 μmolCO₂/mmolH₂O₂. At Guemgoum R’khem variety, 1.87 μmolCO₂/mmolH₂O₂ at Belioumi and 2.29 μmolCO₂/mmolH₂O₂ at variety GTA dur. According to Pearson test positive correlation is noted between the net photosynthesis and the water use efficiency (r = 0.55) (Fig. 6), at the variety Belioumi and this correlation is more important and who reaches around 0.65, 0.75, 0.82 and 0.91, respectively at Djenah Khetaifa, Rahouia, Vitron and GTA dur varieties (Fig. 6A, B, C, D and E). These results are in agreement with those obtained by Kochler [34].

It is lucid that parameters bound to the efficiency of the use of water and tolerance to the drought have a determining agronomic significance for the production of the durum wheat. These parameters are controlled by several physiological mechanisms, that integrate at the foliar level stomatics effects and non stomatics [35] and at the plant level, capacities of translocation of photosynthetics assimilates toward the ear [36, 37]. The term efficacy of water used constitutes a main factor of tolerance therefore to the water supply. In condition of 12% F. C a variability genotype of the efficiency of water used was observed within the studied genotypes [22, 38]. This genotypic variability expresses the potential of production of the dry mass according to the available water. It depends on the level of imbibition of the plant, which results of the balance between the absorption and the transpiration [41].

CONCLUSION

The results obtained of this study, shows that drought tolerance could be a complex trait involving many dynamic interactions and allowed us to establish three groups of varieties that seem to have contrasted performances with regard to their adaptation to drought. The first group consists of varieties with high potential of production of dry mass in dry conditions, these are varieties GTA dur and Vitron. The second group is made up of varieties with intermediate performance concerning the photosynthesis rate and the production of dry mass and is also characterized by a higher stomatal resistance in comparison with two other groups; variety Belioumi is typical of this group. It has a better tolerance to water stress [40] and records a good production of dry mass despite the considerable decrease of water consumption. The last group is characterized by a low production of dry mass and corresponds to varieties Djenah Khetaifa and Rahouia.

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