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Full Length Research Paper

Seed yield and oil content of some sunflower (*Helianthus annuus* L.) hybrids irrigated at different growth stages

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This research was carried out to determine the effects of irrigation applied at different growth stages on yield, yield components and oil content of sunflower during 2002 and 2003. Sunflower cultivars Sanbro, Tarsan-1018 and Ozdemirbey were used as materials in the experiment which was designed in a split plot of randomized complete blocks with three replications. Seven irrigation schedules; I_0 = non-irrigated (control), I_1 = irrigation at vegetative 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. According to the results of the research, plant height and head diameter by cultivars and irrigations ranged between 106 to 183 cm and 12.5 to 19.3 cm, respectively. Irrigations at all growth stages increased seed yield by 43.1% in 2002 and 77.2% in 2003. The results revealed that three irrigations should be scheduled at vegetative, bud formation and flowering stages. Under severe conditions of water scarcity, it would be better if irrigation is applied at flowering stage.

Key words: Sunflower, irrigation, yield, oil ratio.

INTRODUCTION

Oilseed production has been inadequate in Turkey, while it has different ecological conditions which allow growing of various crop plants. Currently, approximately 70% of unrefined edible oil needs are met by imports. Oil seeds, vegetable unrefined oils and refined edible oil imports in Turkey have reached 2.2 billion dollars in 2009 (Anonymous, 2010). Sunflower (*Helianthus annuus* L.) is one of the most important oilseed crops containing high quality edible oil because it can be grown under different ecological conditions due to its high adaptation ability (Weiss, 1983; Ozer et al., 2004; Bakht et al., 2010). It is extensively grown without irrigation in Central Anatolian region of Turkey where potential evapotranspiration exceeds precipitation throughout the growing season. In the region, lack of residual soil moisture and irregular distribution of rainfall leads to water stress and reduced yield (Goksoy et al., 2004). 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 plants to be utilized from late winter and early spring rainfall (Flagella et al., 2002). Angadi and Entz (2002) and Bakht et al. (2010) emphasized that genotypic differences also affect plant growth. Depending on genotype, sunflower yield can be doubled with irriga-tion as it is classified as a low or medium drought sensitive crop (Unger, 1983; Stone et al., 1996; Tolga and Lokman, 2003).

The aim of this paper was to evaluate the influence of irrigation on seed yield, yield components and oil content of three sunflower hybrids cultivated commonly in Central Anatolian Region of Turkey.

MATERIALS AND METHODS

This study was conducted during 2002 and 2003 at the experimental field of the Department of Field Crops, University of Ankara, Turkey. Three oil type sunflower hybrids (Sanbro, Tarsan-

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Table 1. Weather parameters at the experimental field during 2002 and 2003 growing seasons.

Parameter	Year	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
	Average	11.1	15.8	19.8	23.2	23.0	18.5
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
	Average	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
	Average	43.9	52.0	34.2	15.1	11.3	17.3

1018 and Ozdemirbey) were used as materials. The soil at the experimental field was clay loam and alkaline (pH = 7.4). Field capacity of the soil between 0 and 90 cm depth was 404.5 mm.

The experimental design was a randomized complete block design with three replicates. The irrigation treatments in relation to the sunflower growth stage were: 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); $I_6 = I_1 + I_2 + I_3$ + milking stage (four irrigations)

The seeds were sown on 24th April and 1th 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. 1.4 m valley 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 the different soil layers (0 to 30, 30 to 60 and 60 to 90 cm). Total deficit water amount (0 to 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. The oil percentage of the kernel was determined by Soxhlet extraction. The combined analysis of variance of the data and the comparison of the means on the bases of Duncan multiple range tests were carried out using MSTAT-C software.

RESULTS

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

A significant cultivar x irrigation interaction was found for seed yield and oil content in years, plant height and head diameter during 2002, and 1000 seed weight during 2003. The result of the analysis of variance showed that plant height was severely affected by irrigation and cultivar. Higher plant height was obtained from higher irrigation frequency; meaning full irrigation applied at all growth stages (Table 2). The less effective irrigation in increasing plant height was I_3 (irrigation at flowering stage). Also, cv. Ozdemirbey gave the highest plant height during both years in this experiment.

Head diameter of the sunflower cultivars was considerably influenced by irrigation and increased with increased number of irrigations. The maximum head diameter was measured in I_6 treatment, while the minimum diameter was recorded in the control (I_0). Tarsan-1018 had the highest head diameter. Increased irrigation frequency resulted in an increase in 1000 seed weight of the sunflower cultivars. Full irrigation (I_6) showed the highest 1000 seed weight, but it drastically declined with decrease of number of irrigations. Considering sunflower hybrids, cv. Ozdemirbey gave higher seed weight under all the irrigation treatments.

Greater increase in seed yield due to irrigation was very evident ($p < 0.05$). Irrigation enhanced seed yield, while one irrigation treatment (I_1, I_2 and I_3) failed to increase it satisfactorily. Maximum seed yield was recorded under full irrigation and minimum seed yield was recorded under no irrigation conditions, regardless of the sunflower cultivars. Depending on the increase in head diameter and 1000 seed weight, seed yield was promoted by irrigation treatments. Higher seed yield was recorded from I_6 treatment as compared to the control plots. Considering each cultivar, seed oil content fluctuated with irrigation treatments. On the other hands, lower values were determined at I_5 and I_6, but were higher in the no irrigated plants.

DISCUSSION

Irrigation treatments showed enhanced performance of sunflower cultivars under drought stress. Days to flowering were shortened in non-irrigated plants, but irrigation delayed it considerably. Flowering time was shorter in irrigation at flowering stage (data not shown). This could be explained by exposure of the plants to drought till flowering and enforcing them to bloom earlier; suggesting that plant height was lower at I_3. Aziz and Soomro (2001) observed that days to maturity were increased due to

Table 2. Yield and yield components of sunflower hybrids irrigated at different growth stages.

Irrigation treatment	2002			Mean	2003			Mean
	Sanbro	Tarsan-1018	Özdemirbey		Sanbro	Tarsan-1018	Özdemirbey	
Plant height (cm)								
I_0	128^{ijk}	113$^{\ell}$	122$^{jk\ell}$	121^{d}	121	106	124	117^{f*}
I_1	142^{efg}	125^{jk}	154^{cd}	141^{b}	145	123	140	136^{c}
I_2	157^{cd}	130^{h-k}	141^{fgh}	143^{b}	130	123	139	131^{d}
I_3	139^{f-i}	121$^{jk\ell}$	139^{f-i}	133^{c}	126	114	134	125^{e}
I_4	152de	119$^{k\ell}$	159^{cd}	144^{b}	153	132	148	144 ^{b}
I_5	164^{bc}	143^{ef}	182$^{\mathbf{a}}$	163^{a}	156	138	156	150^{a1}
I_6	171^{b}	132^{g-j}	183$^{\mathbf{a}}$	162^{a}	159	149	154	154$^{\mathbf{a}}$
Mean	151^{b}	126^{c}	154^{a}	144	141$^{\mathbf{a}}$	127^{b}	142$^{\mathbf{a}}$	137
Head diameter (cm)								
I_0	14.4^{g}	15.8^{d-g}	12.5^{h}	14.2^{c}	12.9	14.3	12.7	13.3^{f}
I_1	15.1^{efg}	18.6^{ab}	14.7^{fg}	16.1^{b}	14.4	14.6	14.6	14.5^{e}
I_2	14.7^{efg}	18.2^{a}	15.2^{efg}	16.1^{b}	14.7	15.8	14.3	14.9^{de}
I_3	15.6^{efg}	17.7^{bc}	16.2^{def}	16.5^{b}	16.2	16.5	14.7	15.8^{cd}
I_4	15.9^{d-g}	18.1^{ab}	18.2^{ab}	17.4^{a}	17.3	16.7	15.8	16.6^{bc}
I_5	16.3^{cde}	18.4^{ab}	18.4^{ab}	17.7^{a}	17.4	17.6	16.3	17.1^{b}
I_6	17.2^{bcd}	19.3^{a}	18.2^{ab}	18.2^{a}	18.7	18.2	17.3	18.1^{a}
Mean	15.6^{b}	18.0^{a}	16.2^{b}	16.6	15.9^{a}	16.2^{a}	15.1 ^{b}	15.8
One thousand seed weight (g)								
I_0	76.6	76.9	79.9	77.8^{c}	80.9^{h}	66.2^{j}	74.3^{i}	73.8^{e}
I_1	77.6	79.9	81.3	79.6^{c}	84.5^{fgh}	81.4^{gh}	83.1^{gh}	83.0^{d}
I_2	79.9	78.1	81.4	79.8^{c}	84.3^{fgh}	74.1^{i}	85.4^{fg}	81.3^{d}
I_3	80.9	79.0	84.1	81.3^{bc}	87.3^{ef}	89.8^{de}	89.4^{de}	88.8^{c}
I_4	80.1	82.4	87.8	83.4^{ab}	93.3^{cd}	93.2^{cd}	98.7^{ab}	95.1^{b}
I_5	87.6	84.1	87.8	86.5^{a}	93.9^{c}	92.7^{cd}	96.9^{abc}	94.5^{b}
I_6	87.1	83.8	89.3	86.7^{a}	95.7^{bc}	95.5^{bc}	100.7^{a}	97.3^{a}
Mean	81.4^{b}	80.6^{b}	84.5^{a}	82.2	88.6^{a}	84.7^{b}	89.8^{a1}	87.7
Seed yield (kg ha^{-1})								
I_0	2760^{ij}	3180^{hi}	2790^{ij}	2920^{e}	2070^{jk}	1970^{k}	1680$^{\ell}$	1910^{f}
I_1	2550^{j}	3810 $^{b-e}$	3410^{e-h}	3260^{d}	2350^{gh}	2160^{ij}	2050^{jk}	2190^{e}
I_2	3310^{fgh}	3690^{d-g}	3500^{e-h}	3500^{c}	2420^{g}	2230^{hi}	2140^{ij}	2260^{e}
I_3	3290^{gh}	3750^{c-f}	4260^{ab}	3770^{b}	2750^{f}	2770^{f}	2360^{gh}	2630^{d}
I_4	3860^{b-e}	4220^{abc}	3970^{a-d}	4020^{a}	3000de	3090^{cde}	2710^{f}	2940^{c}
I_5	3650^{d-g}	4090 $^{a-d}$	4340^{a}	4030^{a}	3190^{c}	3330^{b}	2980^{e}	3170^{b}
I_6	3990^{a-d}	4180^{abc}	4340^{a}	4170^{a}	3570^{a}	3430^{ab}	3130^{cd}	3380^{a}
Mean	3350^{b}	3850^{a}	3800^{a}	3660	2760^{a}	2710^{a}	2430^{b}	2640
Kernel oil content (%)								
I_0	52.1^{a-e}	55.3^{abc}	50.1^{c-h}	52.5^{ab}	52.4^{def}	56.1^{bc}	59.7^{a}	56.1^{a}
I_1	44.9^{hij}	55.6^{ab}	50.9^{b-g}	50.5^{a-d}	53.9^{b-f}	56.1^{bc}	54.8^{bcd}	54.9^{a}
I_2	44.6^{ij}	50.4^{a-d}	46.8^{f-j}	47.3^{d}	51.1^{e-h}	45.8^{ijk}	52.1^{d-g}	49.7^{c}
I_3	51.3^{b-f}	50.2^{b-h}	57.4^{a}	53.0^{a}	50.7^{fgh}	46.5^{ijk}	53.9^{b-f}	50.4^{bc}
I_4	50.7^{e-j}	51.4^{b-f}	56.8^{a}	53.0^{abc}	50.6^{fgh}	48.3^{hij}	55.1^{ab}	51.4^{b}
I_5	49.6^{d-i}	43.7^{j}	55.3^{abc}	49.5^{cd}	48.9^{ghi}	45.0^{jk}	52.9^{c-f}	48.9^{c}

Table 2. Continues

I_6	49.3^{d-i}	45.7^{g-j}	54.2^{a-d}	49.7^{bcd}	48.3^{hij}	45.2^{k}	54.3^{b-e}	49.3^{c}
Mean	48.9^{c}	50.3^{b}	53.1^{a}	50.8	50.9^{b}	49.0^{c}	54.7^{a}	51.5

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

increase in irrigation levels. It suggested that the water amount for I_3 was much more than the other irrigation treatments due to extended time of flowering. 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 Al-Ghamdi et al. (1991), El-Din et al. (1994), Ilbas et al. (1996) and Taha et al. (2001) who found that plant height increased by reducing irrigation frequency. El-Hafez et al. (2002) indicated that reduced irrigation intervals lead to decrease plant height.

Irrigation clearly improved both head diameter and 1000 seed weight of sunflower cultivars. Furthermore, full irrigation resulted in increase of 1000 seed weight. Similar results were observed by Al-Ghamdi et al. (1991), El-Din et al. (1994), Ilbas et al. (1996), Ali et al. (1998), El-Hafez et al. (2002), Flagella et al. (2002) and Ashoub et al. (2003), who showed that head diameter and 100 seed weight was induced by irrigation. The superiority of irrigation on seed yield could be due to increasing head diameter and 1000 seed weight. Irrigations at all the growth stages increased seed yield by 43.1 and 77.2% in 2002 and 2003, respectively. Ilbas et al. (1996), Ali et al. (1998), Kakar and Soomro (2001), Ashoub et al. (2003) and El-Hafez et al. (2002) 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 the highest seed yield was obtained from full irrigation and deficit irrigation during the critical period of sunflower.

A linear relationship between irrigation and oil content was not determined. This showed that climatic conditions like temperature, altitude and soil structure were more effective on oil content of sunflower than was irrigation. These results are in agreement with those reported by Razi and Assad (1999), Singh et al. (1997) and Erdemoglu et al. (2003); they observed that oil content did not change significantly by irrigation, while Unger (1983), Kumar et al. (1991), Kadayifci and Yildirim (2000) and Kazi et al. (2002) found increased oil content of sunflower seeds by irrigation.

In conclusion, sunflower hybrids showed different responses to irrigation treatments under Central Anatolia conditions. Generally, irrigation at flowering stage was more effective to increase the seed yield of the sunflower hybrids rather than the early and late irrigation. The maximum seed yield was recorded at four irrigations treatment (vegetative + bud + flowering + milking stages), while three irrigations treatment (I_5) gave satisfactory seed yield. One irrigation at flowering stage (I_3) should be preferred if water sources is limited and irrigation cost is high.

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