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# Effect of drought stress on some physiological parameters, yield, yield components of durum (*Triticum durum* desf.) and bread (*Triticum aestivum* L.) wheat genotypes

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**ABSTRACT**

Drought is the most important limiting factor for growth and productivity of crop plants. The aim of this research was to study the effect of soil water deficit on gas exchange parameters, photosynthetic pigments content, relative water content, area, dry weight, leaf specific mass of flag leaves from durum and bread wheat genotypes. Gas exchange parameters of leaves measured by using LI-COR 6400-XT Portable Photosynthesis System. Drought caused reduction in photosynthesis rate, stomatal conductance, transpiration rate, mesophyll conductance, pigments content, area, dry weight, relative water content of flag leaves. Leaf specific mass increased under rain-fed condition. Strong relationships were detected between stomatal conductance and transpiration rate, between mesophyll conductance and photosynthesis rate. Photosynthesis is less inhibited than transpiration rate under water stress. Under influence of water stress the content of photosynthetic pigments, also the ratio of chlorophyll to carotenoids decreases. Drought led decrease in yield and yield components of wheat genotypes.

***Keywords***: wheat, soil water deficit, gas exchange parameters, yield

## Introduction

Drought stress is one of the most widespread environmental stresses when the available water in the soil is reduced and atmospheric conditions cause continuous loss of water by transpiration and evaporation (Kramer 1980). Up to 26% from the usable areas of the Earth is subjected to drought (Blum 1986). Drought is considered as the main factor limiting plant growth and yield worldwide. Wheat the major crop plant in the daily diet of 35% of world population, is a sources of energy from carbohydrates and proteins. Important stages of wheat development (stem elongation, heading-flowering, grain filling) occurs during the time when the water deficit in the soil increases in rain fed regions. Wheat is one of the widely cultivated crops in Azerbaijan, where drought is the main limiting factor for its production (Aliyev 2001). Up to 35% of the 650,000 hectare wheat grown areas is under rain-fed conditions.

The response of plants to water stress depends on several factors such as development stage, severity and duration of stress and cultivar genetics (Beltrano and Marta 2008). The adaptation strategies of the plants to drought stress include drought escape, drought avoidance and drought tolerance (Levitt 1980). Photosynthesis, the most significant process which influence crop production, is also inhibited by drought stress. The effects can be direct, as the decreased $CO_2$ availability caused by diffusion limitations through the stomata and the mesophyll (Flexas et al. 2004) or the alterations of photochemical reactions (Tang et al. 2002) and photosynthetic metabolism (Lawlor and Cornic 2002). Under field conditions, stomatal regulation of transpiration was shown as a primary event in plant response to water deficit leading to decrease of $CO_2$ uptake by the leaves (Chaves 1991, 2002; Cornic and Massacci 1996). Stomatal responses are more closely linked to soil moisture content than to leaf water status. Reduced plant size, leaf area, and leaf area index are a major mechanism for moderating water use and reducing injury under drought stress (Mitchell et al. 1998). Drought causes decrease in grain yield and yield components of field grown wheat genotypes (Veesar et al. 2007; Moayedi et al. 2010; Akram 2011).

The purpose of this research was to study the effect of soil water deficit on some physiological parameters in leaves of durum wheat and bread wheat genotypes and to determine physiological traits which can be used for identification tolerant wheat genotypes under water stress conditions.

## Materials and methods

Field experiment was carried out in the research area of Plant Physiology and Biotechnology Department of Research Institute of Crop Husbandry located in Absheron peninsula, Baku, during the 2012-2013 growing season. Six durum wheat genotypes (Garagylchyg 2, Vugar, Shiraslan 23, Barakatli-95, Alinja- 84, Tartar) seven bread wheat genotypes (Gobustan, Giymatli-2/17, Gyrmyzygul 1, Azamatli-95, Tale-38, 12nd FAWWON№97, 4th FEFWSN№50) were used for this study. Sowing was done at an average density 400 seeds $m^{-2}$ with self-propelled mechanical planter in 1 mx10 m plots, consisting of 7 rows placed 15 cm apart. Each genotype was sown with three replications both in irrigated and rain-fed conditions. Irrigated plots were watered at stem elongation, flowering and grain filling stage. Fertilization was applied as $N_{120}$ , $P_{60}$ , $K_{60}$ per hectare. Thirty per cent of the nitrogen applied at planting and the rest at the beginning of stem elongation.Net photosynthesis rate ($P_n$), stomatal conductance ($g_s$), intercellular $CO_2$ concentration ($C_i$), transpiration rate ($T_r$) were measured with a Portable Photosynthesis System LI-6400 XT (LI-COR Biosciences, Lincoln, NE, USA). Light intensity was measured by using Light-Meter LI-250A (LI-COR Biosciences) equipped with Pyranometer PY 71968 (LI-COR Biosciences). Figure 1 shows the daily variation of photosynthetically active radiation (PAR). PAR reaches maximum in the 13th hour of the day. Flag leaf photosynthetic pigments content (mg $g^{-1}$ DW) was determined following the method of Lichtenthaler (1987). About 0,1 g fresh leaves were ground in 96% ethanol for the extraction of chlorophyll and carotenoids. Absorbance of the supernatant was recorded at 664,2, 648,6 and 470 nm spectrophotometrically (Genesys 20, Thermo Scientific, USA). Pigments content calculated by the following formulas.

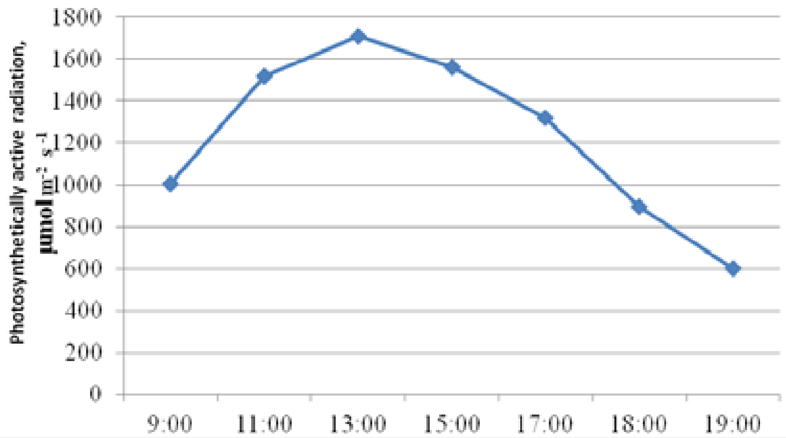
Chl a=$(13,36 \cdot A_{664,2} - 5,19 \cdot A_{648,6}) \cdot 25/DW$ Chl b=$(27,43 \cdot A_{648,6} - 8,12 \cdot A_{664,2}) \cdot 25/DW$

Chl (a+b)=$(5,24 \cdot A_{664,2} + 22,24 \cdot A_{648,6}) \cdot 25/DW$

Car(x+c)=$(4,785 \cdot A_{470} + 3,657 \cdot A_{664,2} - 12,76 \cdot A_{648,6}) \cdot 25/DW$

The flag leaf area (LA, $sm^2$) was measured with an area meter (AAC-400, Hayashi Denkon Co, LTD, Japan).Leaf dry weight was then determined, and Leaf Specific Mass (LSM, leaf dry matter per unit leaf area, mg $mm^{-2}$) was calculated. The relative water content (RWC) of the flag leaf was determined gravimetrically. Immediately after cutting at the base of lamina, leaves were preserved within plastic bags and in time transferred to the laboratory. Fresh weight (FW) was determined after removal and turgid weight (TW) was measured after saturating leaves in distilled water for 24 h at room temperature. After saturating, leaves were carefully blotted dried with tissue paper. Dry weight (DW) was measured after oven drying the leaves samples at 105°C for 24 h. RWC was calculated by using the following formula: RWC(%)= (FW-DW)/(TW-DW)x100.

**Figure 1. Daily variation of photosynthetically active radiation**



Plant height and exposed peduncle length (the distance from the flag leaf ligule to the base of spike) were determined from 30 plants per plot. Spike weight, spike length and width, number of spikelet per spike, number and weight of grain per spike were determined from five plants per plot. Soil moisture content was determined in the 0-20, 20-40, 40-60 cm depths and expressed as percentage of the field moisture capacity (Table 1).

Correlations among parameters, standard errors of means were calculated by SPSS software.

Table 1. Soil moisture content (% of the field capacity)

| Soil layer, cm | Irrigated | Rain-fed |
|---|---|---|
| Heading stage | | |
| 0-20 | 69,43±1,2 | 32,47±1,83 |
| 20-40 | 52,83±2,76 | 37,35±1,44 |
| 40-60 | 58,94±3,64 | 29,33±1,42 |
| Grain formation | | |
| 0-20 | 61,04±0,84 | 24,18±0,85 |
| 20-40 | 59,94±1,23 | 32,13±1,16 |
| 40-60 | 60,72±0,63 | 15,94±1,18 |

**Results and discussion**

There were differences between genotypes for heading time (Table 2). Water stress affected heading time. The genotypes Garagylchyg 2, Gobustan, Azamatli 95 were early-heading. The genotypes Tale 38, 4thFWFWSN№50, Gyrmyzygul 1 were late-heading. Early- heading has been known as a major drought escaping mechanism, particularly in terminal drought stresses (Levitt 1980), allows plants to finish the life cycle before deeper water deficit. Early-heading genotypes have much time for the accumulation of assimilates in the grain.

Effect of drought stress on gas exchange parameters. Photosynthesis is the primary source of dry matter production and grain yield of crop plants (Shao et al. 2005). Leaf photosynthesis may vary with leaf age, position, leaf surface, and general plant and development stage (Richards 2000). Variations in daily time course of weather parameters such as light intensity, temperature, relative humidity, etc. also affect leaf gas exchange. Water deficit significantly affected the leaf gas exchange parameters (Table 3). In the heading stage, we did not observe a sharp decrease of flag leaf gas exchange parameters. Reduction in $g_s$ during grain formation more affected on $T_r$, than $P_n$. This trend continued in the grain filling stage (date not shown).

Table 2. Number of days to 50% heading of wheat genotypes (days calculated from sowing time-1st November)

| Wheat genotypes | Irrigated | Rain-fed |
|---|---|---|
| Garagylchyg 2 | 174 | 172 |
| Vugar | 183 | 180 |
| Shiraslan 23 | 182 | 177 |
| Barakatli 95 | 179 | 174 |
| Alinja 84 | 178 | 172 |
| Tartar | 182 | 180 |
| Gobustan | 175 | 170 |
| Giymatli 2/17 | 179 | 174 |
| Gyrmyzygul 1 | 184 | 181 |
| Azamatli 95 | 172 | 169 |
| Tale 38 | 188 | 182 |
| 12ndFAWWON№97 | 182 | 180 |
| 4thFEFWSN№50 | 188 | 185 |

A strong reduction of $P_n$, $g_s$, $T_r$ during grain formation were observed in durum wheat genotypes Vugar (42%, 79%, 60%), Alinja 84 (36%, 71%, 56%), Shiraslan 23 (34%, 85%, 69%), Barakatli 95 (35%, 69%, 50%), Tartar (31%, 72%, 52%), in bread wheat genotypes Gobustan (37%, 88%, 74%), Gyrmyzygul 1 (40%, 76%, 65%), Azamatli-95 (45%, 37%, 41%), 12$^{nd}$FAWWON№97 (35%, 64%, 49%). Relatively smaller reduction of gas exchange parameters were found in genotypes Giymatli-2/17, Tale-38, 4$^{th}$FEFWSN№50. Gas exchange parameters of genotypes Barakatli 95, Alinja 84, Gyrmyzygul 1, Azamatli 95 were strongly affected by water stress in both stages. In the heading stage, we found an increase in $C_i$, due to decreased conductance of mesophyll cells to $CO_2$. However, in the grain formation stage we found a reduction in $C_i$. Perhaps this was due to stronger decrease in gs. The mesophyll conductance ($g_m$) is determined by the rate of electron transport (Q-quenching) from photosystem II to photosystem I over the thylakoid membranes and by the rate of $CO_2$ assimilation by the Calvin cycle (E-quenching) (Schapendonk et al. 1989). The mesophyll conductance ($g_m$) was calculated as the ratio of $P_n$ to $C_i$, water use efficiency (WUE) was calculated as the ratio of $P_n$ to $T_r$ (Table 4). The gm decreased, but the water use efficiency (WUE) increased under the influence of water stress.

Table 3. Gas exchange parameters of T.durum Desf.and T.aestivum L. genotypes in response to drought stress.

| Wheat genotypes | Experiment condition | Pn, μmol$CO_2$m$^{-2}$ s$^{-1}$ | | $g_s$, mol$H_2O$ m$^{-2}$ s$^{-1}$ | | $C_i$, μmol$CO_2$ mol$^{-1}$ | | $T_r$, mmol$H_2O$m$^{-2}$ s$^{-1}$ | |
|---|---|---|---|---|---|---|---|---|---|
| | | Heading stage | Grain formation | Heading stage | Grain formation | Heading stage | Grain formation | Heading stage | Grain formation |
| *Triticum durum* Desf. | | | | | | | | | |
| Garagylchyg 2 | Irrigated | 14,2 | 18,1 | 0,892 | 0,529 | 348 | 303 | 4,36 | 6,13 |
| | Rain-fed | 11,3 | 16,6 | 0,688 | 0,223 | 355 | 246 | 3,47 | 3,81 |
| Vugar | Irrigated | 14,8 | 21,6 | 0,589 | 0,647 | 319 | 299 | 4,14 | 7,93 |
| | Rain-fed | 13,3 | 12,5 | 0,445 | 0,135 | 318 | 226 | 3,64 | 3,24 |
| Shiraslan 23 | Irrigated | 17,2 | 16,3 | 0,584 | 0,568 | 322 | 310 | 4,84 | 7,25 |
| | Rain-fed | 13,8 | 10,8 | 0,559 | 0,087 | 345 | 291 | 4,50 | 2,24 |
| Barakatli 95 | Irrigated | 18,2 | 22,0 | 0,540 | 0,555 | 315 | 302 | 4,85 | 8,13 |
| | Rain-fed | 13,0 | 14,3 | 0,410 | 0,173 | 318 | 225 | 4,01 | 4,10 |
| Alinja 84 | Irrigated | 15,3 | 21,5 | 0,498 | 0,492 | 318 | 273 | 4,61 | 6,94 |
| | Rain-fed | 11,2 | 13,8 | 0,380 | 0,144 | 334 | 214 | 3,82 | 3,04 |
| Tartar | Irrigated | 18,4 | 23,5 | 0,501 | 0,640 | 302 | 282 | 4,55 | 8,84 |
| | Rain-fed | 13,5 | 16,2 | 0,426 | 0,173 | 309 | 195 | 4,37 | 4,21 |
| *Triticum aestivum* L. | | | | | | | | | |
| Gobustan | Irrigated | 14,8 | 16,5 | 0,642 | 0,717 | 335 | 338 | 5,05 | 6,57 |
| | Rain-fed | 11,9 | 10,4 | 0,524 | 0,086 | 338 | 314 | 4,49 | 1,71 |
| Giymat-li-2/17 | Irrigated | 15,8 | 19,4 | 0,421 | 0,364 | 302 | 279 | 4,65 | 4,78 |
| | Rain-fed | 10,4 | 16,2 | 0,289 | 0,209 | 318 | 286 | 3,02 | 3,33 |
| Gyrmyzy gul1 | Irrigated | 18,0 | 14,3 | 0,481 | 0,366 | 304 | 306 | 4,28 | 5,33 |
| | Rain-fed | 12,7 | 8,6 | 0,229 | 0,088 | 281 | 254 | 3,18 | 1,89 |
| Azamatli 95 | Irrigated | 15,9 | 17,1 | 0,570 | 0,325 | 313 | 273 | 5,95 | 5,69 |
| | Rain-fed | 13,6 | 9,38 | 0,221 | 0,206 | 268 | 276 | 3,61 | 3,35 |
| Tale-38 | Irrigated | 20,8 | 20,7 | 0,728 | 0,598 | 300 | 313 | 8,24 | 6,82 |
| | Rain-fed | 12,2 | 17,6 | 0,399 | 0,308 | 317 | 256 | 5,13 | 5,36 |
| 12$^{nd}$ FAW-WON N97 | Irrigated | 13,2 | 16,2 | 0,260 | 0,312 | 279 | 278 | 4,59 | 5,32 |
| | Rain-fed | 10,7 | 10,5 | 0,238 | 0,113 | 288 | 254 | 3,37 | 2,69 |
| 4$^{th}$ FEFWSN N50 | Irrigated | 20,8 | 24,3 | 0,525 | 0,485 | 284 | 279 | 6,65 | 6,95 |
| | Rain-fed | 16,8 | 17,8 | 0,474 | 0,298 | 296 | 236 | 5,39 | 6,47 |

Table 4. Effect of drought stress on mesophyll conductance (gm) and water use efficiency (WUE)

| Wheat genotypes | Experiment condition | gm $molCO_2\ m^{-2}s^{-1}$ | | WUE $\mu molCO_2\ mmol^{-1}H_2O$ | |
|---|---|---|---|---|---|
| | | Heading stage | grain formation | Heading stage | grain formation |
| *T.durum* Desf. | | | | | |
| Garagylchyg 2 | Irrigated | 0,040 | 0,060 | 3,26 | 2,95 |
| | Rain-fed | 0,032 | 0,067 | 3,26 | 4,36 |
| Vugar | Irrigated | 0,046 | 0,072 | 3,57 | 2,72 |
| | Rain-fed | 0,042 | 0,055 | 3,65 | 3,86 |
| Shiraslan 23 | Irrigated | 0,054 | 0,053 | 3,55 | 2,25 |
| | Rain-fed | 0,040 | 0,037 | 3,07 | 4,82 |
| Barakatli 95 | Irrigated | 0,058 | 0,073 | 3,75 | 2,71 |
| | Rain-fed | 0,041 | 0,064 | 3,24 | 3,49 |
| Alinja 84 | Irrigated | 0,048 | 0,079 | 3,32 | 3,10 |
| | Rain-fed | 0,034 | 0,064 | 2,93 | 4,54 |
| Tartar | Irrigated | 0,060 | 0,083 | 4,04 | 2,66 |
| | Rain-fed | 0,043 | 0,083 | 3,09 | 3,85 |
| *T.aestivum* L. | | | | | |
| Gobustan | Irrigated | 0,044 | 0,049 | 2,93 | 2,51 |
| | Rain-fed | 0,035 | 0,033 | 2,65 | 6,08 |
| Giymatli 2/17 | Irrigated | 0,052 | 0,070 | 3,40 | 4,06 |
| | Rain-fed | 0,033 | 0,057 | 3,44 | 4,86 |
| Gyrmyzygul 1 | Irrigated | 0,059 | 0,047 | 4,21 | 2,68 |
| | Rain-fed | 0,045 | 0,034 | 3,99 | 4,55 |
| Azamatli 95 | Irrigated | 0,051 | 0,063 | 2,67 | 3,00 |
| | Rain-fed | 0,051 | 0,034 | 3,77 | 2,80 |
| Tale 38 | Irrigated | 0,069 | 0,066 | 2,52 | 3,03 |
| | Rain-fed | 0,039 | 0,068 | 2,38 | 3,28 |
| 12ndFAWWON №97 | Irrigated | 0,047 | 0,058 | 2,88 | 3,04 |
| | Rain-fed | 0,037 | 0,041 | 3,17 | 3,90 |
| 4thFEFWSN №4 | Irrigated | 0,073 | 0,087 | 3,13 | 3,50 |
| | Rain-fed | 0,057 | 0,076 | 3,12 | 2,75 |

An increase in WUE could be due to more reduction in $T_r$ than $P_n$ by water deficit. More reduction of gm was observed in genotypes Shiraslan 23, Barakatli 95, Alinja 84, Tartar, Giymatli 2/17, Gyrmyzygul 1, Tale 38 during heading stage, in genotypes Vugar, Shiraslan 23, Alinja 84, Gobustan, Gyrmyzygul 1, Azamatli 95, 12ndFAWWON№97 during grain formation. This could be due to more decrease in Pn, than in $C_i$. A sharp increase in the WUE of genotypes Garagylchyg 2, Shiraslan 23, Gobustan, Gyrmyzygul 1 indicates a strong decrease in the $T_r$. Table 5 shows correlation between gas exchange parameters and calculated $g_m$ and WUE under irrigated and rain-fed conditions. Positive and significant correlations were found between the $P_n$ and $g_s$, $T_r$, $g_m$. Correlation between the $P_n$ and gm, was more strong than between the $P_n$ and $g_s$, indicating the dominance of $g_m$ in reducing of $P_n$ (Siddique et al. 1999). Negative correlation was observed between Pn and $C_i$. Positive correlations were observed between gs and $C_i$, $T_r$. Correlation between $g_s$ and WUE was negative and significant under rain-fed condition. Negative and significant correlations were found between $C_i$ and $g_m$. Correlation between $T_r$ and gm was positive and significant. Negative and significant correlation was observed between $T_r$ and WUE. Correlation between $g_m$ and WUE was positive and significant under rain-fed condition.

Table 5. Correlation coefficients between gas exchange parameters, gm and WUE.

| | Parameters | $P_n$ | $g_s$ | $C_i$ | $T_r$ | $g_m$ | WUE | |
|---|---|---|---|---|---|---|---|---|
| **Irrigated** | Pn | 1 | 0,433** | -0,070 | 0,819** | 0,778** | 0,058 | **Rain-fed** |
| | gs | 0,341** | 1 | 0,592** | 0,592** | 0,019 | -0,271* | |
| | Ci | -0,459** | 0,500** | 1 | 0,156 | -0,594** | -0,399** | |
| | Tr | 0,800** | 0,366** | -0,305* | 1 | 0,535** | -0,445** | |
| | gm | 0,975** | 0,196 | -0,622* | 0,766** | 1 | 0,244* | |
| | WUE | 0,130 | -0,161 | -0,228 | -0,458** | 0,163 | 1 | |

**, Correlation is significant at the 0,01 level; *, Correlation is significant at the 0,05 level

Effect of water deficit on RWC. During drought stress, the water balance of plants is disrupted, as result of which the RWC and water potential of leaves decreases (Bajjii et al.2001). Although RWC was higher in non-stressed plants than stressed ones, there were no significant differences between cultivars at these levels of RWC (Figure 2). Higher RWC was observed in genotypes Barakatli 95, Alinja 84, Tartar, Gyrmyzygul 1, Tale38, 12ndFAWWON№97, and 4thFEFWSN№50. The genotypes Tartar, Gyrmyzygul 1, Tale 38, 12ndFAWWON№97, and 4thFEFWSN №50 were late heading, and their younger flag leaves contained relatively more water. Lower RWC was observed in genotypes Shiraslan 23, Gobustan, Giymatli 2/17, Azamatli95. The genotypes Azamatli 95 and Gobustan were the earliest heading. Under the influence of water stress significant reduction of RWC was found in genotypes Garagylchyg 2 (12%), and Giymatli 2/17(14%). A slight decrease of RWC was observed in genotypes Vugar, Alinja

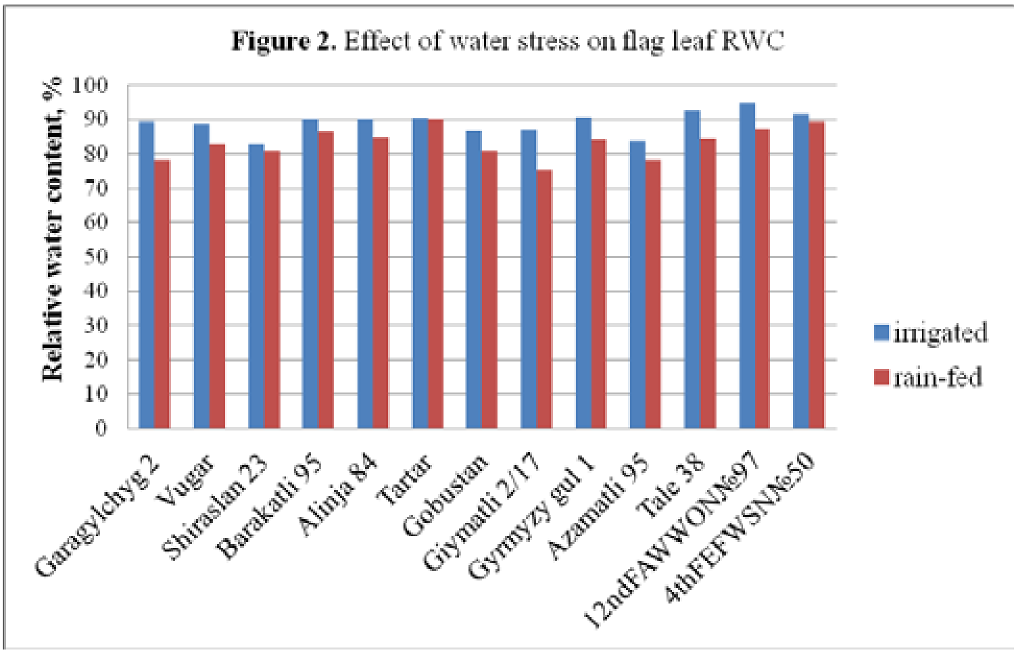



**Figure 2.** Effect of water stress on flag leaf RWC

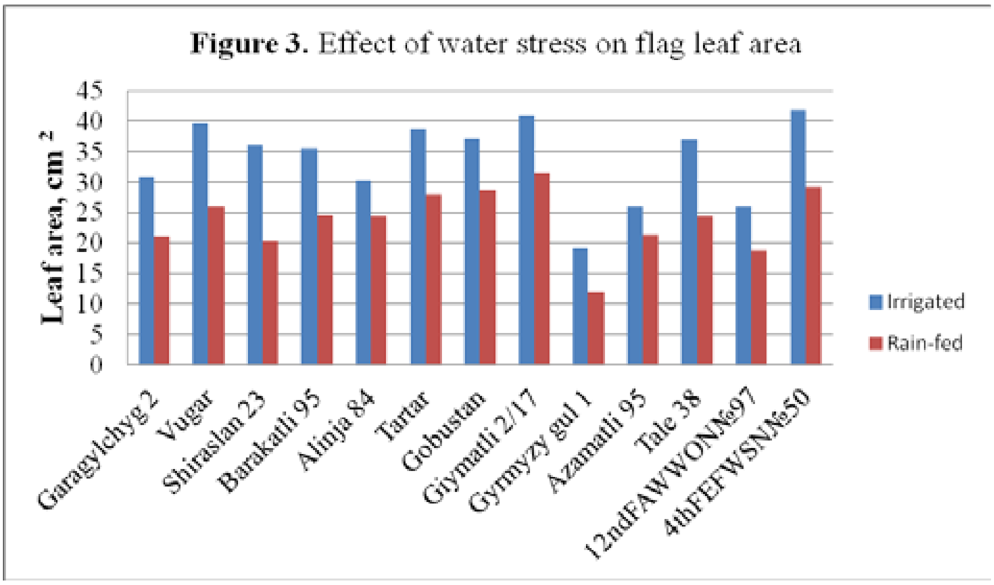
84, Gobustan, Gyrmyzygul 1, Azamatli 95, Tale 38, 12ndFAWWON№97, non-significant reduction in genotypes Shiraslan 23, Barakatli 95, and 4thFEFWSN№50. The difference in RWC of irrigated and rain-fed plants was almost imperceptible in genotype Tartar. In the field, strengthening of water stress occurs gradually, it allows plants to develop various mechanisms of adaptation to resist to water scarcity.

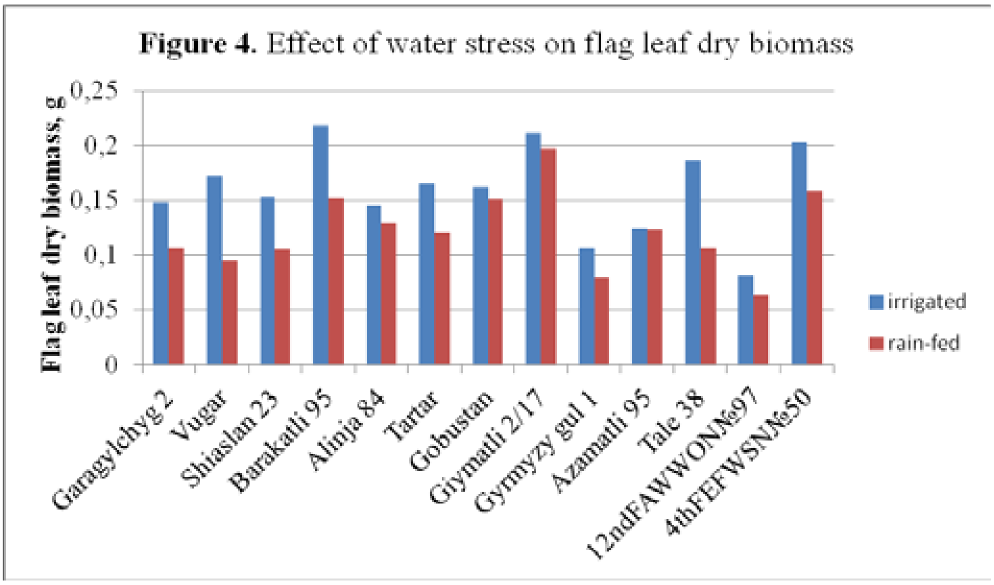
Effect of water stress on flag leaf area. Water stress limits the growth of assimilating surface area of flag leaf of tested wheat genotypes (Figure 3). The reduction in leaf size which results in smaller transpiring area, is an adaptive response to water deficit (Tardieu 2005). A significant decrease in the flag leaf area was observed in all genotypes. More profound reduction of flag leaf area was observed in genotypes Shiraslan 23 (44%) and Vugar (35%), Gyrmyzy gul 1(37%), Tale 38 (34%), Garagylchyg 2 (31%), Barakatli 95 (31%), 4thFEFWSN№50 (30%), 12ndFAWWON№97 (28%), Tartar (28%). Relatively little reduction of flag leaf area under water stress was observed in genotypes Azamatli 95(18%), Alinja 84 (20%), Gobustan (23%), Giymatli 2/17 (23%). Deep reduction can be explained to the fact that the formation of the flag leaf of late- heading wheat genotypes

(Vugar, Shiraslan 23, Tartar, Gyrmyzy gul1, Tale 38, 4thFEFWSN№50, and 12ndFAWWON№97) occurs at a severe water shortage. A more profound reduction of flag leaf area in these genotypes was compensated with conservation of RWC at high level.

Effect of water stress on flag leaf dry biomass. A common adverse effect of water stress on crop plants is the reduction in fresh and dry biomass production (Zhao et al. 2006). Water scarcity causes a decrease in dry biomass of flag leaf (Figure 4).

As in the case of leaf area, a strong reduction

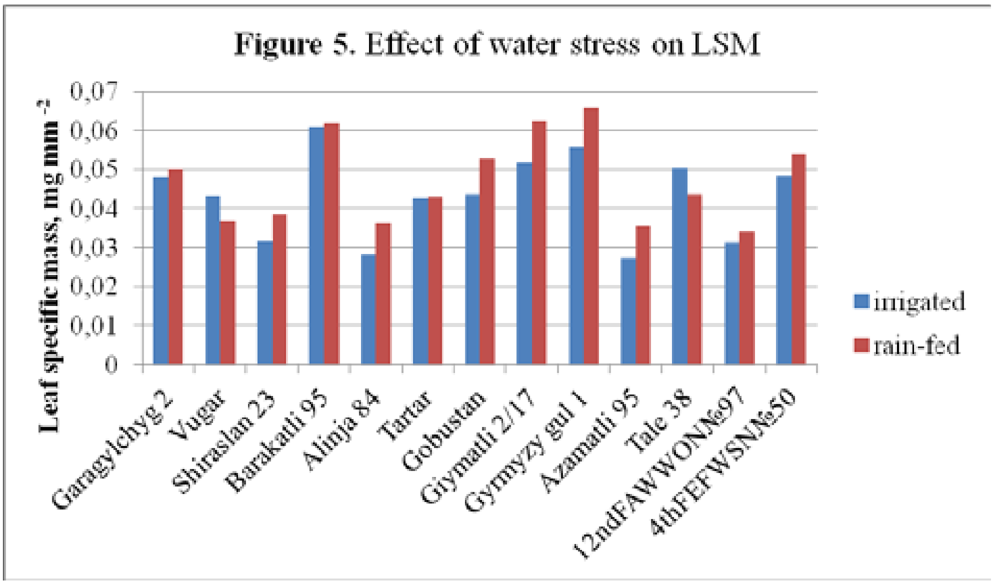



of dry biomass was observed in all genotypes of durum wheat, with exception of Alinja 84, in bread wheat genotypes Gyrmyzygul 1, Tale 38, 12ndFAWWON№97, 4thFEFWSN№50. A smaller reduction of flag leaf dry biomass under water stress was observed in genotypes Azamatli 95, Gobustan, Giymatli 2/17, Alinja 84. A more profound reduction of flag leaf dry mass was detected in genotypes Vugar (44%) and Tale 38 (43%).

Effect of water stress on Leaf Specific Mass (LSM). LSM calculated from the ratio of flag leaf dry mass to flag leaf area and it is inverse leaf specific area. LSM is considered to reflect relative carbon accumulation, at lower nutrient or moisture availabilities or at higher light irradiances, leaves tended to be smaller, with higher LSM, density and thickness (Witkowski and Byron 1991). It was revealed an increase of LSM under water stress in most wheat genotypes (Figure 5).Such an increase in the LSM is probably adaptive response to drought and is due to the relatively greater reduction in leaf area than the dry mass. A reduction of LSM was observed in genotypes Vugar and Tale 38, because of the greater reduction in dry mass. A higher LSM was observed in genotypes Barakatli 95, Gyrmyzygul 1, Giymatli 2/17, Tale 38, 4thFEFWSN№50,

Garagylchyg 2, lower LSM was observed in




genotypes Azamatli 95, Alinja 84, 12ndFAWWON№97, Shiraslan 23. A slight increase in LSM was observed in genotypes Garagylchyg 2, Barakatli 95, Tartar, more profound increase was observed in genotypes Azamatli 95, Alinja 84, Shiraslan 23, Giymatli 2/17, Gobustan, Gyrmyzygul 1.

Effect of water stress on photosynthetic pigments content. Photosynthetic pigments are important to plants mainly for harvesting light and production of reducing powers (Anjum et al. 2011). In general, water stress caused significant declines in photosynthetic pigments content, in the ratio of Chl(a+b)/Car(x+c) and increase in the ratio of Chla/b (Table 6).The decrease in chlorophyll content under drought stress may be the result of pigment photo-oxidation and chlorophyll degradation. Lower values of the ratio Chl(a+b)/Car(x+c) indicates water stress damage to the photosynthetic apparatus, which is expressed by faster breakdown of chlorophylls than carotenoids. Photosynthetic pigments were higher among bread wheat genotypes than durum wheat ones. Higher decrease of chlorophyll content was observed in genotypes Vugar (35%), Shiraslan 23 (29%), Barakatli 95 (21%), Gobustan (29%), Giymatli 2/17 (31%), Azamatli 95 (37%), and 4thFEFWSN№50 (28%). A slight decrease was observed in genotypes Gyrmyzy gul 1, 12ndFAWWON№97, Alinja 84, Tale 38 and Garagylchyg 2. An increase in Chl a/b could be due to more reduction in Chlb than Chla by water deficit.

Correlations between physiological parameters. Table 7 shows correlations between studied physiological parameters. The Pn was positively and significantly correlated with RWC, LA, and DW. The relationship between $P_n$ and $C_{hl}$ content was positive, but non-significant. Because the LSM is characteristics for water stress condition, the correlation between the Pn and LSM was negative, but non-significant. The RWC positively and significantly correlated with $C_{hl}$ content, positively but non-significantly correlated with LA and DW. Correlation between LA and DW was positive and significant, correlation between LA and Chl was positive but non-significant. The DW was positively, non-significantly correlated with LSM.

**Effect of water stress on plant height, exposed peduncle length, spike components:** Plant height and number of spikelet per spike, spike length and width were not reduced significantly under the influence of soil drought (Table 8). However, spike weight, number and weight of grains per spike were severely, as well as the exposed peduncle length was significantly reduced under the influence of soil drought.The decrease in the height of cultivars was more expressed among bread wheat genotypes. A significant reduction in plant height was observed in durum wheat genotype Tartar, and in all genotypes of bread wheat with the exception of Gobustan. The exposed peduncle has been identified as one of the photosynthetically active organs in wheat, contributes about 9-12% of grain dry mass (Wang et al. 2001). Long exposed peduncle was detected in genotypes Vugar, Shiraslan 23, Gobustan, Azamatli 95, 4thFEFWSN№50, short exposed peduncle was detected in genotypes Giymatli 2/17, Gyrmyzygul 1. Spike weight, grain number and grain weight per spike were more reduced in durum wheat genotypes Garagylchyg 2, Vugar, Barakatli 95, Alinja 84, Tartar, in bread wheat genotypes Gobustan, Giymatli 2/17, Gyrmyzygul 1, Azamatli 95, Tale 38, 12ndFAWWON№97, 4thFEFWSN№50. Large aboveground biomass was formed in genotypes Shiraslan 23, Gobustan, Tale 38, Gyrmyzygul 1 less in genotypes 12ndFAWWON№97, 4thFEFWSN№50. More reduction of aboveground biomass was observed in genotypes Vugar, Shiraslan 23, Alinja 84, Gobustan, Tale 38 less reduction in

Table 6. Changes of Chl a, b and Chl (a+b) contents, Car (x+c) content, Chl a/b and Chl (a+b)/Car (x+c) of wheat genotypes under water stress condition.

| Wheat genotypes | | Chl a mg $g^{-1}$dw | Chl b mg $g^{-1}$dw | Chl (a+b) mg $g^{-1}$dw | Car (x+c) mg $g^{-1}$dw | Chl a/b | Chl (a+b)/ Car (x+c) |
|---|---|---|---|---|---|---|---|
| *T. durum* Desf. | | | | | | | |
| Garagylchyg 2 | irr. | 7,14 | 3,34 | 10,48 | 1,76 | 2,14 | 5,96 |
| | r-f | 5,50 | 3,06 | 8,56 | 1,18 | 1,80 | 7,25 |
| Vugar | irr. | 6,02 | 2,93 | 8,95 | 1,45 | 2,06 | 6,16 |
| | r-f | 4,00 | 1,86 | 5,86 | 0,98 | 2,15 | 5,97 |
| Shiraslan 23 | irr. | 5,68 | 2,68 | 8,36 | 1,41 | 2,12 | 5,93 |
| | r-f | 4,08 | 1,89 | 5,97 | 1,02 | 2,15 | 5,84 |
| Barakatli 95 | irr. | 6,08 | 2,81 | 8,89 | 1,54 | 2,16 | 5,76 |
| | r-f | 4,83 | 2,19 | 7,02 | 1,15 | 2,21 | 6,09 |
| Alinja 84 | irr. | 5,10 | 2,66 | 7,76 | 1,24 | 1,92 | 6,26 |
| | r-f | 4,46 | 2,01 | 6,47 | 1,16 | 2,22 | 5,57 |
| Tartar | irr. | 4,90 | 2,51 | 7,41 | 1,17 | 1,96 | 6,34 |
| | r-f | 6,23 | 2,69 | 8,92 | 1,58 | 2,32 | 5,66 |
| *T.aestivum* L. | | | | | | | |
| Gobustan | irr. | 6,78 | 3,30 | 10,08 | 1,58 | 2,06 | 6,37 |
| | r-f | 5,08 | 2,57 | 7,65 | 1,20 | 1,98 | 6,35 |
| Giymatli 2/17 | irr. | 5,85 | 2,68 | 8,53 | 1,38 | 2,18 | 6,17 |
| | r-f | 4,07 | 1,84 | 5,91 | 1,12 | 2,21 | 5,26 |
| Gyrmyzygul 1 | irr. | 7,19 | 3,22 | 10,41 | 1,86 | 2,23 | 5,60 |
| | r-f | 7,17 | 3,06 | 10,24 | 1,93 | 2,34 | 5,31 |
| Azamatli 95 | irr. | 6,68 | 3,70 | 10,38 | 1,38 | 1,81 | 7,50 |
| | r-f | 4,43 | 2,06 | 6,49 | 1,12 | 2,15 | 5,82 |
| Tale 38 | irr. | 7,68 | 3,54 | 11,22 | 1,84 | 2,17 | 6,08 |
| | r-f | 6,44 | 3,13 | 9,57 | 1,60 | 2,06 | 5,99 |
| 12$^{nd}$FAWWON №97 | irr. | 6,80 | 3,57 | 10,37 | 1,67 | 1,98 | 6,21 |
| | r-f | 6,68 | 3,29 | 9,97 | 1,65 | 2,03 | 5,98 |
| 4$^{th}$FEFWSN №50 | irr. | 7,14 | 3,49 | 10,63 | 1,80 | 2,04 | 5,92 |
| | r-f | 5,20 | 2,49 | 7,69 | 1,34 | 2,08 | 5,75 |

Note: irr.-irrigated; r-f.-rain-fed

Table7. Correlations between different physiological parameters

| Parameters | $P_n$ | RWC | LA | DW | LSM | Chl |
|---|---|---|---|---|---|---|
| Pn | 1 | | | | | |
| RWC | 0,527** | 1 | | | | |
| LA | 0,798** | 0,321 | 1 | | | |
| DW | 0,674** | 0,116 | 0,845** | 1 | | |
| LSM | -0,171 | -0,327 | -0,201 | 0,330 | 1 | |
| Chl | 0,274 | 0,623** | 0,113 | -0,043 | -0,235 | 1 |

**. Correlation is significant at the 0, 01 level genotypes Tartar, 4$^{th}$FEFWSN№50, Gyrmyzygul 1, Giymatli 2/17. 1000 kernel weight (TKW) is a major yield component determining final yield, it may be a form of compensation for the spike reduction under water deficit condition (Moayedi et al. 2010). TKW was higher in genotypes Alinja 84, Tartar, Giymatli 2/17, was lower in genotypes Gyrmyzygul 1, 12$^{nd}$FAWWON№97 and 4$^{th}$FEFWSN№50. Profound decrease in the TKW observed in genotypes Tale 38, 12$^{nd}$FAWWON№97 and 4$^{th}$FEFWSN №50. The harvest index (HI) is the proportion of grain yield to biological yield and it shows the ability of the plants to translocate physiological matters to grains. We found an increase in HI in all genotypes with the exception of Gobustan.

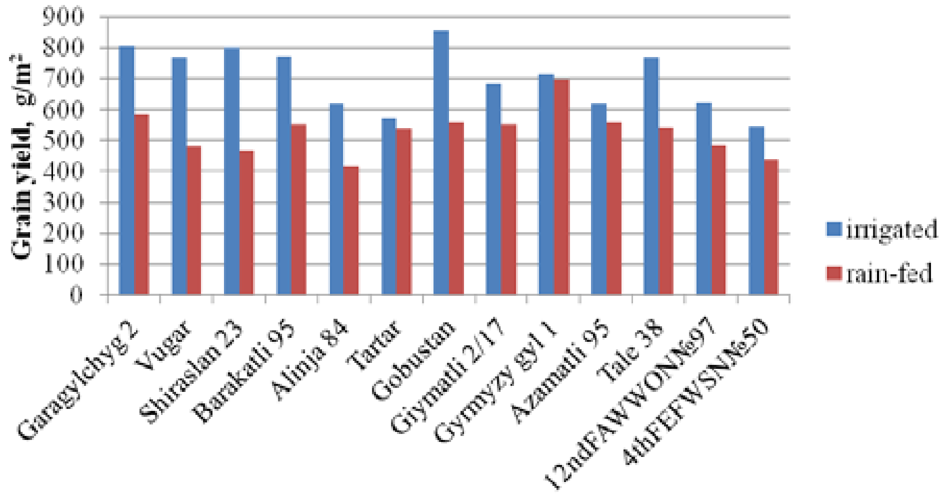
In rain-fed condition the ratio of grain yield to

Table 8. Effect of drought stress on yield and yield components

| | Genotypes | Plant height, cm | Exposed peduncle, cm | AGB, g | Spike weight, g | Spike length, cm | Spike width, cm | Spikelet per spike | Grain number per spike | Grain weight per spike,g | TKW g | HI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Irrigated condition | Garagilchig 2 | 100,00±0,49 | 18,57±0,24 | 1924 | 4,77±0,35 | 7,8±0,16 | 1,62±0,06 | 22,2±0,97 | 68,2±2,82 | 3,65±0,29 | 49,56 | 0,42 |
| | Vugar | 103,13±0,72 | 22,42±0,30 | 1971 | 4,42±0,26 | 7,8±0,15 | 1,64±0,02 | 22,2±0,58 | 68,0±3,56 | 3,43±0,18 | 45,35 | 0,39 |
| | Shiraslan 23 | 102,64±0,42 | 21,32±0,39 | 2053 | 3,50±0,18 | 8,0±0,21 | 1,56±0,05 | 19,8±0,70 | 50,0±3,65 | 2,72±0,16 | 47,51 | 0,39 |
| | Barakatli 95 | 101,97±0,72 | 18,29±0,21 | 1880 | 3,53±0,12 | 7,86±0,29 | 1,54±0,06 | 21,4±0,24 | 60,4±0,81 | 2,62±0,13 | 49,41 | 0,41 |
| | Alinja 84 | 102,97±0,50 | 18,26±0,25 | 1584 | 4,31±0,31 | 7,90±0,10 | 1,48±0,05 | 18,2±0,49 | 59,2±2,03 | 3,37±0,19 | 53,80 | 0,39 |
| | Tartar | 104,81±0,68 | 16,51±0,21 | 1587 | 4,77±0,48 | 8,63±0,16 | 1,78±0,07 | 20,0±0,57 | 57,6±6,28 | 3,40±0,36 | 57,63 | 0,36 |
| | Gobustan | 109,83±0,58 | 22,24±0,33 | 2021 | 3,41±0,14 | 10,86±0,07 | 1,28±0,03 | 17,8±0,2 | 58,6±2,5 | 2,72±0,12 | 44,45 | 0,42 |
| | Giymatli 2/17 | 104,07±0,65 | 13,07±0,27 | 1657 | 4,04±0,26 | 8,98±0,15 | 1,56±0,04 | 21,4±0,51 | 65,8±2,71 | 3,30±0,24 | 51,38 | 0,41 |
| | Gyrmyzygul 1 | 91,54±0,42 | 9,66±0,09 | 1949 | 2,11±0,10 | 7,78±0,16 | 1,14±0,05 | 16,0±0,31 | 49,4±2,23 | 1,71±0,09 | 36,07 | 0,37 |
| | Azamatli 95 | 108,61±0,48 | 24,49±0,29 | 1788 | 3,28±0,08 | 11,90±0,42 | 1,42±0,03 | 18,4±0,24 | 60,0±2,21 | 2,55±0,10 | 43,56 | 0,35 |
| | Tale 38 | 106,5±0,47 | 17,58±0,22 | 2039 | 4,11±0,14 | 11,16±0,14 | 1,22±0,05 | 21,0±0,31 | 64,2±2,81 | 3,02±0,10 | 44,03 | 0,38 |
| | 12$^{nd}$FAWWON№97 | 95,75±0,48 | 16,53±0,18 | 1498 | 1,88±0,15 | 8,10±0,26 | 1,12±0,04 | 14,3±0,49 | 39,0±2,39 | 1,49±0,12 | 37,22 | 0,42 |
| | 4$^{th}$FEFWSN№50 | 104,35±0,42 | 21,48±0,22 | 1334 | 3,65±0,11 | 10,38±0,08 | 1,46±0,02 | 19,2±0,37 | 62,2±0,91 | 2,73±0,09 | 42,66 | 0,41 |
| Rain-fed condition | Garagylchyg 2 | 93,91±0,57 | 15,29±0,16 | 1318 | 3,17±0,06 | 7,6±0,22 | 1,16±0,05 | 20,0±0,71 | 44,2±1,39 | 2,42±0,03 | 48,64 | 0,44 |
| | Vugar | 97,87±0,35 | 16,42±0,29 | 1186 | 3,17±0,18 | 7,0±0,17 | 1,48±0,05 | 20,2±0,58 | 50,8±2,54 | 2,59±0,16 | 44,74 | 0,41 |
| | Shiraslan 23 | 98,48±0,47 | 16,88±0,25 | 1146 | 2,72±0,20 | 6,88±0,09 | 1,40±0,03 | 18,7±0,42 | 45,0±2,31 | 2,17±0,20 | 43,91 | 0,41 |
| | Barakatli 95 | 96,12±0,54 | 15,13±0,14 | 1311 | 2,70±0,19 | 6,82±0,27 | 1,36±0,07 | 17,8±0,58 | 41,8±2,15 | 2,12±0,18 | 45,94 | 0,42 |
| | Alinja 84 | 98,12±0,48 | 14,72±0,23 | 1046 | 2,75±0,14 | 7,44±0,42 | 1,32±0,04 | 18,2±0,58 | 42,0±2,49 | 2,12±0,17 | 47,66 | 0,40 |
| | Tartar | 93,59±0,41 | 12,72±0,20 | 1290 | 3,25±0,40 | 8,12±0,38 | 1,38±0,05 | 18,8±0,8 | 44,6±4,69 | 2,46±0,31 | 54,12 | 0,42 |
| | Gobustan | 101,93±0,45 | 18,67±0,29 | 1353 | 2,17±0,27 | 9,62±0,24 | 1,00±0,03 | 16,2±0,37 | 43,6±3,53 | 1,75±0,20 | 41,73 | 0,41 |
| | Giymatli 2/17 | 89,22±0,72 | 10,89±0,25 | 1279 | 2,65±0,15 | 8,44±0,11 | 1,24±0,04 | 18,6±0,24 | 47,0±1,84 | 2,11±0,13 | 46,43 | 0,43 |
| | Gyrmyzygul 1 | 81,56±0,46 | 7,61±0,10 | 1518 | 1,30±0,04 | 7,72±0,03 | 0,98±0,02 | 15,5±0,22 | 36,0±1,87 | 1,07±0,07 | 31,72 | 0,46 |
| | Azamatli 95 | 97,10±0,46 | 19,82±0,33 | 1346 | 1,85±0,14 | 9,84±0,34 | 1,10±0,04 | 14,4±0,50 | 33,8±2,88 | 1,39±0,09 | 38,80 | 0,42 |
| | Tale 38 | 91,24±0,48 | 11,22±0,17 | 1391 | 1,72±0,08 | 8,60±0,07 | 1,08±0,03 | 16,6±0,24 | 36,8±1,15 | 1,14±0,06 | 35,94 | 0,39 |
| | 12$^{nd}$FAWWON№97 | 84,90±0,45 | 14,67±0,20 | 1103 | 1,26±0,04 | 7,04±0,14 | 0,96±0,02 | 12,4±0,24 | 29,6±0,40 | 1,01±0,04 | 30,50 | 0,44 |
| | 4$^{th}$FEFWSN№50 | 94,06±0,59 | 18,76±0,17 | 1053 | 2,05±0,13 | 8,96±0,33 | 1,12±0,03 | 16,2±0,73 | 41,4±2,80 | 1,51±0,09 | 30,33 | 0,42 |

Note: AGB-aboveground biomass, TKW-thousand kernel weight, HI- harvest index

**Figure 6.** Effect of water stress on grain yield




AGM significantly increased in genotypes Tartar, Gyrmyzygul 1, Azamatli 95.

The grain yield is the total out-put of all the yield components. The average yield of all genotypes dropped considerably under water deficit condition (Figure 6). More reduction of grain yield was observed in genotypes Vugar (37%), Shiraslan 23(42%), Barakatli 95 (29%), Alinja 84 (33%), Gobustan (35%), and Tale 38 (29%). We consider these genotypes as drought susceptible. Less reduction of grain yield was observed in genotypes Gyrmyzygul 1(2%), Tartar (6%), Azamatli 95(9%). We consider these genotypes as drought tolerant.

In the present study, it was observed that leaf gas exchange parameters ($P_n$, $g_s$, $T_r$) were positively correlated with DH, PH, AGB, SW, spike width, spikelet per spike, GNS, GWS (Table 9). Correlation between $g_s$ and EPL, $g_s$ and GY, also $T_r$ and EPL, $T_r$ and GY were significant. The lack of significant correlation between $P_n$ and grain yield suggests that selection for higher rates of leaf photosynthesis has not improved yield most probably because the source is less limiting than the sink (Bogale et al. 2011). LA was strongly correlated with PH and SW, SGN and SGW, which suggests that large leaf area contributes formation of more assimilates that is transported to the spike. RWC was only significantly correlated with DH. LDW was positively and significantly correlated with PH, AGB, SW, spike width, spikelet per spike, SGN and SGW. Chl content was positively and significantly correlated with PH, spike/m², AGB, SL and GY. PH, SW, spikelet per spike, SGN, SGW positively and significantly correlated with most physiological parameters. Therefore, these traits may deem a good criterion for selection.

Note: DH- days to heading, PH-plant height,

Table 9. Correlations between physiological parameters and plant height, exposed peduncle length, yield and yield components

| Traits | Pn | gs | Tr | LA | RWC | LDW | LSM | Chl |
|---|---|---|---|---|---|---|---|---|
| DH | 0,471* | 0,390* | 0,496** | 0,321 | 0,688** | 0,130 | -0,282 | 0,444* |
| PH | 0,566** | 0,665** | 0,588** | 0,742** | 0,170 | 0,587** | -0,199 | 0,080 |
| EPL | 0,325 | 0,484* | 0,458* | 0,504** | 0,00 | 0,322 | -0,300 | 0,067 |
| Spike/m2 | -0,056 | 0,132 | 0,034 | -0,073 | 0,384 | -0,136 | -0,086 | 0,656** |
| AGB | 0,435* | 0,775** | 0,612** | 0,498** | 0,324 | 0,413* | -0,024 | 0,545** |
| GY | 0,329 | 0,723** | 0,515** | 0,416* | 0,283 | 0,361 | 0,033 | 0,563** |
| SW | 0,683** | 0,696** | 0,659** | 0,635** | 0,261 | 0,496* | -0,160 | 0,059 |
| SL | 0,271 | 0,383 | 0,312 | 0,360 | 0,027 | 0,329 | 0,001 | 0,412* |
| SWH | 0,600** | 0,578** | 0,641** | 0,555** | 0,218 | 0,414* | -0,166 | -0,145 |
| Spikelet/Spike | 0,584** | 0,534** | 0,524** | 0,529** | 0,121 | 0,511** | 0,036 | -0,028 |
| SGN | 0,745** | 0,788** | 0,720** | 0,715** | 0,378 | 0,621** | -0,074 | 0,297 |
| SGW | 0,669** | 0,695** | 0,652** | 0,634** | 0,257 | 0,495* | -0,162 | 0,040 |
| TKW | 0,456* | 0,371 | 0,375 | 0,408* | 0,020 | 0,345 | -0,066 | -0,263 |
| HI | -0,493* | -0,463* | -0,525** | -0,451* | -0,223 | -0,327 | 0,173 | -0,094 |

**, Correlation is significant at the 0, 01 level *, Correlation is significant at the 0, 05 level

EPL-exposed peduncle length, S/$m^2$-spike per $m^2$, AGB-aboveground biomass, GY-grain yield, SW-spike weight, SL-spike length, SWH- spike width, SGN-spike grain number, SGW-spike grain weight, TKW- thousand kernel weight, HI- harvest index

**Conclusion**

Soil water deficit caused a decrease in gas exchange parameters, area, dry weight, photosynthetic pigments of flag leaf from durum and bread wheat genotypes. Stomatal conductance regulates photosynthesis rate and transpiration rate. Strong relationships were detected between stomatal conductance and transpiration rate, between mesophyll conductance and photosynthesis rate. Photosynthesis is less inhibited than transpiration rate under water stress. Despite the fact that the gas exchange parameters, leaf area and dry mass strongly influenced by drought, relative water content in the flag leaf remained relatively high. Water scarcity leads to a greater reduction in leaf area than the dry weight, as a result of the specific leaf mass increases. Under influence of water stress the content of photosynthetic pigments, also the ratio of chlorophyll to carotenoids decreases. Water stress significantly reduces spike weight, grain number and grain weight per spike. Grain yield non-significantly correlated with photosynthesis rate, but significantly correlated with chlorophyll content. Most decrease in the area and dry mass of flag leaf was observed in durum wheat genotypes. The chlorophyll content was highest in the flag leaf of bread wheat genotypes. The greatest reduction in plant height was observed in genotypes of bread wheat. The largest decrease in the weight of the spike, in the number and weight of grain per spike were observed in genotypes of bread wheat. Durum wheat genotype Vugar, and bread wheat genotype Tale 38 were more sensitive to soil drought.

## References


Akram M (2011). Growth and yield components of wheat under water stress of different growth stages. Bangladesh J.Agril.Res. 36(3) :455- 468.

Aliyev J.A (2001). Physiological bases of wheat breeding tolerant to water stress. Proceedins of the 6th International Wheat Conference, Budapest, Hungary, 2000. In: Wheat in a Global Environment (Bedo Z, Lang L, eds.), Kluwer Academic Publishers, Dordrecht, Boston, London 9:693-698.

AnjumSA, Xie X, Wang L, Salem MF, Man Cand Lei W (2011). Morphological, physiological and biochemical responses of plants to drought stress. African Journal of Agricultural Research 6(9): 2026-2032.

Bajjii M, Lutts S, Kinet KM (2001). Water deficit effects on solute contribution to osmotic adjustment as a function of leaf ageing in three durum wheat (*Triticum durum* Desf) cultivars performing in arid conditions. Plant Science 60: 669-681.

Beltrano J, Marta GR (2008). Improved tolerance of wheat plants (*Triticumaestivum* L.) to drought stress and rewatering by the arbuscularmycorrhizal fungus Glomusclaroideum: Effect on growth and cell membrane stability. Braz.J.Plant Physiol 20(1): 29-37.

Blum A (1986). Breeding crop varieties for stress environments.Critical Reviews in Plant Sciences 2: 199-237.

Bogale A, Tesfaye K, Geleto T (2011). Morphological and physiological attributes associated to drought toleranxe of Ethiopian durum wheat genotypes under water deficit condition. Journal of Biodiversity and Environmental Sciences 1(2):22-36.

Chaves MM (1991). Effects of water deficits on carbon assimilation. Journal of Experimental Botany 42: 1-16.

Chaves MM, Pereira JS, Maroco J, Rodrigues ML, Ricardo CP, Osorio ML, CarvalhoJ, Faria T and Pinheiro C (2002). How Plants Cope with Water Stress in the Field. Photosynthesis and Growth. Annals of Botany 89:907-916.

Cornic G, Massacci A (1996). Leaf photosynthesis under drought stress. In: Baker NR, ed. Photosynthesis and Environment. The Netherlands: Kluwer Academic Publishers.

Flexas J, Bota J, Loreto F, Cornic Gand Sharkey TD (2004). Diffusive and metabolic limitations to photosynthesis under drought and salinity in C3 plants. Plant Biology 6: 269-279.

Kramer PJ (1980). Drought, stress, and the origin of adaptation. In Adaptation of Plants to Water and High Temperature Stress (eds N. C. Turner and P.J.Kramer) pp. 7-20. John Wiley and Sons, New York, NY, USA.

Lawlor DW, Cornic G. (2002). Photosynthetic carbon assimilation and associated metabolism in relation to water deficits in higher plants. Plant, Cell & Environment 25: 275-294.

Levitt J(1980). Stress terminology. In: Turner NC, Kramer PJ, editors. Adaptation of plants to water and high temperature stress. New York: Wiley pp.439-473.

Lichtenthaler HK (1987). Chlorophylls and carotenoids: Pigments of photosynthetic biomembranes.-Methods in Enzymology 148: 350-382.

Mitchell JH, Siamhan D, Wamala MH, Risimeri JB, Chinyamakobvu E, Henderson SA, Fukai S (1998). The use of seedling leaf death score for evaluation of drought resistance of rice. Field Crops Research 55: 129-139.

Moayedi AA, Boyce AN, Barakbah SS (2010). The Performance of Durum and Bread Wheat Genotypes Associated with Yield and Yield Component under Different Water Deficit Conditions. Australian Journal of Basic and Applied Sciences 4(1): 106-113.

Richards A (2000). Selectable traits to increase crop photosynthesis and yield of grain crops. Journal of Experimental Botany 51:447-458.

Schapendonk AHCM, Spitters CJT, Groot PJ (1989) .Effects of water stress on photosynthesis and chlorophyll fluorescence of five potato cultivars. Potato Research 32: 17-32.

Shao HB, Liang ZS, Shao MA, Wang BC (2005). Changes of some physiological and biochemical indices for soil water deficits among 10 wheat genotypes at seedling stage.Colloids Surf. B: Biointerfaces 42(2): 107-211.

Siddique MRB, Hamid A, Islam MS (1999). Drougth stress effects on photosynthetic rate and leaf gas exchange of wheat. Bot.Bull.Acad.Sin. 40: 141-145.

Tang AC, Kawamitsa Y, Kanechi M and Boyer JS (2002). Photosynthesis at low water potentials in leaf discs lacking epidermis. Annals of Botany 89(7):861-870.

Tardieu F (2005). Plant tolerance to water deficit: physical limits and possibilities for progress. Comptes Rendus Geoscience 337: 57-67.

Veesar NF, Channa AN, Rind MJ, Larik AS (2007). Influence of water stress imposed at different stages on growth and yield attributes in bread wheat genotypes (*Triticum aestivum* L.) Wheat Inf. Serv. 104: 15-19.

Wang ZM, Wei AI, Zheng DM (2001). Photosynthetic characteristics of non-leaf organs of winter wheat cultivars differing in ear type and their relationship with grain mass per ear. Photosynthetica 39(2):239-244.

Witkowski, ETF and Lamont BB (1991). Leaf specific mass confounds leaf density and thickness. Oecologia 88(4): 486-493.

Zhao TJ, Sun S, Liu Y, Liu JM, Yan YB, Zhou HM (2006). Regulating the drought-responsive element (DRE)-mediated signaling pathway by synergic functions of transactive and transinactive DRE binding factors in Brassica napus. J.Biol.Chem. 281: 10752-10759.