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# Changes in morphological and physiological characteristics of sunflower (*Helianthus annuus* L.) hybrids in relation to the water deficit stress

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**Sunflower is one of the most cultivated oil crops in the world. In Middle East environments where water deficit frequently occurs, tolerant cultivars and irrigation are used to overcome environmental constraints due to water scarcity. Since, in the literature, the data on the effect of these techniques on morphological and physiological characteristics of sunflower are scarce and contrasting, the aim of this paper was to evaluate the effect of the water deficit stress on morphological and physiological characteristics of sunflower hybrids in a Middle East environment. For this purpose, four hybrids (Azargol, Alstar, Hysun 33 and Hysun 25) sowed under three water regimes [normal irrigation, mild water deficit stress (WD2) and intense water deficit stress (WD3)] in 2009. The results of this study indicated that the highest and least seed yield in normal irrigation was found on Azargol (3448 kg ha$^{-1}$) and Hysun 25 (1688 kg ha$^{-1}$), respectively. However, in the mild and intense water stress conditions the seed yield with cultivar Alstar having the highest value (2121 and 829 kg ha$^{-1}$, respectively) and Azargol and Hysun 33 had the lowest value (893 and 263 kg ha$^{-1}$, respectively). The result of this study indicated that application of WD2 and WD3 caused a decrease in leaf area index (LAI) and total dry weight (TDW) of all sunflower hybrids that are studied in this research.**

**Key words:** Sunflower, morphology, physiology, leaf area index (LAI), water deficit stress.

## INTRODUCTION

Sunflower (*Helianthus annuus* L.), with a world production of grain and oil, respectively over 28.5 × $10^6$ and 10.5 × $10^6$ Mg achieved on around 22.6 × $10^6$ ha with a seed yield of 1.3 Mg ha$^{-1}$ (FAO-STAT Agriculture, 2009), is one of the most important sources of edible oil, widely grown in many countries throughout the world (Perry, 1978). In recent years, sunflower planted area has increased because of moderate cultivation requirements and high oil yield. Due to the sunflower ability to tolerate short periods of water deficit (Hattendorf et al., 1988; Me´rrien and Grandin, 1990), the potential exists for it to become an important crop also in sub-arid environments and wherever available irrigation water is limited (Boyer, 1982). The term stress is most often used subjectively and with various meanings. Stress is the altered physiological condition caused by factors that tend to alter equilibrium. Strain is any physical and chemical change produced by a stress (Gasper et al.,

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**Table 1.** Physicochemical characteristics of field soil.

| Soil Characteristics | Results |
|---|---|
| Soil texture | loam |
| Sand (%) | 36 |
| Silt (%) | 39 |
| Clay (%) | 25 |
| Saturation percentage | 33 |
| Organic matter (%) | 1.1 |
| $NH_4$–N (mg $kg^{-1}$ dry soil) | 0.11 |
| Available phosphorus ( mg $kg^{-1}$ dry soil) | 3.1 |
| Potassium ( mg $kg^{-1}$dry soil) | 245 |
| Calcium ( mg $kg^{-1}$ dry soil) | 62.81 |
| Soil pH | 7.62 |
| Electrical conductivity ($dSm^{-1}$) | 1.8 |

2002; Chaves et al., 2002; Chaves et al., 2003; Hu et al., 2006).Some evidences have indicated that water stress deficit causes considerable decrease in yield of sunflower (Stone et al., 2001; Angadi and Entz, 2002). Growth is one of the most drought-sensitive physiological processes due to the reduction of turgor pressure. Cell expansion can only occur when turgor pressure is greater than the cell wall yield threshold. Water stress greatly suppresses cell expansion and cell growth due to the low turgor pressure (Karthikeyan et al., 2007; Jaleel et al., 2007). The reduction in plant height is associated with the decline in the cell enlargement and more leaf senescence in the plant *Abelmoschus esculentum* under water stress (Manivannan et al., 2007). During water stress, the total leaf area per plant decreased significantly in *Eragrostis curvula*, *Oryza sativa*, *A. esculentum*, and *Asteriscus maritimus* (Rucker et al., 1995; Sadras et al., 1993; Shubhra and Ooswami, 2003). Reduction in leaf area by water stress is an important cause of reduced crop yield through reduction in photosynthesis (Rucker et al., 1995). The reduction in plant height and leaf area under water stress may be associated with the decline in the cell enlargement and more leaf senescence in *A. esculentum*. A decrease in total dry matter may be due to the considerable decrease in plant growth, photosynthesis and canopy structure, as indicated by leaf senescence during water stress in *A. esculentum*. Morphological parameters like fresh and dry weights have a profound effect in water-limited conditions. There was a one-third reduction in fresh and dry weights of the *Ziziphus rotundifolia* plant under drought conditions (Tsialtas et al., 2001). Progressive drought resulted in a significant reduction in early allocation of dry matter and decreased fresh and dry weight in all plant parts in *Populus davidiana*. Under water-deficit stress, the biomass production was decreased in *Populus cathayana* and drought severely affected all growth parameters. There was a significant reduction in shoot dry weight due to water-stress treatments in sugar beet genotypes (Zhang et al., 2004), and mild stress affected the dry weights of shoots, while shoot dry-weight loss was greater than root dry-weight loss under severe stress. Reduced biomass production due to water stress has been observed in almost all genotypes of sunflower (Jaleel et al., 2007; Martinez et al., 2003).

However, some genotypes showed better stress tolerance than others did. Tahir et al. (2003) evaluated 25 inbred lines of sunflower for drought tolerance. They reported a decrease in plant height, leaf area, head diameter, 100-achene weight, yield per plant, and plant biomass due to water stress. They further suggested that these traits could be used as a selection criterion for higher yield per plant under water deficit. The effect of water deficits on the harvest index of sunflower is complex due to the interactions between the timing and intensity of the stress relative to the developmental processes that determine the components of yield.

The objectives of this research were to evaluate the effect of the water deficit stress on morphological and physiological characteristics of sunflower hybrids in a Middle East environment.

## MATERIALS AND METHODS

The experimental factors were irrigation regimes consisting of tree levels of irrigation after 50 (normal irrigation), 100 (mild stress) and 150 (intense stress) mm cumulative evaporation from evaporation pan Class A, respectively, and genotype represented by four sunflower hybrids (Azargol, Alstar, Hysun 33 and Hysun 25). Sunflower seeds were obtained from the Plant Improvement Institute in Karaj, Iran. All combinations of the above treatments were laid out in 2009 in the field according to a split-plot randomized complete block design (RCBD) with three replicates, assigning water supply treatments to the whole units and genotypes to the subunits. The soil used was loam. The soil texture was determined with the hygrometer method (Dewis and Freitas, 1970). The physiochemical characteristics are presented in Table 1. Electrical conductivity, pH and ions of saturation extract were determined according to Jackson (1962). The available

**Table 2.** Mean square values from analysis of variance (ANOVA) of leaf number, plant height, head diameter, harvest index and yield of sunflower hybrids (H) in relation to the water deficit stress (WD).

| S.O.V | df. | Leaf Number | Plant height (cm) | Head diameter (cm) | Harvest index (%) | Seed yield (kg ha$^{-1}$) |
|---|---|---|---|---|---|---|
| Rep | 2 | 0.49 Ns | 272.91$^{NS}$ | 0.75* | 79.22** | 147177.33** |
| Water deficit (WD) | 2 | 22.77** | 5724.63** | 117.547** | 1238.43** | 12825106.54** |
| Error a | 4 | 0.24 | 59.18 | 0.10 | 15.88 | 16140.67 |
| hybrid (H) | 3 | 89.75** | 523.80** | 28.896** | 188.06** | 1130703.75** |
| WD × H | 6 | 4.39$^{NS}$ | 1180.99** | 2.10** | 90.78** | 840906.04** |
| Error b | 18 | 3.41 | 91.60 | 0.21 | 14.32 | 48939.56 |
| CV | | 7.36 | 8.7 | 4.22 | 14.98 | 15.01 |

* = p ≤ 0.05; ** = p ≤ 0.01; NS = non-significant.

phosphorous was determined from saturated paste extract (Olsen and Sommers, 1982). The ammonium was estimated by acid digested material (Bremner and Mulvaney, 1982) and organic matter through sulphuric acid using the Walkley-Black Method (Sahrawat, 1982). The pre-planting irrigation was applied 15 days before sowing. When the soil came into condition of field capacity, then it was well ploughed for sowing. Seeds were hand drilled on 14 May, 2009 with row to row spacing of 65 cm. Thinning the plants was done 15 days after germination to keep plants at a spacing of 20 cm. The plant density was 70000 plant ha$^{-1}$. Water deficit treatments were applied at the vegetative stages of plant growth (Chimenti and Hall, 1993). All dry weights were expressed on a unit area basis after drying samples in a forced air oven at 70°C for at least 72 h. At maturity, yield plant$^{-1}$ was recorded. The plants of a 5.2 m$^2$ area in the middle of each subplot were harvested and their seed were separated manually from heads to determine their yield. Harvest index was calculated as the ratio of seed yield to aboveground biomass (carbohydrate equivalent) at maturity. Leaf area index (LAI) and dry matter were measured from each Phenological stage to calculate LAI and total dry weight (TDW). Analysis of variance (ANOVA) of the data from each attribute was computed using the SAS package (SAS Institute, 1985) and MSTAT Computer Program (MSTAT Development Team, 1989). The Duncan's New Multiple Range test at 5% level of probability was used to test the differences among mean values (Steel and Torrie, 1980). Microsoft office Excel (2007) was used for figures drawing.

## RESULTS AND DISCUSSION

The ANOVA for the studied traits shows that water stress had significant effect (P ≤ 0.01) on leaf number, plant height, head diameter, harvest index and seed yield of all sunflower hybrids (Table 2). Differences among hybrids were also found significant (P ≤ 0.01) for the studied traits (Table 2). The water treatment-hybrid interaction (WD-H) were significant for plant height, head diameter, harvest index and seed yield. Results also revealed non-significant role of WD-H in leaf number (Table 2). The decrease in seed yield was more pronounced in intense water deficit stress (WD3, 150 mm cumulative evaporation from evaporation pan Class A) than that in the mild water deficit stress (WD2, 100 mm cumulative evaporation from evaporation pan Class A), which may be due to decrease in some morphologic and physiologic traits (Boyer, 1982).

Application of WD2 and WD3 caused a 51 and 79% decrease in seed yield of water stressed plants, respectively, as compared with normally irrigated ones (Table 3). The highest and least seed yield in normal irrigation was found on Azargol (3448 kg ha$^{-1}$) and Hysun 25 (1688 kg ha$^{-1}$), respectively (Table 4). However, in the mild and intense water stress conditions the seed yield with cultivar Alstar having the highest value (2121 and 829 kg ha$^{-1}$, respectively) and Azargol and Hysun 33 had the lowest value (893 and 263 kg ha$^{-1}$, respectively) (Table 4). The means comparison between the three irrigation treatments for the studied traits shows that water deficit stress (WD) has significant adverse effect on all traits (Table 3). The mean values of the leaf number, plant height, head diameter and the harvest index are lower in water deficit conditions (WD2 and WD3) compared with the normal irrigation (Table 3). Hybrids exhibited different response toward water stress conditions. Thus, within hybrid the Alstar showed the highest head diameter and harvest index, (13.30 cm, and 32% respectively), while Hysun 33 exhibited the least values of head diameter and the harvest index (9.50 cm, and 21%), respectively, also Hysun 33 showed the highest leaf number (29.18) and Azargol showed the highest plant height (116.78 cm) (Table 3). Ashraf and Mehmood (1990) reported that even a short term water deficit stress can cause substantial losses in crop yield that is in agreement with our results. The means comparison for the WD-H is summarized in Table 4. In the normal irrigation treatments, Hysun 33 exhibited the highest leaf number and Alstar exhibited the least value of leaf number, but there is non-significant difference in term of plant height between Hysun 33 and Azargol, but the highest amount of plant height was obtain by Azargol (153.50 cm). The results of this study indicated that in normal irrigation conditions Alstar having the highest and Hysun 33 having the least amount of head diameter and harvest index, respectively (Table 4). In WD2 and WD3 Alstar had much higher head diameter (13.50 and 10.76 cm, respectively) and the harvest index (34 and 21%), respectively (Table 4). Our result is also in agreement

**Table 3.** Effect of water deficit stress and hybrids on studied attributes of sunflower hybrids.

| Treatments[†] | | Leaf number | Plant height (cm) | Head diameter (cm) | Harvest index (%) | Seed yield (kg ha$^{-1}$) |
|---|---|---|---|---|---|---|
| Water stress (WD)[1] | WD1 | 26.36$^{a}$ | 130.91$^{a}$ | 14.30$^{a}$ | 37$^{a}$ | 2591$^{a}$ |
| | WD2 | 25.23$^{b}$ | 111.75$^{b}$ | 10.30$^{b}$ | 22$^{b}$ | 1274$^{b}$ |
| | WD3 | 23.62$^{c}$ | 87.33$^{c}$ | 8.20$^{c}$ | 17$^{c}$ | 552$^{c}$ |
| Hybrid (H)[2] | H1 | 25.84$^{b}$ | 116.78$^{a}$ | 9.60$^{c}$ | 25$^{b}$ | 1585$^{b}$ |
| | H2 | 23.12$^{c}$ | 105.31$^{b}$ | 13.30$^{a}$ | 32$^{a}$ | 1914$^{a}$ |
| | H3 | 29.18$^{a}$ | 116.17$^{a}$ | 9.50$^{c}$ | 21$^{c}$ | 1284$^{c}$ |
| | H4 | 22.14$^{c}$ | 101.72$^{b}$ | 11.40$^{b}$ | 24$^{bc}$ | 1107$^{c}$ |

[†] WD1 = Normal irrigation, WD2 = Mild water deficit stress, WD3 = Intense water deficit stress, H1 = Azargol, H2 = Alstar, H3 = Hysun 33, H4 = Hysun 25. [† a, b, c, d] Within columns, means followed by the same letters are not significantly different (*P* ≤ 0.05).

**Table 4.** Effect of irrigation treatment-hybrid interaction on seed number per head, 1000 seed weight, head diameter, harvest index and seed yield sunflower hybrids.

| Treatments[†] | | Leaf Number | Plant height (cm) | Head diameter (cm) | Harvest index (%) | Seed yield (kg ha$^{-1}$) |
|---|---|---|---|---|---|---|
| WD1[1] | H1 | 26.30$^{ab}$ | 153.50$^{a}$ | 13.90$^{b}$ | 43$^{a}$ | 3448$^{a}$ |
| | H2 | 23.56$^{bc}$ | 112.30$^{bc}$ | 15.63$^{a}$ | 39$^{a}$ | 2793$^{ab}$ |
| | H3 | 31.86$^{a}$ | 151.60$^{a}$ | 13.53$^{b}$ | 34$^{ab}$ | 2437$^{b}$ |
| | H4 | 23.73$^{bc}$ | 106.30$^{bcd}$ | 14.40$^{ab}$ | 30$^{abc}$ | 1688$^{cd}$ |
| WD2[1] | H1 | 26.06$^{ab}$ | 121.20$^{ab}$ | 8.43$^{d}$ | 18$^{cd}$ | 893$^{ef}$ |
| | H2 | 23.03$^{bc}$ | 103.00$^{bcd}$ | 13.50$^{b}$ | 34$^{ab}$ | 2121$^{bc}$ |
| | H3 | 28.56$^{ab}$ | 122.30$^{ab}$ | 8.70$^{d}$ | 18$^{cd}$ | 1154$^{de}$ |
| | H4 | 23.26$^{bc}$ | 100.50$^{bcd}$ | 10.73$^{c}$ | 20$^{bcd}$ | 929$^{ef}$ |
| WD3[1] | H1 | 25.16$^{bc}$ | 75.67$^{cd}$ | 6.53$^{e}$ | 14$^{d}$ | 413$^{ef}$ |
| | H2 | 22.76$^{bc}$ | 100.70$^{bcd}$ | 10.76$^{c}$ | 21$^{bcd}$ | 829$^{ef}$ |
| | H3 | 27.13$^{ab}$ | 74.67$^{d}$ | 6.27$^{e}$ | 11$^{d}$ | 263$^{f}$ |
| | H4 | 19.43$^{c}$ | 98.33$^{bcd}$ | 9.23$^{cd}$ | 21$^{bcd}$ | 704$^{ef}$ |

[†] WD1 = Normal irrigation, WD2 = Mild water deficit stress, WD3 = Intense water deficit stress, H1 = Azargol, H2 = Alstar, H3 = Hysun 33, H4 = Hysun 25. [† a, b, c, d, e, f, g] Within columns, means followed by the same letters are not significantly different (*P* ≤ 0.05).

with the results obtained in sunflower by Stone et al. (2001) and Angadi and Entz (2002).

In normal irrigation, the highest and the least LAI was obtain by Azargol (3.61) and Hysun 25 (1.82), respectively (Figures 1, 2, 3 and 4). However, in the irrigation after 100 and 150 mm evaporation (WD2 and WD3, respectively) the LAI ranged from 1.9 to 0 and 1.4 to 0, respectively with Azargol having the highest value in R6 stage (1.9 and 1.4, respectively) and Hysun 25 had the lowest value in R9 stage (43.59 and 36.47%), respectively (Figures 1, 2, 3 and 4). The result of this study indicated that application of WD2 and WD3 caused a decrease in LAI of all sunflower hybrids that studied in this research.

The normal irrigation treatments generally had the highest TDW in R6-R8 stages (range from 385 to 423 g), while the water deficit stress conditions (irrigation after 100 and 150 mm evaporation) decreased the TDW for all the sunflower hybrids studied (Figures 5, 6, 7 and 8). This suggests that water stress treatments significantly decreased TDW in all the sunflower hybrids, although result of this study indicated that WD3 condition (irrigation after 150 mm evaporation) caused the severe decreased in TDW (Figures 5, 6, 7 and 8). However, in normal irrigation there are significant differences in the TDW in the phenological R6-R7 stages among the various genotypes with Azargol having the highest TDW (408 g) in stage R7, while Hysun 25 had the least values of TDW

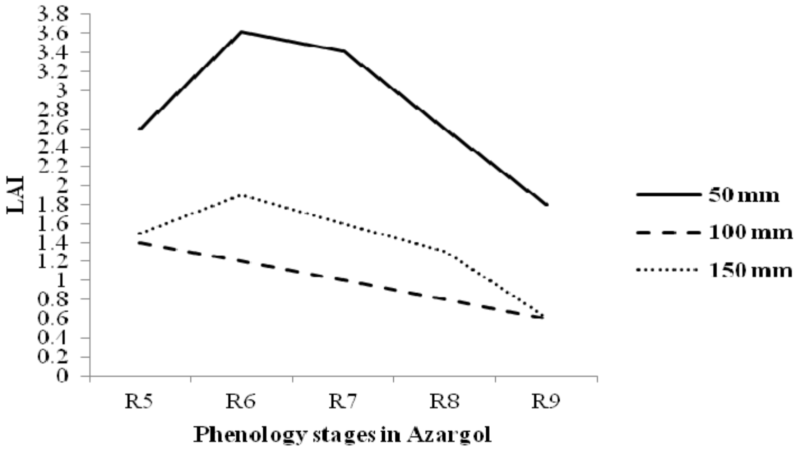

**Figure 1.** Effect of irrigation treatments on the leaf area index (LAI) of Azargol.

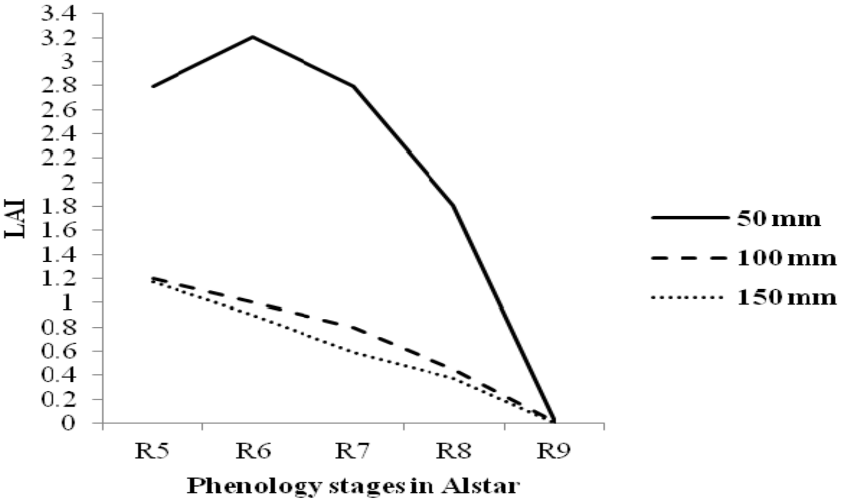

**Figure 2.** Effect of irrigation treatments on the leaf area index (LAI) of Alstar.

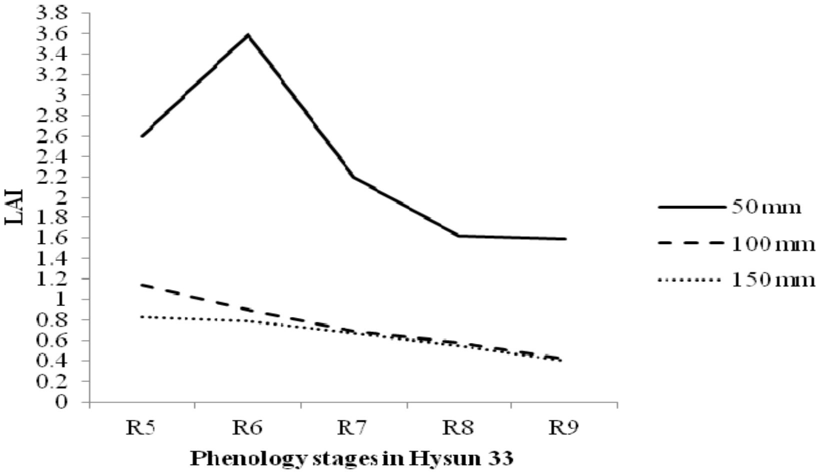

**Figure 3.** Effect of irrigation treatments on the leaf area index (LAI) of Hysun 33.

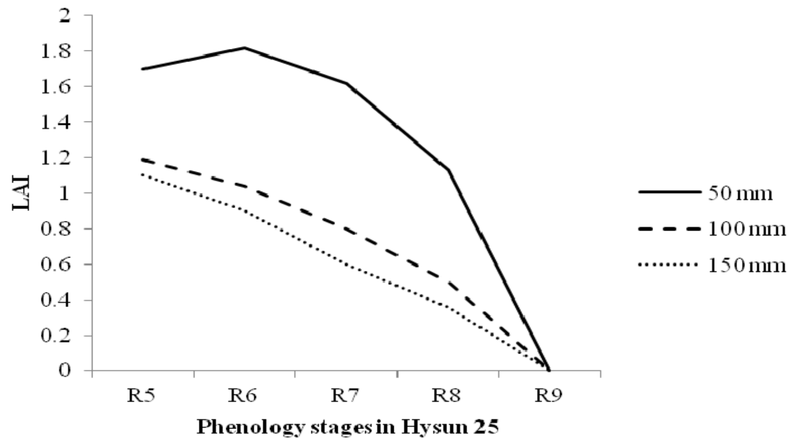

**Figure 4.** Effect of irrigation treatments on the leaf area index (LAI) of Hysun 25.

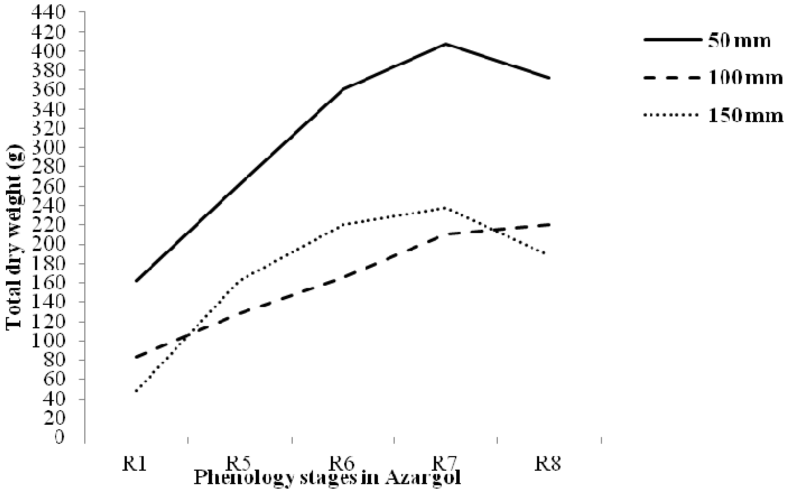

**Figure 5.** Effect of irrigation treatments on total dry weight of Azargol.

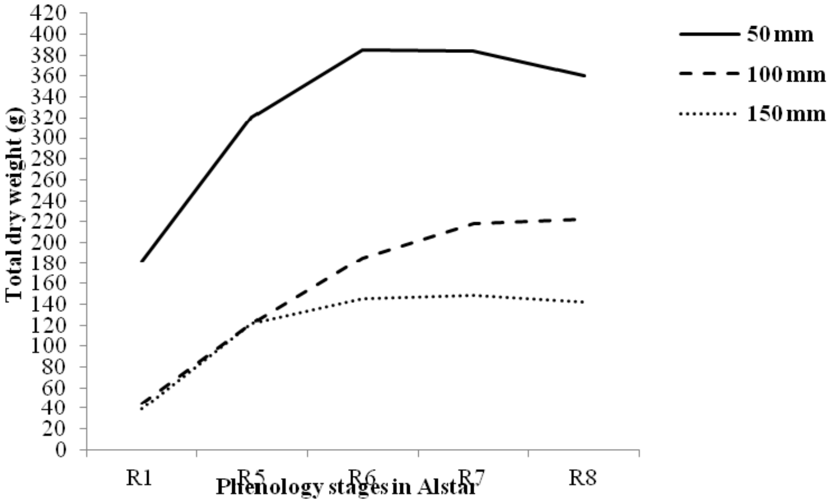

**Figure 6.** Effect of irrigation treatments on total dry weight of Alstar.

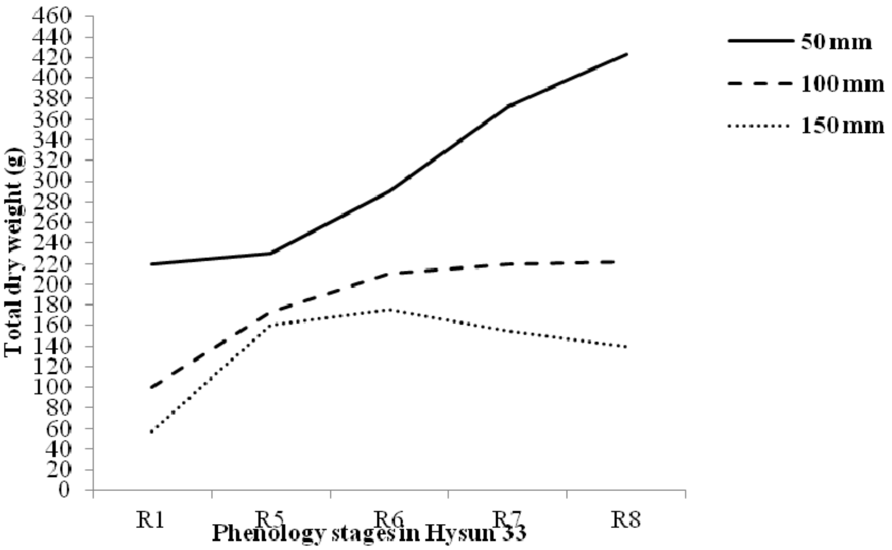

**Figure 7.** Effect of irrigation treatments on total dry weight of Hysun 33.

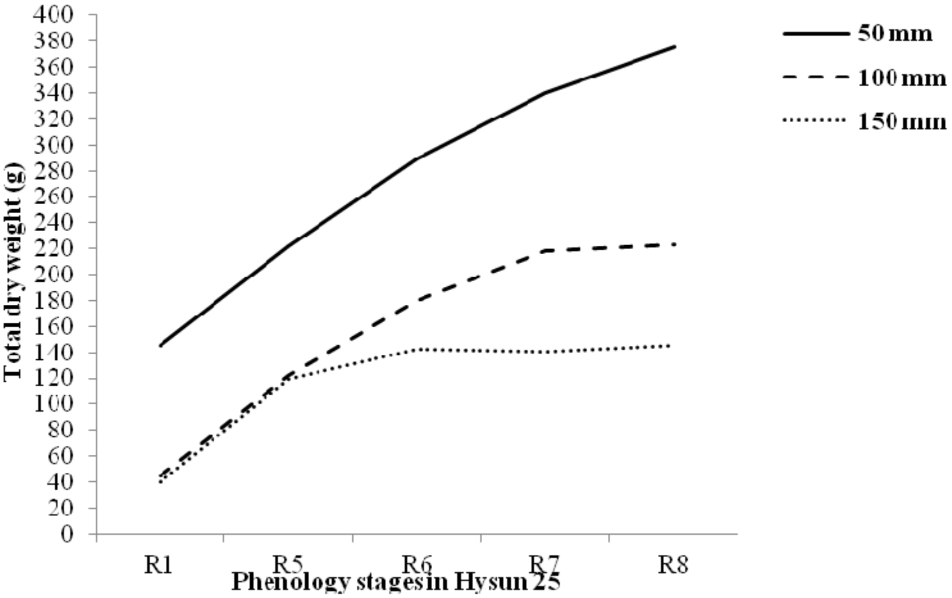

**Figure 8.** Effect of irrigation treatments on total dry weight of Hysun 25.

(340 g) in this phonological stage (Figures 5, 6, 7 and 8). In the irrigation after 100 mm evaporation (WD2) and among R1-R8 stages, the TDW ranged from 45 to 223 g with Hysun 25 having the highest value and Azargol had the lowest value in R8 stage and in the WD3 (irrigation after 150 mm evaporation) and among R1-R8 stages the TDW ranged from 39 to 57 g with Azargol having the highest value (238 g) and Hysun 25 having the lowest value (141 g) in R7 stage (Figure 2). It is evident that in the all water treatments and among all the cultivars studied, sunflower dwarf cultivars such as Alstar and Hysun 25 have the lowest LAI and TDW compared with tall cultivars such as Azargol and Hysun 33.

The result of this study suggests that variety and irrigation treatments significantly influence the leaf number, plant height, head diameter, harvest index, seed yield, LAI and TDW. It appears from the present and the previous studies that water stress has adverse effect on all studied traits in this research. A large genetic variation was observed for leaf number, plant height, head diameter, harvest index, seed yield, LAI and TDW under well watered and water deficit conditions. In our study dwarf cultivars especially Alstar under water stress conditions have the highest amount of seed yield.

## Conclusion

Drought is a worldwide problem, constraining global crop production and quality seriously, and recent global climate change has made this situation more serious. Drought is also a complex physical-chemical process, in which many biological macromolecules and small molecules are involved, such as nucleic acids, proteins, carbohydrates, lipids, hormones, ions, free radicals, mineral elements. Currently, drought study has been one of the main directions in global plant biology and biological breeding. The result of this study suggested that seed yield, morphological and physiological characteristics of sunflower are dependent on cultivars and irrigation treatments. Also, our study showed that dwarf cultivars under water stress conditions have the highest amount of seed yield.

## Conflict of Interests

The authors have not declared any conflict of interests.

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