Effect of Irrigation Ending Date on Physiological Growth Parameters, and Yields of Sunflower Hybrids

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ABSTRACT

In order to study effect of irrigation ending stress on dry matter accumulation trend, physiological parameters and yields of three sunflower hybrids, an experiment was conducted with three replications using split plots based on Randomized complete blocks design. The procedures were carried out in 2010 cropping year. In this experiment, irrigation treatments (I) included complete irrigation(I 1), irrigation until heading stage(I 2) and irrigation until grain formation(I 3), in the main plot. The studied hybrids were Euroflour (H 1), Azargol (H 2) and SHF81-196 (H 3) allocated in subplots. The results indicated that dry matter accumulation trend and physiological indices (CGR, RGR, NAR, LAI) declined in water ending treatments (irrigation until grain formation and irrigation until heading stage) compared to the desirable treatment. Furthermore, dry matter accumulation trend and physiological indices (CGR, NAR and LAI) were different for the studied hybrids while RGR index was not remarkably different. Largest LAI belonged to Euroflour cultivar and harvest index was less affected by water deficiency conditions for this hybrid comparatively. Also, the aforementioned cultivar exhibited the most favorable grain yield in drought stress conditions. Desirable yield of this hybrid resulted from better partitioning of photosynthetic products to vegetative period and grain maturation stage. Therefore, by planting this hybrid, it is possible to consume less water and achieve the optimal yield.

Key words: Irrigation ending, Sunflower Hybrid, Physiological Parameters, Grain Yield

Introduction

Need for providing edible oil has led to considerable increase in sunflower cropping in Iran and world during the recent years. Today, large portion of research activities is devoted to study responses of crops to water deficiency and drought stress conditions. Thus, it seems inevitable to have adequate knowledge about responses of crops versus ambient stresses, particularly dryness, in order to attain higher productivity in crop euleric programs for producing drought-inflicted cultivars [1]. Growth models, which are normally achieved based on amount of dry matter accumulation in different stages and organs, in fact indicate roles of environment, genetic factors, management and/or interaction effects of these agents.

Accordingly, it is essential to have insight on dry matter accumulation trend during growth period in cropping programs [2-3]. Growth pattern and its relationship with ambient conditions can be determined through measuring dry weights of different crop organs besides total dry weight of aerial organs. JassodeRodriguez et al [4] reported that the cultivars assumed similarly low dry weights during starring and budding stages in dryness tension conditions but some difference was observed among cultivars at the beginning and end of heading stage in terms of dry weight. This difference was 58% between the highest and lowest values for cultivars.

Crop growth rate (CGR) and crop growth duration along with other vegetative and reproductive parameters have great significance for obtain of high yielding variety.

Data regarding dry matter accumulation, leaf area index (LAI), crop growth rate and duration are some of the key parameters for evaluation of cultivars in term of dry matter production and yield differences [5-6].

Naderidarbaghshahi [7] showed that applying drought stress caused reduction in crop growth rate. Kalhori [8] concluded that irrigation cutting resulted in reduction of relative growth rate in all growth stages of sunflower; this reduction was more severe.

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Materials And Methods

This research was conducted in summer 2010 using three sunflower hybrids in a farm located in Behbehan City Khuzestan, Iran (latitude: northern 30°36' - longitude: eastern 50°14' - altitude: 313 meters above free sea level). Soil texture was silt-clayey-loamy type, with 7.7pH and electrical conductivity of 2.9. The experiments were carried out with three replications in split plots based on Randomized Complete Blocks Design. Irrigation treatments in 3 levels of desirable irrigation (I1), water ending tension in heading stage (I2), and water ending tension in grain formation stage (I3) were regarded as the main plot. The studied hybrids, namely Euroflour (H1) Azargol (H2) and SHF81-196(H3) were allocated in the subplots. Amount of phosphate compost was computed and consumed on the basis of 90 kg phosphorous per hectare from triple super phosphate source. Nitrogen was applied as split in two application; half with sowing and the remaining half at the 8-leaf stage. Cultural practices, control of insects and weeds and furrow irrigation were given as needed during the growth season according to the local recommendations. All other production practices were recommended standards.

Every plot contained 6 lines each 5 meters long and 75 cm apart from each other. Thinning operation was performed in 4.5-leaf stage.

First samples were collected 21 days after start of planting in order to study growth trend and physiological indices; sampling was repeated every 15 days. To determine the total plant dry weight (TDW) at each sampling, shoots were chopped and located in the oven in the temperature of 72 degrees centigrade for 48 hours. Leaf area index was determined by leaf area meter (LP-80 Accupar PAR/LAI Cepptomter) The final harvesting area was equal to 4.8 m-2which was done from two middle lines of planting. Final measurements were conducted from these samples. For moisture measurement grains were located in the oven in the temperature of 72 degrees centigrade for 48 hours. Crop growth rate (CGR) was worked out by adopting the formula of Watson [18] and expressed as g m⁻² day⁻¹.

\[
\text{CGR (g m}^{-2}\text{ day}^{-1}) = \frac{W_2 - W_1}{t_2 - t_1}
\]

\[
W_1 = \text{Total Dry weight (g m}^{-2}\text{) at time } t_1
\]

\[
W_2 = \text{Total Dry weight (g m}^{-2}\text{) at time } t_2
\]

\[
t_2 - t_1 = \text{Time interval in days}
\]

Relative growth rate (RGR) is the ratio of increase in dry weight per unit dry weight already present and it’s expressed in g per gram dry weight per day. Relative growth rate at various stages was calculated as suggested by Radford [19].

\[
\text{RGR (g g}^{-1}\text{ day}^{-1}) = \frac{\ln W_2 - \ln W_1}{t_2 - t_1}
\]

Abbadi and Gerendas[14] showed that optimal and high supply nitrogen in sunflower produced grain yield more efficient than low supply of nitrogen. Palmer et al [15] found that the availability of nitrate has a strong effect on leaf expansion in sunflower.

Karimzadeh et al [10] showed physiological indices including CGR, RGR and NAR declined as the irrigation interval increased. Santamaria et al [11] reported that relative growth rate and net photosynthesis level of sunflowers was in their peak at the beginning of growth season and they decreased with increasing crop age.

Irrigation cutting in grain filling stage poorly influences net absorption rate. Heading stage is regarded as the most sensitive period to water deficiency leading to extreme reduction in crop yield because fewer flowers reach to complete growth stage [12-13]. Grain formation is the next sensitive stage to water deficiency and brings about severe reduction in both crop yield and oil amount [9]. Nitrogen is essential elemental for growth and change its values accessible to the plant performance can affect the intensity. Scientists believe poor management of irrigation and nitrogen; the main factors decreasing the performance of corn are considered [14].

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Where,
\[ W_1 = \text{Total Dry weight of plant (g) at time } t_1 \]
\[ W_2 = \text{Total Dry weight of plant (g) at time } t_2 \]
\[ t_2 - t_1 = \text{Time interval in days} \]

Net Assimilate Rate (NAR) was worked out by adopting the formula of Radford (1967) and expressed as g m\(^{-2}\) day\(^{-1}\).

\[
\text{NAR (g m}^{-2}\text{ day}^{-1}) = \frac{\ln (\text{LAI}_2) - \ln (\text{LAI}_1)}{\text{CGR}(t_2 - t_1)}
\]

\[ \text{LAI}_1 = \text{Leaf area index at time } t_1 \]
\[ \text{LAI}_2 = \text{Leaf area index at time } t_2 \]

Statistical analysis of data was performed using computer software MINITAB and MSTATC and comparison of the means was done by Duncan's test at a probability level of 5 percent.

Results And Discussion

Leaf Area Index (LAI):

Leaf area index is a fundamental parameter to show incremental state of crops in agriculture. Leaf area index increases as time elapses, then remains constant for a short duration and assumes a declining trend afterwards depending on cultivars and ambient conditions. Leaf area index variation trend for different treatments and cultivars are illustrated in figures 1 and 2. Results showed leaf area exhibited a decreasing trend when the irrigation ending treatment was applied and drought stress exceeded. Maximal and minimal leaf area indices were respectively obtained in complete irrigation and irrigation cutting in heading stage respectively. Having applied dryness tension, leaf area index decreased 51 days after planting date in heading stage for all three treatments. Desirable irrigation possessed greatest LAI throughout this period. Findings of Cox et al [20] reveal the fact that leaf area index is the most sensitive vegetative growth attribute of sunflower to water and soil deficiencies. Flenet et al [21] reported that reduction in leaf area index due to dryness tension seems to be caused by deceleration of new leaves production rate and acceleration of leaves aging process which are most noticeably manifested in heading stage. Karam et al [22] showed that with increasing drought stress leaf area index decreased. According to results of the current study, H1 the best leaf area index compared to other studied hybrids. This cultivar features better leaf area development than two other hybrids (H2 and H3); therefore, it enjoys greater potential for producing dry matter. Better leaf area development of H1 hybrid contributes to more carbohydrate production factories and is considered a very good quality for this cultivar.

![Fig. 1](image1.png)

**Fig. 1:** The trend of changes in LAI affected by different levels of irrigation

![Fig. 2](image2.png)

**Fig. 2:** The trend of changes in LAI affected by hybrids
Total Dry Weight (TDW):

Dry matter accumulation pattern in sunflower assumes a sigmoid curve and consists of slow-speed growth, fast growth and maturation stages. Major part of total dry weight is produced during heading stage onwards and there is a highly positive correlation between amount of dry matter and the grain yield. Effect of water ending stress in different growth stages on dry matter accumulation trend is shown in figure 3. As observed, dry matter is accumulated slowly in early growth stages and no remarkable contrast is seen for different treatments. By applying dryness tension, the contrast in terms of dry matter accumulation was revealed 51 days after greening. Irrigation cutting treatments exhibited diminishing total dry weight in comparison with the desirable treatment. Complete irrigation and water cutting treatment in heading stage respectively yielded largest and smallest values of this parameter.

The reason for reduction in dry matter accumulation with exceeding dryness tension intensity was shrinkage of leaf area as well as reduction in net photosynthetic rate. Greenwey & Munns [23] stated, seemingly the impact of drought stress on decline of leaf area index, the increase in stomata and mesophyll resistance, and consequently current photosynthesis reduction is the major reason for decrease in total dry matter accumulation resulting from water shortage condition. These results were in agreement with findings of [24]. According to results of this research, variation trends of dry weight were similar in all under-study hybrids (fig 4). Dry matter was accumulated slowly since start of greening until emergence of reproductive buds but its accumulation increased exponentially with steep slope afterwards up to heading stage. Euroflour hybrid showed the largest amount of dry matter accumulation in this study. The reason can be attributed to more favorable leaf area index of this hybrid compared to two other cultivars. The results are in accordance with findings of Larki [25] and Bonhomme [26] concerning improvement of dry matter accumulation with increasing leaf area index.

Crop Growth Rate (CGR):

Variation trends of crop growth rate in different irrigation treatments and for the studied hybrids are represented in figure 4-6. As it can be observed, crop growth rate declined by applying dryness tension; the largest value (17 g/m²/day) belonged to desirable irrigation after applying water cutting tension. Influences crop growth rate via affecting leaves development and dry matter production. Water deficiency in sunflower affects net photosynthesis rate and therefore, reduces dry weights of leaves, roots and stems. Findings of research by Rushdi [27] also matched the results discussed above. Schussler and Westgate [28] also reported drought stress causes reduction in leaf photosynthesis. On the other hand, decreasing value of crop growth rate (CGR) can be attributed to more dissipation and faster aging of leaves in mild and particularly severe drought stress conditions in comparison with desirable irrigation situation. These results were in alignment with findings of Lorens et al [29].

Fig. 3: The trend of changes in TDW affected by different levels of irrigation
The highest crop growth rate is achieved for H1 cultivar among the available hybrids; its crop growth rate had declining trend with gentler slope (fig 6). This hybrid features better leaf area development compared to two other ones. Taking into account the direct relationship between leaf area index and crop growth rate, one might infer that this cultivar has greater potential to reach maximal growth rate thanks to maintaining its leaf area and because of being able to produce more carbohydrates through absorbing more radiation. These results are in alignment with reports by Tan [30]; Bakht et al [31].

Variation trend of net absorption rate in H1 cultivar is in the most favorable state among others due to having higher LAI and CGR (fig 8). This finding is in agreement with results obtained by Bakht et al [31].

Relative Growth Rate (RGR):

In the current study, analysis of relative growth rate (RGR) diagram with respect to time from heading stage until physiological maturity showed that relative growth rate declined by applying drought stress treatment (Fig 7). Relative growth rate assumes a decreasing variation trend. As Saneoka & Agata [33] reported, probably in water tension conditions, mature dividing tissues appear to form sooner or the formation rate of dividing tissues apparently decreases. By imposing drought stress—particularly intense drought stress in heading stage, relative growth rate declined in this research. This phenomenon can be justified by closure of stomas, reduction in photosynthesis rate and decreasing dry matter production. As presented in figure 4-10, there is no tangible contrast among different sunflower hybrids in terms of RGR. These results were in accordance with those reported by Hajihasaniasl [24] and Dadnia [1].
Fig. 6: The trend of changes in CGR affected by hybrids

Fig. 7: The trend of changes in NAR affected by different levels of irrigation

Fig. 8: The trend of changes in CGR affected by hybrids

Fig. 9: The trend of changes in RGR affected by different levels of irrigation
Fig. 10: The trend of changes in RGR affected by hybrids

Grain yield:

Results indicate that irrigation treatment, hybrids and their interaction effects have significant difference in 1% probability value on grain yield (Table 1). The maximal and minimal grain yields were obtained for desirable irrigation treatment and ending of irrigation in heading stage with averages of 447.228 and 333.55 g/m² respectively. Hybrids H1 and H2 respectively assumed the largest and smallest values of this parameter with averages of 417 and 332.88 g/m² (Table 2).

Reduction is caused by water restriction during reproductive period. Reason for diminishing grain yield in limited irrigation conditions can be attributed to reductions in receptacle diameter, number of grains in receptacle, and weight 1000 grains as well as increase in hollowness ratio.

Water deficiency causes leaf area index, and disorder in absorption of water and nutrients; it also reduces mobilization of photosynthetic products to grains. This study was in line with results reported [35]. The lowest grain yield was obtained for irrigation cutting tension in heading stage for all hybrids (Tab 2). Higher value of this attribute in H1 cultivar is indicative of its greater productive potential in optimal and timely moisture conditions.

Table 1: Analysis of variance for grain yield

<table>
<thead>
<tr>
<th>S.O.V</th>
<th>d.f</th>
<th>Grain yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>2</td>
<td>*</td>
</tr>
<tr>
<td>Irrigation(I)</td>
<td>2</td>
<td>**</td>
</tr>
<tr>
<td>Ea</td>
<td>4</td>
<td>457.76</td>
</tr>
<tr>
<td>Hybrid(H)</td>
<td>2</td>
<td>*</td>
</tr>
<tr>
<td>I * H</td>
<td>4</td>
<td>**</td>
</tr>
<tr>
<td>Eb</td>
<td>12</td>
<td>372.22</td>
</tr>
<tr>
<td>CV</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

Ns*and, **: Not significant, significant at probability levels 5% and 1% respectively

Table 2: Mean comparison grain yield

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Grain yield (gm⁻²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigation</td>
<td></td>
</tr>
<tr>
<td>complete irrigation (I1)</td>
<td>447.2a</td>
</tr>
<tr>
<td>irrigation until heading stage(I2)</td>
<td>333.5b</td>
</tr>
<tr>
<td>irrigation until grain formation(I3),</td>
<td>411.5c</td>
</tr>
<tr>
<td>Hybrid</td>
<td></td>
</tr>
<tr>
<td>H1</td>
<td>417a</td>
</tr>
<tr>
<td>H2</td>
<td>332.8b</td>
</tr>
<tr>
<td>H3</td>
<td>411.9a</td>
</tr>
</tbody>
</table>

Means with same letter in each column are not significantly different at the 5% probability level- using Duncan Multiple Range Test (DMT)
Karam [22] reported 20 and 15% reduction in flower grain yield by limiting irrigation in early and middle heading stage. It seems that balanced water consumption during different increment stages including heading and grain formation periods bring about improvement of flower grain yield. H1 and H2 hybrids were superior to H2 in terms of grain yield. Consequently, two superior cultivars seem to exhibit such behavior due to having larger leaf area in reproductive stage, rapid physiological growth, sending sufficient photosynthetic products to reproductive organs, and ultimately, ideally benefitting from ambient resources.

**Conclusions:**

The results show that variation trends of leaf area index and dry matter accumulation were affected by cultivar type and drought stress treatment. The greatest reduction in leaf area index and dry matter accumulation from heading stage to physiological maturity belonged to irrigation cutting in heading stage and H2 cultivar. The results indicated crop growth variations in drought stress conditions is more significantly affected by variations of leaf area index and net assimilation rate. The results also showed that variations of crop growth rate for H1 hybrid and in drought stress conditions are influenced by changes in leaf area index and net assimilation rate.

**Fig. 11:** Mean Comparison of interaction H×I on grain yield

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**References**