ABSTRACT

A trial was conducted in greenhouse of Crop Physiology Department at Giza Experimental Research Station, ARC, during the two summer seasons of 2012 and 2013 to study the physiological behavior of two grain sorghum genotypes i.e. Dorado cultivar and hybrid 305 to different levels of water applied i.e. 3500 m³/fed (wet), 3000 m³/fed (moist), 2500 m³/fed (medium) and 2000 m³/fed (dry).

Results could be summarized as follows:
- Decreasing water applied treatments up to irrigation by 2000 m³/fed (dry treatment) significantly decreased plant height, leaf area index (LAI) at 49, 63, 77 and 91 days after sowing (DAS), crop growth rate (CGR) at (49-63), (63-77) and (77-91) periods and chlorophyll fluorescence. Dry treatment (2000 m³/fed) significantly reduced head length, grain weight/head, 1000-kernel weight, green and grain yields as well as total carbohydrates in grain. Exposing grain sorghum plants to dry conditions (2000 m³/fed) decreased relative water content (RWC), seasonal water consumptive use (WCU) and water use efficiency (WUE).
- Hybrid 305 surpassed Dorado cultivar in all traits under study. Hybrid 305 recorded the maximum values of grain yield and water use efficiency under all irrigation treatments compared with Dorado cultivar which improved that hybrid 305 endure water deficit conditions.

The interaction between water applied treatment and sorghum genotypes had a significant effect on all traits under study. The maximum value of grain yield was obtained when hybrid 305 irrigated by wet treatment followed by moist treatment. While, the maximum value of WUE was obtained by irrigated hybrid 305 with moist treatment followed by wet treatment, with no significant effect between such treatments.

Key words: Grain sorghum, Sorghum bicolor, Physiological behavior, Water supply, Productivity.

Introduction

Grain sorghum (Sorghum bicolor (L.) Moench) is considered as one of the most adapted summer cereal crops to water deficit and salinity conditions. In Egypt, water supply is the main limiting factor for increasing the cultivated area. Therefore estimating water consumptive use, water use efficiency and productivity of Sorghum genotypes at different growth and reproductive stages are very important aspects to optimize crop water requirements and the optimum genotype for high production under water deficit conditions. With respect to the effect of water supply on grain sorghum production, Bashir et al. (1994) reported that the maximum grain yield of sorghum crop was obtained from the wet soil moisture level and water deficit significantly decreased grain yield. Ibrahim (1995) found that grain and forage yield were significantly reduced by soil moisture stress. Sankarapandian and Sanganusamy (1996) noted that the interaction between sorghum genotypes and water stress treatments was significant for grain and stover yield. Ragheb and Elnagar (1997) reported that irrigated grain sorghum plants at 30-days interval significantly reduced the grain yield by 20.14% and depressed the growth of sorghum plants compared to 10-days interval. Latifet al. (2000) showed that irrigation at 21 days intervals significantly decreased plant height, leaf area index (LAI), panicle length, panicle weight, panicle grain weight and grain yield comparing with 7 and 14 days intervals. Mouradet al. (2000) concluded that increasing number of irrigations from 2 to 5 increased panicle weight, grain weight per panicle, 1000 kernel weight, green yield, total biomass and grain yield of Shandwell-2 hybrid. Mourad and Anton (2007) reported that increasing soil moisture stress up to 65-70% available soil moisture depletion (ASMD) decreased plant height, leaf area index (LAI) and crop growth rate (CGR) of grain sorghum plant. Abdel-Motagally (2010) found that irrigated Shandaweel-6 hybrid by 6240 m³/ha gave the highest values of head length, head weight, grain yield/head and straw yield kg/plot.

The present investigation was carried out to study the physiological behavior of two grain sorghum genotypes to different irrigation of water applied levels.

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Materials and Methods

The present work was carried out in greenhouse of Crop Physiology Department at Giza Experimental Research Station, ARC, during the two summer seasons of 2012 and 2013 to study the physiological behavior of two grain sorghum genotypes under different irrigation of water applied levels. The experiment was carried out in cementing basins 10m length, 2m width and 70 cm depths. The soil was clay loam in structure with pH value of 7.8 and 1.8% organic matter and containing 34.2 ppm nitrogen. The experiment was laid out in a split plot design with three replicates. The main plots were occupied by water applied levels, while sub-plots contained genotypes of grain sorghum. Each sub-plot was 3m² (1.5×2m) and included 3 ridge, 2m long and 50 cm apart.

The treatments are as follows:

I- Main plots (water applied levels):
   A- Irrigation by 3500 m³/fed (wet).
   B- Irrigation by 3000 m³/fed (moist).
   C- Irrigation by 2500 m³/fed (medium).
   D- Irrigation by 2000 m³/fed (dry).

II- Sub-plots (Genotypes):
   1- Dorado cultivar.
   2- Hybrid 305.

Sorghum grains were planted on 12/6/2012 and 9/6/2013 in the first and second season, respectively, in hills spaced 20cm. Plants were thinned to two plants per hill 21 days after sowing. 15 kg P₂O₅/fed as calcium superphosphate was added before sowing. 60 kg N/fed (33.5% N) as ammonium nitrate and 24 kg K₂O/fed in the form of potassium sulphate (48% K₂O) were added at 21 days after sowing. Irrigation treatments were applied at 30 days after sowing. Cultural practices were practiced according to methods being adopted for growing grain sorghum crop in the locality.

Growth traits:

For growth analysis, five plants were randomly taken from the outer ridges of the three replications. The sampling dates were 49, 63, 77 and 91 days after sowing (DAS). In each sample, plants were separated into their components; i.e., roots, leaves, stems and panicles. Plant parts were dried at 70°C in a ventilated oven to the constant weight. To determine leaf area (LA) = leaf length × maximum leaf width × 0.75, according to Strickler (1964). The following characters were collected:

1- Leaf area index (LAI).
2- Crop growth rate (CGR), in g/plant/week.

The following formulae were used to determine such characters according to Watson (1952).

LAI = Unit leaf area per plant / unit ground area occupied by plant
CGR = (w₂ - w₁) / (t₂ - t₁).

Where:

w₂-w₁ = differences in dry mter accumulation of whole plants between two successive samples, in grams.
t₂-t₁ = Number of days between two successive samples, in weeks.

Yield and its attributes:

Harvesting took place 16/10/2012 and 13/10/2013 in the first and second season, respectively. At harvest time, five individual guarded plants were randomly taken from each sub-plot to determine:

1- Plant height (cm).
2- Head length (cm).
3- Grain weight / head (g).
4- 1000 kernel weight (g).
5- Green yield (Kg/m²).
6- Grain yield (g/m²).

Green and grain yields were obtained from a central ridge (m²) in each sub-plot to avoid the border effect.

Physiological traits:

1- Leaf chlorophyll fluorescence was determined for each treatment at 70 days after sowing to calculate the maximum quantum yield of photo-system II (PSII) using Chlorophyll Fluorometer (OS-30, Opti-Sciences, Inc. USA) in four plants by formula of Maxwell and Johnson (2000) as follow:

Fv/Fm = (Fm - F₀) / Fm

Where:
Fv/Fm is the maximal quantum efficiency of PSI (MQE), Fm is the maximal chlorophyll fluorescence and F0 is the minimum chlorophyll fluorescence (in the dark).

2- Relative water content of leaves (RWC%)

At 70 days after sowing, leaf samples were immediately weighed (fresh weight, Fw) and transferred into sealed flasks, then rehydrated in water for 5h until fully turgid at 4°C, surface swabbed and reweighed (turgid weight, TW). Leaf samples were oven dried at 70°C for 48 h and reweighed (dry weight, DW). RWC% was calculated according to Lazcano-Ferrat and Lovatt (1999) as follows:

\[ \text{RWC} \% = \frac{(F_w - D_w)}{(T_w - D_w)} \times 100 \]

Mature grains samples from the two growing seasons were subjected to determine the total carbohydrates content as glucose % according to Dubois et al (1956).

Water relations:

A- Water consumptive use (WCU):

Soil samples were taken, using a regular auger, at planting time, just before and 48 hours after each irrigation and at harvesting time for soil moisture determination. Duplicate of soil samples were taken from 0-150, 150-300, 300-450 and 450-600 mm depths and their moisture contents were determined gravimetrically. Field capacity, permanent wilting point, bulk density and available moisture were determined for the experimental site and presented in the following Table.

<table>
<thead>
<tr>
<th>Depth (mm)</th>
<th>Wilting point %</th>
<th>Field capacity %</th>
<th>Available water %</th>
<th>Bulk density g/cm³</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-150</td>
<td>19.34</td>
<td>40.82</td>
<td>21.48</td>
<td>1.05</td>
</tr>
<tr>
<td>150-300</td>
<td>15.01</td>
<td>31.68</td>
<td>16.67</td>
<td>1.14</td>
</tr>
<tr>
<td>300-450</td>
<td>12.02</td>
<td>25.38</td>
<td>13.36</td>
<td>1.20</td>
</tr>
<tr>
<td>450-600</td>
<td>8.36</td>
<td>18.07</td>
<td>9.51</td>
<td>1.26</td>
</tr>
</tbody>
</table>

The following equation was used to calculating water consumptive use according to (Israelsen and Hansen, 1962):

\[ \text{Cu} = D \times \text{Bd} \times (e_2 - e_1) / 100 \]

Where:

\( \text{Cu} \) = water consumptive use (ET) in mm
\( D \) = Soil depth (mm)
\( \text{Bd} \) = Bulk density in g/cm³
\( e_1, e_2 \) = Soil moisture content before and after each irrigation

B- Water use efficiency (WUE):

Water use efficiency was calculated for each treatment according to the equation described by Vites (1965). As follows:

\[ \text{WUE} = \frac{\text{grain yield (g/fed)}}{\text{seasonal water consumption in m}^3/\text{fed}} \]

Data of the two seasons were combined and statistically analyzed according to Steel and Torrie (1980). The discussion of the results were carried out on the basis of combined analysis for the two seasons.

Results and Discussion

I- Growth traits:

1- Leaf area index (LAI):

Data in Table (1) show that leaf area index (LAI) increased with increasing plant age up to 91 days after sowing (DAS). This is mainly due to the production of new leaves as well as leaves expansion. The wet treatment had the highest value of LAI followed by the moist one at different growth stages under study i.e. 49, 63, 77 and 91 DAS. It can be noticed that a significant difference was recorded between wet and moist treatments on LAI at 49 and 91 DAS. However, medium and dry treatments gave the lowest values of leave area index at different growth stages. Such reduction may be due to the decrease in leaf area and number of leaves/plant. These results are in harmony with those obtained by Mourad et al. (2000) and Mourad and Anton (2007).

Regarding the behavior of grain sorghum genotypes under study, a significant difference in LAI was recorded. Hybrid-305 surpassed Dorado cultivar in this trait.
Concerning the interaction between water applied treatments and genotypes, a significant effect on LAI was recorded at different growth stages. The maximum values of LAI at different growth stages were obtained when hybrid-305 was irrigated by 3500 m³/fed. Mourad and Anton (2007) recorded similar results.

2- Crop growth rate (CGR):

Table (1) shows CGR of grain sorghum genotypes as affected by water applied treatments. CGR of grain sorghum plant was higher in the second period (63-77 DAS) than in the third one (77-91 DAS). Such decrease at the third period is mainly due to that grain sorghum plants directed its effort to flowering and grain formation. It is worthy to mention that the lowest value of CGR was gained at the first period (49-63 DAS). In addition, the maximum value of CGR at the second period (63-77 DAS) revealed that this period is considered the peak period of growth for grain sorghum plants. It is clear that water applied treatments recorded a significant effect on CGR at the three growth periods.

Decreasing water applied levels from 3500 m³/fed to 2000 m³/fed significantly decreased CGR at all studied growth periods.

Such trend may be due to the importance of water to dry matter accumulation of photosynthesate compounds. These results are in harmony with those obtained by Abdel-Aziz and El-Bialy (2002). They reported that CGR of maize plants significantly decreased by increasing soil moisture depletion from 35-40% to 75-80% at all studied growth periods. Bibiet et al. (2012) they found that dry and fresh weights of grain sorghum roots were decreased during the drought period as their leaf size remained small to minimize transpiration, ultimately plant dry weight also reduced.

Regarding the behavior of grain sorghum genotypes, results of Table (1) recorded a significant effect on CGR at all periods under study. It could be observed that hybrid-305 significantly surpassed Dorado cultivar. Similar results were obtained by Mourad and Anton (2007) on grain sorghum plant.

The interaction between the two factors under study had a significant effect on CGR. The maximum value of CGR was obtained when hybrid-305 received 3500 m³/fed at the three growth periods i.e. (49-63 DAS), (63-77 DAS) and (77-91 DAS).

Table 1: Leaf area index (LAI) and crop growth rate (CGR) of two grain sorghum genotypes as affected by water applied levels in 2012 and 2013 summer seasons.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Genotypes</th>
<th>49 DAS</th>
<th>63 DAS</th>
<th>77 DAS</th>
<th>91 DAS</th>
<th>49-63 DAS</th>
<th>63-77 DAS</th>
<th>77-91 DAS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3500 m³/fed (wet)</td>
<td>Dorado H. 305</td>
<td>6.85</td>
<td>7.04</td>
<td>7.62</td>
<td>8.47</td>
<td>13.66</td>
<td>13.91</td>
<td>13.94</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>7.18</td>
<td>7.30</td>
<td>7.87</td>
<td>8.56</td>
<td>14.12</td>
<td>14.37</td>
<td>14.40</td>
</tr>
<tr>
<td>3500 m³/fed (moist)</td>
<td>Dorado H. 305</td>
<td>5.67</td>
<td>5.87</td>
<td>6.36</td>
<td>7.18</td>
<td>11.05</td>
<td>11.61</td>
<td>11.64</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>5.82</td>
<td>5.96</td>
<td>6.55</td>
<td>7.37</td>
<td>11.37</td>
<td>11.93</td>
<td>11.96</td>
</tr>
<tr>
<td>2500 m³/fed (medium)</td>
<td>Dorado H. 305</td>
<td>4.37</td>
<td>4.54</td>
<td>5.04</td>
<td>5.74</td>
<td>9.73</td>
<td>10.32</td>
<td>10.35</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>4.47</td>
<td>4.63</td>
<td>5.23</td>
<td>5.93</td>
<td>10.60</td>
<td>11.29</td>
<td>11.32</td>
</tr>
<tr>
<td>2000 m³/fed (dry)</td>
<td>Dorado H. 305</td>
<td>3.42</td>
<td>3.58</td>
<td>4.07</td>
<td>4.74</td>
<td>8.82</td>
<td>9.41</td>
<td>9.44</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>3.52</td>
<td>3.68</td>
<td>4.21</td>
<td>4.90</td>
<td>9.79</td>
<td>10.48</td>
<td>10.51</td>
</tr>
<tr>
<td>General mean of genotypes</td>
<td>Dorado H. 305</td>
<td>3.70</td>
<td>3.86</td>
<td>4.34</td>
<td>5.01</td>
<td>8.93</td>
<td>9.52</td>
<td>9.55</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>3.81</td>
<td>4.02</td>
<td>4.50</td>
<td>5.19</td>
<td>9.87</td>
<td>10.56</td>
<td>10.59</td>
</tr>
</tbody>
</table>

II. Plant height and yield attributes:

1- Plant height:

Results in Table (2) indicated that both water applied treatments and genotypes had significant effects on plant height. The tallest plants were obtained from the wet treatment which was watered by 3500 m³/fed followed by the moist one which irrigated by 3000 m³/fed with no significant difference between them. However, the shortest plants were obtained from irrigated plants by dry treatment (2000 m³/fed). These findings explain that, increasing water applied level enhanced plant height by controlling the elongation of the above ground part of plant. In this respect, Noureldine et al. (1986) reported that the reduction in plant height of maize plants exposed to water stress conditions may be due to the reduction in internodes length. In addition, Abdel-Motagally (2010) showed that irrigation grain sorghum plants by 4680 m³/ha gave the highest values of plant height.

The difference between the two grain sorghum genotypes under study was found to be significant with respect to plant height. Hybrid-305 surpassed Dorado cultivar in plant height trait. In this connection, Bakheit(1990) as well as Mourad and Anton (2007) concluded that the differences between the long-stem and the short-stem cultivars could be attributed to the genetic marks up of cultivars.
The interaction between water applied treatments and genotypes had a significant effect on plant height. The maximum value of plant height was obtained when hybrid-305 received 3500m³/fed (wet treatment). The genotypic differences in plant height might be due to water stress treatments (Blum, 1982).

2-Head characters:

Data in Table (2) show that water applied treatments had a significant effect on head length, grain weight/head and 1000 kernel weight. Such characters significantly increased when plants were irrigated by wet treatment followed by moist treatment with no significant difference between wet and moist treatments for 1000 kernels weight trait. In addition, such characters significantly decreased when plants were exposed to severe water deficit (dry treatment).

These results revealed that increasing soil moisture stress reduced grain sorghum growth, which in turn affected yield attributes. On the contrary, high moisture level (wet treatment) enhanced growth of plants thereby improved yield attributed traits. In this connection, Bashir et al. (1994) concluded that irrigating grain sorghum at 25.30% depletion of available soil moisture increased panicle length, panicle width, grain weight/panicle, number of grains/panicle and seed index.

Results in Table (2) show significant differences between the two genotypes in head length, grain weight/head and 1000 kernel weight. Hybrid 305 had the maximum values of such traits compared with Dorado cultivar.

The interaction between water applied treatments and genotypes had significant effect on all yield attributes traits under study. The maximum values of head length, grain weight/head and 1000 kernel weight were obtained by hybrid-305 when watered by 3500m³/fed (wet treatment). In this connection, Abdel-Motagally (2010) reported that the highest value of head length and head weight were obtained when Shandaweel-6 hybrid irrigated by 6240 m³/ha.

III- Green and grain yields:

The effect of water applied treatment and genotypes on the productivity of grain sorghum expressed as green yield kg/m² and grain yield g/m² are presented in Table (2). Both green and grain yields recorded a significant effect. The highest values of green yield and grain yields/m² were scored from the wet treatment (3500m³/fed), followed by the moist treatment (3000m³/fed). The lowest productivity of green and grain yields/m² were recorded from severe water deficit, 2000 m³/fed (dry treatment) with significant difference between this treatment and other irrigation treatments. This trend could be due to the effect of water deficit on grain sorghum growth and yield attributes which were in turn reflected on green and grain yield productivity. In this respect, El-Sarag and Abu Hashem (2009) found that forage sorghum exposed to water stress reduced dry matter which affected negatively forage yield. Also, Beheshi and Behoodi-Fard (2010) showed that water stress significantly decreased biological and grain yield of grain sorghum plants. It can be observed that the difference in yield production between the wet and moist treatments was found to be insignificant.

Table 2: Plant height, yield and yield attributes of two grain sorghum genotypes as affected by water applied levels in 2012 and 2013 summer seasons.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Water applied levels</th>
<th>Genotypes</th>
<th>Plant Height</th>
<th>Head length (cm)</th>
<th>Grain weight / head (g)</th>
<th>1000 - kernels weight (g)</th>
<th>Grain yield (g/m²)</th>
<th>Green Yield (kg/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3500 m³/fed (wet)</td>
<td>Dorado H. 305</td>
<td>158.7</td>
<td>173.7</td>
<td>21.7</td>
<td>18.9</td>
<td>52.43</td>
<td>50.86</td>
<td>51.55</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>154.3</td>
<td>160.6</td>
<td>20.8</td>
<td>17.2</td>
<td>53.86</td>
<td>51.57</td>
<td>52.93</td>
</tr>
<tr>
<td>3000 m³/fed (moist)</td>
<td>Dorado H. 305</td>
<td>150.6</td>
<td>173.2</td>
<td>23.6</td>
<td>20.0</td>
<td>54.72</td>
<td>52.86</td>
<td>53.83</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>151.2</td>
<td>173.7</td>
<td>23.3</td>
<td>19.6</td>
<td>54.87</td>
<td>52.79</td>
<td>53.86</td>
</tr>
<tr>
<td>2500 m³/fed (medium)</td>
<td>Dorado H. 305</td>
<td>150.6</td>
<td>173.2</td>
<td>23.3</td>
<td>19.6</td>
<td>54.87</td>
<td>52.79</td>
<td>53.86</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>151.2</td>
<td>173.7</td>
<td>23.3</td>
<td>19.6</td>
<td>54.87</td>
<td>52.79</td>
<td>53.86</td>
</tr>
<tr>
<td>2000 m³/fed (dry)</td>
<td>Dorado H. 305</td>
<td>144.2</td>
<td>170.6</td>
<td>23.3</td>
<td>19.6</td>
<td>54.87</td>
<td>52.79</td>
<td>53.86</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>144.2</td>
<td>170.6</td>
<td>23.3</td>
<td>19.6</td>
<td>54.87</td>
<td>52.79</td>
<td>53.86</td>
</tr>
<tr>
<td>General mean of genotypes</td>
<td>Dorado H. 305</td>
<td>158.1</td>
<td>173.6</td>
<td>23.3</td>
<td>19.6</td>
<td>54.87</td>
<td>52.79</td>
<td>53.86</td>
</tr>
<tr>
<td>F.T.</td>
<td>Genotypes</td>
<td>LSD 0.05</td>
<td>Intergr.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F.T.</td>
<td>LSD 0.05</td>
<td>6.7</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intergr.</td>
<td>LSD 0.05</td>
<td>8.2</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From the previous results, it could be concluded that the best irrigation treatment for grain sorghum productivity at Giza Governorate was the moist treatment (3000m³/fed).
Such treatment is recommended from economic point of view as there is no significant yield reduction by Appling 3000 m$^3$/fed (moist treatment) and at the same time saving water. Similar results were obtained by Mourad and Anton (2007).

Concerning grain sorghum genotypes, both green and grain yields/m$^2$ recorded significant differences between two genotypes under study. The maximum values of green and grain yields/m$^2$ were obtained by hybrid 305 compared with Dorado cultivar. Similar results were obtained by Abdel-Motagally (2010).

Data in Table (2) showed that the interaction between water applied treatments and genotypes for green and grain yields/m$^2$ was found to be significant. The highest value was obtained when hybrid 350 irrigated by 3500 m$^3$/fed (wet treatment).

IV- Physiological traits:

1- Leaf chlorophyll fluorescence:

In recent years chlorophyll fluorescence can be used to study the components of the photosynthetic apparatus and their reaction changes in the environment as well as the photosynthesis as a whole. This is interesting in the view that photosynthesis is a good indicator for plants adaption to their environment. Since the measurements are non-intrusive, fast and reliable, this makes chlorophyll fluorescence an attractive tool for environmental research such as water stress.

Data presented in Table (3) show that both water applied treatments and sorghum genotypes recorded a significant effect on chlorophyll fluorescence at 70 DAS. Decreasing water applied up to dry treatment (2000 m$^3$/fed) gradually deceased the values of photosystem II (PSII). These results due to the harmful effect occur on PSII by exposin grain sorghum plants to severe water stress (dry treatment). On grain sorghum plants, Vinita et al. (1998) reported that a reduction in photochemical efficiency of photosystem II (PSII), activities of phosphoenolpyruvatecarboxylase (PEPcase) and ribulose-1, 5 bi phosphatecarboxylase / oxygenase (Rubisco) ascribed to severe water stress condition. Similar results were obtained by Abdo (2007) on maize plants. Regarding the difference between genotypes for chlorophyll fluorescence, data of Table (3) revealed that the maximum value of this trait was obtained by hybrid 305 compared with Dorado cultivar.

Data in Table (3) clearly show that the interaction between water applied treatments and grain sorghum genotypes, was found to be significant. The highest value of chlorophyll fluorescence was obtained when hybrid 305 irrigated by 3500 m$^3$/fed (wet treatment).

2- Relative water content of leaves (RWC%):

RWC was proposed as a good indicator of plant water status (Sinclair and Ludlow, 1985) because RWC through its relation to cell volume, may be more closely reflects the balance between water supply to the leaf and transpiration rate.

Table (3) show that RWC at 70 DAS significantly affected by the two factors under study. Results indicated that decreasing water applied treatment up to irrigation by 2000 m$^3$/fed (dry treatment) significantly decreased RWC. Such finding show that water status in plant cells was affected by water stress conditions. Similar results was obtained by Abdo (2007) on maize plants.

Concerning the difference between the two grain sorghum genotypes, it could be noticed that hybrid 305 significantly surpassed Dorado cultivar in such trait.

The interaction between water applied treatments and genotypes recorded a significant effect. The highest value of RWC was obtained when hybrid 305 irrigated by 3500 m$^3$/fed (wet treatment).

3- Total carbohydrates content of grains:

Table (3) show that the maximum total carbohydrates in grain sorghum kernels was obtained under irrigation by 3500 m$^3$/fed (wet treatment). Increasing water deficit by decreasing applied water up to 2000 m$^3$/fed (dry treatment), decreased total carbohydrates of grains. Whereas, the moist and medium treatments had intermediate values of such trait. Similar results on maize plants were obtained by El-Kalla et al. (1985), who explained such carbohydrates reduction, to that water shortage causes stomatal closure and this in turn prevents CO$_2$ diffusion into the air inside the tissue of plants and consequently the photosynthetic efficiency becomes low.

As for the difference between two genotypes. It could be observed that hybrid 305 had higher value of total carbohydrates content in grains than Dorado cultivar. The highest carbohydrates content of sorghum grains be achieved when hybrid 305 irrigated by 3500 m$^3$/fed.
V- Water relation

1- Seasonal water consumption (WCU):

Results of Table (3) indicated that the seasonal water consumptive use for grain sorghum ranged from 1558.9 to 2478.0 m³/fedans mean of both seasons under study. The results revealed that water consumption was increased with increasing water applied from 2000 m³/fed to 3500 m³/fed. It is worthy to mention that both moist and medium treatments had intermediate values. Such results could be explained on the basis that increasing water applied provides chance for more luxuriant use of water. These findings could be ascribed to the availability of soil water to grain sorghum plants, in addition to higher evaporation rate from wet soil surface than the dry one. In this connection, Bashir et al. (1994) reported that the value of water consumption use by grain sorghum crop increased as soil moisture stress decreased. They added, when soil moisture was kept wet by frequent irrigations, higher seasonal evapotranspiration was attained. Similar results was obtained by Mourad and Anton (2007). Regarding the difference between genotypes, the maximum value of WCU was obtained by hybrid 305 compared with Dorado cultivar.

Data in Table (3) showed that the highest value of WCU was obtained when hybrid 305 irrigated by 3500 m³/fed (wet treatment), whereas the lowest value was obtained when Dorado cultivar irrigated by 2000 m³/fed (dry treatment).

2-Water use efficiency (WUE):

Water use efficiency by grain sorghum expressed as grams kernels produced per m³ water consumed in complete evapotranspiration is presented in Table (3). WUE recorded the maximum value when plants irrigated by 3000 m³/fed (moist treatment), whereas it was lower under wet, medium and dry treatments due to the high grain yield which obtained from plants under moist treatment in proportion to their water consumed. The difference between wet and moist treatments was insignificant in this trait. So, it could be concluded that moist treatment (3000 m³/fed) seemed to be more efficient in consuming water compared with other irrigation treatments. In other words, from the stand point of water conservation, moist treatment seemed to be more economic for saving water and gained a suitable grain yield. Similar results on sesame was obtained by Anton and El-Raies (2000).

As for the two genotypes under study with respect to WUE, the maximum value was obtained by hybrid 305 compared to Dorado cultivar under all irrigation treatments.

With regard to the interaction between water applied treatment and grain sorghum genotypes, the maximum value of WUE was obtained when hybrid 305 received 3000 m³/fed (moist treatment). While, the minimum value was results from irrigated Dorado cultivar with 2000 m³/fed (dry treatment).

Table 3: Chlorophyll fluorescence, relative water content % (RWC), total grain carbohydrate percentage, seasonal water consumptive use (WCU) and water use efficiency (WUE) of two grain sorghum genotypes as affected by water applied levels in 2012 and 2013 summer seasons.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Chlorophyll fluorescence 70 DAS (%)</th>
<th>(RWC %) 70 DAS</th>
<th>Total carbohydrates % in grains</th>
<th>(WCU) m³/fed</th>
<th>Mean (WUE) g/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water applied levels</td>
<td>Genotypes</td>
<td>2012</td>
<td>2013</td>
<td>2012</td>
<td>2013</td>
</tr>
<tr>
<td>3500 m³/fed (wet)</td>
<td>Dorado H. 305</td>
<td>0.726</td>
<td>0.708</td>
<td>0.742</td>
<td>82.25</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>0.805</td>
<td>0.809</td>
<td>0.897</td>
<td>84.50</td>
</tr>
<tr>
<td>3000 m³/fed (moist)</td>
<td>Dorado H. 305</td>
<td>0.811</td>
<td>0.820</td>
<td>0.820</td>
<td>83.38</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>0.767</td>
<td>0.762</td>
<td>0.623</td>
<td>80.08</td>
</tr>
<tr>
<td>2500 m³/fed (medium)</td>
<td>Dorado H. 305</td>
<td>0.637</td>
<td>0.638</td>
<td>0.623</td>
<td>82.40</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>0.683</td>
<td>0.539</td>
<td>0.695</td>
<td>80.65</td>
</tr>
<tr>
<td>2000 m³/fed (dry)</td>
<td>Dorado H. 305</td>
<td>0.512</td>
<td>0.549</td>
<td>0.531</td>
<td>74.29</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>0.600</td>
<td>0.611</td>
<td>0.606</td>
<td>77.41</td>
</tr>
<tr>
<td>General mean of genotypes</td>
<td>Dorado H. 305</td>
<td>0.556</td>
<td>0.539</td>
<td>0.509</td>
<td>75.35</td>
</tr>
<tr>
<td>F. 1 : Genotypes</td>
<td>LSD 0.05 : Irrig.</td>
<td>0.060</td>
<td>0.062</td>
<td>0.040</td>
<td>3.64</td>
</tr>
<tr>
<td></td>
<td>Interc.</td>
<td>0.072</td>
<td>0.076</td>
<td>0.048</td>
<td>4.44</td>
</tr>
</tbody>
</table>

Conclusion:

In the light of the present results, irrigation of grain sorghum plants could be practiced by adding 3000 m³/fed for high grain yield and WUE under Giza region conditions. Such treatment can be recommended from the standpoint of water conservation. Hybrid 305 recorded higher grain yield and WUE under all irrigation levels than Dorado cultivar.
References


