# Water Use Features of Sunflower (*Helianthus annuus* L.) Hybrids Irrigated at Different Growth Stages

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**Abstract**

The response of some sunflower hybrids to seven irrigation treatments was studied in the field experiments during 2002 and 2003 seasons. Sunflower hybrids of Sanbro, Tarsan-1018 and Özdemirbey were used as material. A rainfed (non-irrigated) treatment as the control ($I_0$) and $I_1$= irrigation at vegetative growth stage, $I_2$= irrigation at heading stage, $I_3$= irrigation at flowering stage, $I_4$= $I_1$ + $I_3$ two irrigations, $I_5$= $I_1$ + $I_2$ + $I_3$, three irrigations, and $I_6$= $I_1$ + $I_2$ + $I_3$ + irrigation at milking stage were applied. Research revealed that irrigations at all growing stages ($I_6$) increased average seed yield of all sunflower hybrids as 43% and 77% in 2002 and 2003, respectively. Increased water amount and irrigation frequency caused a decreasing in irrigation water use efficiency (IWUE) and an increase in irrigation efficiency (IE). Higher IWUE and lower IE were obtained from non-irrigated or one irrigation treatments. The highest IWUE (35.6 kg $ha^{-1}$ $mm^{-1}$) was obtained from Tarsan-1018 irrigated at vegetative stage ($I_1$). Özdemirbey irrigated with $I_6$ gave the highest irrigation efficiency (IE) with 186%.

**Keywords:** Sunflower, irrigation, yield, irrigation efficiency, IWUE

## Farklı Gelişme Dönemlerinde Uygulanan Sulamaların Hibrit Ayçiçeği (*Helianthus annuus* L.)'nde Su Kullanım Özellikleri

**Özet**

Bazı hibrit ayçiçeği çeşitlerinin yedi sulama uygulamasına tepkileri 2002 ve 2003 yıllarında incelenmiştir. Sanbro, Tarsan-1018 ve Özdemirbey ayçiçeği çeşitleri materyal olarak kullanılmıştır. Sulama yapılmayan parseller kontrol olarak değerlendirilmiş ve $I_1$= vejetatif gelişme başında, $I_2$= tabla oluşumu, $I_3$= çiçeklenme, $I_4$= $I_1$ + $I_3$ iki sulama, $I_5$= $I_1$ + $I_2$ + $I_3$, üç sulama ve $I_6$= $I_1$ + $I_2$ + $I_3$ + süt olum döneminde olmak üzere yedi sulama konusu uygulanmıştır. Araştırma sonuçlarına göre tüm gelişme dönemlerinde yapılan sulama uygulaması (I6) verimi 2002 yılında %43, 2003 yılında %77 oranında arttırmıştır. Artan sulama suyu miktarı sulama suyu kullanım etkinliğini (IWUE) azaltırken sulama etkinliğini (IE) arttırmıştır. Daha yüksek IWUE ve daha düşük IE sulanmayan veya bir sulama uygulamasından elde edilmiştir. En yüksek IWUE (35.6 kg $ha^{-1}$ $mm^{-1}$) vejetatif gelişme döneminde ($I_1$) sulanan Tarsan-1018 çeşidinde belirlenmiştir. En yüksek sulama etkinliği ise %186 ile Özdemirbey çeşidinde $I_6$ uygulamasından saptanmıştır.

### Introduction

Sunflower (*Helianthus annuus* L.) is one of the most important oil seed crops in Turkey because it has advantages in crop rotation due to high adaptation ability, suitable for mechanization and low labor needs (Ozer et al., 2004; Kazemeini et al., 2009). Its tolerance to drought makes sunflower more important in arid and semiarid regions like Central Anatolia region of Turkey where the climate is characterized for semiarid due to irregular and insufficient rainfall and hot weather during vegetation period for sunflower production (Flagella et al., 2002; Reddy et al., 2003). Average productivity is relatively low because sunflower is mostly cultivated under rainfed conditions. Consequently, irrigation is very important to increase seed yield because of high productivity under irrigated conditions (Unger, 1983).

Water stress during the critical period results in poor plant growth and low seed yield. Although drought is unavoidable in arid and semi-arid regions, early sowing allows the plant to utilize from late winter rainfall and early spring rainfall (Flagella et al., 2002). On the other hand, genotypic differences in sunflower for drought tolerance have been reported by several researchers (Angadi and Entz, 2002; Bakht et al., 2010). Sunflower yield is generally doubled with irrigation while it is classified as a low or medium drought sensitive crop (Unger, 1983; Stone et al., 1996; Tolga and Lokman, 2003). Seed yield response to irrigation is generally peaked when sunflower is watered at the beginning of flowering (Unger, 1983; Kadayıfçı and Yıldırım, 2000; Göksoy et al., 2004). Unger (1982) reported that limited irrigation water resulted in higher water use efficiency than full irrigation.

The aim of this paper was to evaluate the influence of irrigation at different growth stages on seed yield, amount of irrigation water, IWUE and irrigation efficiency (IE) of three sunflower hybrids cultivated commonly in Central Anatolia region of Turkey.

**Materials and Methods**

This study was conducted at the experimental field of Department of Field Crops, University of Ankara, TURKEY using three oil type sunflower hybrids, Sanbro, Tarsan-1018 and Özdemirbey in 2002 and 2003. The soil at the experimental field was clay loam and alkaline (pH=7.4). Field capacity, wilting point and water holding capacity of the soil between 0 and 90 cm depth were 404.5 mm, 256.2 mm and 148.3 mm, respectively.

The irrigation treatments in relation to sunflower growth stage were arranged as

**$I_0$**= non irrigated (control),

**$I_1$**= vegetative growth,

**$I_2$**= budding stage,

**$I_3$**= flowering stage,

**$I_4$= $I_1$ + $I_3$**, two irrigations,

**$I_5$= $I_1$ + $I_2$ + $I_3$**, three irrigations and

**$I_6$**= **$I_1$** + **$I_2$ + $I_3$** + milking stage, four irrigations

The seeds were sown on 24$^{th}$ April and 1$^{th}$ May during 2002 and 2003, respectively. The plots were 3.5 m wide and 6 m long and consisted of five rows. Plant density was allocated as 0.7 x 0.3 m. Three seeds were sown in a hill and thinned to one plant per hill when the plants were at the four leaf stage. A 1.4 m alley was left around each plot to avoid water leakage between the plots. Soil moisture content at each irrigation treatment was determined gravimetrically from the samples collected from different soil layers (0-30, 30-60 and 60-90 cm). Total deficit water amount (0-90 cm soil layer) was provided by increasing soil to field capacity.

At maturity, ten random plants from each plot were harvested and then yield and yield components for each treatment at each replicate were determined. Irrigation water use efficiency (IWUE) was calculated as the ratio seed yield to irrigation water amount described by Unger (1982) and Chen et al. (2009) [IWUE= seed yield (kg ha$^{-1}$) / irrigation water amount (mm)]. Irrigation efficiency (IE) was formulated as

$$IE = \frac{Yi}{Yr} \times 100$$

$Y_i$ = yield of irrigated plant [kg ha$^{-1}$]

$Y_r$ = yield of non irrigated plant [kg ha$^{-1}$]

The experimental design was a randomized complete block design with three replicates. The combined analysis of variance of the data and the comparison of the means on the base of Duncan Multiple Range Test were carried out using MSTAT-C software.

**Results and Discussion**

Air temperature, rainfall and relative humidity for the experimental field during the years of experiments are presented in Table 1. The average rainfall in 2002 and 2003 are 210 mm and 91.5 mm, respectively. In general, the 2002 growing season was cooler and received higher rainfall compared with the 2003 season which was warmer with drought.

A significant cultivar x irrigation interaction was found for seed yield, plant weight, harvest index and IWUE in both years and IE in 2003. The result of the analysis of variance showed that seed yield was severely affected by irrigation and hybrids. Irrigation enhanced seed yield while one irrigation treatments ($I_1$, $I_2$ and $I_3$) failed to increase it satisfactorily. Maximum seed yield were recorded under full irrigation and minimum under no irrigation conditions regardless of sunflower hybrids (Table 2).

Table 1. Monthly and long term average of temperature, relative humidity and precipitation at the experimental field in 2002 and 2003.

| | Years | April | May | June | July | August | September |
|---|---|---|---|---|---|---|---|
| Temperature (°C) | 2002 | 10.4 | 16.7 | 20.8 | 24.8 | 22.5 | 18.3 |
| | 2003 | 10.3 | 19.0 | 22.6 | 23.5 | 24.3 | 18.0 |
| | Long term* | 11.1 | 15.8 | 19.8 | 23.2 | 23.0 | 18.5 |
| Relative humidity (%) | 2002 | 65.4 | 50.2 | 53.4 | 56.7 | 59.1 | 64.9 |
| | 2003 | 62.4 | 52.9 | 46.6 | 49.5 | 48.1 | 58.9 |
| | Long term | 59.0 | 58.0 | 52.0 | 45.0 | 44.0 | 48.0 |
| Precipitation (mm) | 2002 | 101.1 | 38.7 | 29.0 | 35.3 | 6.6 | 54.7 |
| | 2003 | 70.3 | 18.0 | 0.0 | 3.0 | 0.2 | 15.1 |
| | Long term | 43.9 | 52.0 | 34.2 | 15.1 | 11.3 | 17.3 |

*Long term refers to average values between 1940 and 2001 in Ankara.

Table 2. Water use features, yield and some yield components of sunflower hybrids in relation to irrigation treatments

| Hybrid | Irrigation | Precipitation (mm) | Irrigation water amount (mm) | Seed yield (kg ha$^{-1}$) | Plant weight (g plant$^{-1}$) | Harvest index (%) | IWUE (kg ha$^{-1}$ mm$^{-1}$) | IE (%) |
|---|---|---|---|---|---|---|---|---|
| | | | | **2002** | | | | |
| Sanbro | $I_0$ | 118 | - | 2760 $^{ij}$ | 165 $^{ij}$ | 35.8 $^{gh}$ | -$^{k*}$ | - |
| | $I_1$ | | 107 | 2550 $^{j}$ | 180 $^{hi}$ | 38.1 $^{efg}$ | 24.0 $^{c}$ | 105 |
| | $I_2$ | | 185 | 3310 $^{fgh}$ | 192 $^{gh}$ | 36.2 $^{fgh}$ | 17.9 $^{fg}$ | 120 |
| | $I_3$ | | 199 | 3290 $^{gh}$ | 200 $^{gh}$ | 40.9 $^{cd}$ | 16.5 $^{g}$ | 119 |
| | $I_4$ | | 313 | 3860 $^{b-e}$ | 210 $^{fg}$ | 43.5 $^{ab}$ | 12.3 $^{h}$ | 140 |
| | $I_5$ | | 430 | 3650 $^{d-g}$ | 246 $^{de}$ | 43.5 $^{ab}$ | 8.5 $^{ij}$ | 132 |
| | $I_6$ | | 578 | 3990 $^{a-d}$ | 276 $^{bc}$ | 45.0 $^{a}$ | 6.9 $^{j}$ | 144 |
| Tarsan-1018 | $I_0$ | | - | 3180 $^{hi}$ | 206 $^{fg}$ | 38.6 $^{def}$ | -$^{k}$ | - |
| | $I_1$ | | 107 | 3810 $^{b-e}$ | 237 $^{e}$ | 36.7 $^{fgh}$ | 35.6 $^{a}$ | 121 |
| | $I_2$ | | 185 | 3690 $^{d-g}$ | 227 $^{ef}$ | 37.9 $^{efg}$ | 20.0 $^{e}$ | 117 |
| | $I_3$ | | 225 | 3750 $^{c-f}$ | 235 $^{e}$ | 36.4 $^{fgh}$ | 16.7 $^{g}$ | 119 |
| | $I_4$ | | 342 | 4220 $^{abc}$ | 249 $^{de}$ | 37.5 $^{efg}$ | 12.3 $^{h}$ | 134 |
| | $I_5$ | | 432 | 4090 $^{a-d}$ | 280 $^{bc}$ | 38.6 $^{def}$ | 9.5 $^{i}$ | 130 |
| | $I_6$ | | 580 | 4180 $^{abc}$ | 327 $^{a}$ | 34.2 $^{h}$ | 7.2 $^{j}$ | 133 |
| Özdemirbey | $I_0$ | | - | 2790 $^{ij}$ | 150 $^{j}$ | 40.0 $^{cde}$ | -$^{k}$ | - |
| | $I_1$ | | 107 | 3410 $^{e-h}$ | 203 $^{g}$ | 38.1 $^{efg}$ | 31.9 $^{b}$ | 122 |
| | $I_2$ | | 185 | 3500 $^{e-h}$ | 207 $^{fg}$ | 38.3 $^{efg}$ | 18.9 $^{ef}$ | 126 |
| | $I_3$ | | 195 | 4260 $^{ab}$ | 244 $^{de}$ | 41.0 $^{cd}$ | 21.8 $^{d}$ | 153 |
| | $I_4$ | | 307 | 3970 $^{a-d}$ | 267 $^{cd}$ | 41.4 $^{bc}$ | 12.9 $^{h}$ | 142 |
| | $I_5$ | | 442 | 4340 $^{a}$ | 295 $^{b}$ | 36.6 $^{fgh}$ | 9.8 $^{i}$ | 155 |
| | $I_6$ | | 605 | 4340 $^{a}$ | 263 $^{cd}$ | 45.0 $^{a}$ | 7.2 $^{j}$ | 156 |
| | | | | **2003** | | | | |
| Sanbro | $I_0$ | 31 | - | 2070 $^{jk}$ | 161 $^{i}$ | 36.5 $^{ef}$ | -$^{l}$ | -$^{k}$ |
| | $I_1$ | | 160 | 2350 $^{gh}$ | 206 $^{g}$ | 41.8 $^{ab}$ | 14.7 $^{a}$ | 115 $^{hij}$ |
| | $I_2$ | | 264 | 2420 $^{g}$ | 211 $^{g}$ | 39.4 $^{cd}$ | 9.4 $^{cd}$ | 118 $^{hi}$ |
| | $I_3$ | | 276 | 2750 $^{f}$ | 246 $^{f}$ | 35.5 $^{fg}$ | 10.0 $^{c}$ | 135 $^{f}$ |
| | $I_4$ | | 370 | 3000 $^{de}$ | 264 $^{e}$ | 41.4 $^{abc}$ | 8.7 $^{de}$ | 146 $^{e}$ |
| | $I_5$ | | 551 | 3190 $^{c}$ | 271 $^{e}$ | 38.0 $^{de}$ | 5.8 $^{g}$ | 156 $^{d}$ |
| | $I_6$ | | 769 | 3570 $^{a}$ | 407 $^{a}$ | 28.5 $^{j}$ | 4.6 $^{h}$ | 174 $^{bc}$ |
| Tarsan-1018 | $I_0$ | | - | 1970 $^{k}$ | 109 $^{k}$ | 40.2 $^{bcd}$ | -$^{l}$ | -$^{k}$ |
| | $I_1$ | | 175 | 2160 $^{ij}$ | 234 $^{f}$ | 32.1 $^{hi}$ | 12.4 $^{b}$ | 110 $^{j}$ |
| | $I_2$ | | 271 | 2230 $^{hi}$ | 298 $^{cd}$ | 30.5 $^{ij}$ | 8.3 $^{e}$ | 114 $^{ij}$ |
| | $I_3$ | | 274 | 2770 $^{f}$ | 323 $^{b}$ | 30.6 $^{ij}$ | 10.1 $^{c}$ | 141 $^{ef}$ |
| | $I_4$ | | 378 | 3090 $^{cde}$ | 311 $^{bcd}$ | 35.9 $^{ef}$ | 8.2 $^{e}$ | 157 $^{d}$ |
| | $I_5$ | | 549 | 3330 b | 422 $^{a}$ | 25.8 $^{k}$ | 6.1 $^{g}$ | 169 $^{c}$ |
| | $I_6$ | | 726 | 3430 $^{ab}$ | 417 $^{a}$ | 28.8 $^{j}$ | 4.6 $^{h}$ | 175 $^{bc}$ |
| Özdemirbey | $I_0$ | | - | 1680 $^{l}$ | 129 $^{j}$ | 38.9 $^{d}$ | -$^{l}$ | -$^{k}$ |
| | $I_1$ | | 175 | 2050 $^{jk}$ | 210 $^{g}$ | 33.5 $^{gh}$ | 11.7 $^{b}$ | 122 $^{gh}$ |
| | $I_2$ | | 271 | 2140 $^{ij}$ | 183 $^{h}$ | 43.5 $^{a}$ | 7.9 $^{e}$ | 127 $^{g}$ |
| | $I_3$ | | 274 | 2360 $^{gh}$ | 231 $^{f}$ | 41.9 $^{ab}$ | 8.6 $^{de}$ | 140 $^{ef}$ |
| | $I_4$ | | 378 | 2710 $^{f}$ | 314 $^{bc}$ | 32.0 $^{hi}$ | 7.2 $^{f}$ | 161 $^{d}$ |
| | $I_5$ | | 548 | 2980 $^{e}$ | 308 $^{bcd}$ | 33.2 $^{h}$ | 5.4 $^{g}$ | 177 $^{b}$ |
| | $I_6$ | | 726 | 3130 $^{cd}$ | 295 $^{d}$ | 36.5 $^{ef}$ | 4.3 $^{h}$ | 186 $^{a}$ |

*: Means followed by the same letter(s) in each column are not significantly different at $p< 0.05$ level.

Higher seed yield was recorded from $I_6$ treatment compared to non irrigated plots. Considering average yield of sunflower hybrids, irrigations at all growth stages increased seed yield as 43% and 77% in 2002 and 2003, respectively. Chaniara et al. (1989), Ilbaş et al. (1996), Ali et al. (1998), Mahender et al. (2000) and Kakar and Soomro (2001) indicated that increase in seed yield of sunflower depended on hybrids and irrigations intervals. Sunflower hybrids showed different responses to irrigation treatments and the least affected hybrid was Sanbro. Angadi and Entz (2002) reported that dwarf sunflower under drought had the highest productivity while standard height hybrids under irrigated conditions were efficient. Kazemeini et al. (2009) reported that highest seed yield was obtained from full irrigation and deficit irrigation during the critical period of sunflower should be avoided.

Higher plant weight was obtained from higher irrigation frequency; meaning full irrigation applied at all growth stages (Table 2). No irrigation gave the lowest plant weight while the highest values were recorded from $I_5$ and $I_6$ treatments. Apparent trend for harvest index by irrigation was not determined. Maximum harvest index was taken by the treatments receiving irrigation $I_1$, $I_2$ and $I_3$ during both growing seasons (2002-03). It was observed that irrigation before flowering stage enhanced vegetative growth while seed yield increased with irrigations at flowering and late flowering stages. The results are in line with the findings of Chimenti et al. (2002) and Kazemeini et al. (2009), who stated that biomass dry weight was declined in the plants exposed to water stress but harvest index was promoted. Similarly Tomar et al. (1997) found that limited irrigation water caused an increase in harvest index of sunflower.

Increased irrigation water amount and frequency caused decreasing in IWUE. Especially, the highest IWUE was observed at $I_1$ in both years and all sunflower hybrids while full irrigation led to reduce it considerably. Similar results were observed by Unger (1982) and Demir et al. (2006) who determined that the highest IWUE in sunflower was detected in irrigation at flowering stage and increased irrigation number led to decrease in IWUE. However, Chen et al. (2009) showed that IWUE was changed drastically by irrigation water quality and increased salinity in irrigation water resulted in an increase in IWUE. Differences in irrigation efficiency (IE) in 2002 was not significant ($p$<0.05). In general, two or three irrigation ($I_4$) increased IE of sunflower hybrids.

In conclusion, sunflower hybrids showed different responses to irrigation treatments under Central Anatolia conditions. Generally, irrigation at flowering stage was more effective to increase seed yield of sunflower hybrids rather than earlier and later irrigation. The maximum seed yield was recorded at four irrigations (vegetative + bud + flowering + milking stages), while three irrigations ($I_5$) gave satisfactorily seed yield. Irrigation at flowering stage ($I_3$) should be preferred due to higher IWUE if water sources were limited and irrigation cost was high.

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