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Water – Use Characteristics of Sunflower (*Helianthus annuus L.*) Under Deficit Irrigation

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Abstract: This study was carried out to determine the influence of limited irrigation on growth; seed yield and yield components, and water use and water efficiency of sunflower under Thrace conditions. Five irrigation treatments were applied, designated as T_1 full irrigation, and T_2, T_3, T_4 and T_5 received 75, 50, 25 and 0 % of applications of the fully irrigated treatment on the same day. Seed yields averaged highest with full irrigation treatment (T_1) and differences between full irrigation and other treatments were significant. Although linear relationships were found between seed yield versus total irrigation water, and seed yield versus seasonal evapotranspiration, respectively. The yield response factor (k_y) was determined as 0.98, 0.77 and 0.69 (avg 0.78) during the experimental years. Irrigation water use efficiency (IWUE) and water use efficiency (WUE) were found to be between 0.80 – 2.47 kg/da-mm and 0.62 – 0.94 kg/da-mm, respectively, for the treatments.

Key Words: Sunflower (*Helinthus annuus L.*), deficit irrigation, evapotranspiration, yield response factor (k_y), water use efficiency

Introduction

Diminishing water resources are beginning to limit irrigation in the world. In some locations, the available water supply is inadequate to produce the maximum yield on the irrigable area. In other regions, the water available for irrigation is already regulated and requires deficit irrigation. For many surface water projects, the annual supply of irrigation water is limited by reservoir capacity and the annual reservoir inflow. These examples highlight the need for deficit irrigation management on different crops (Martin *et al.*, 1989).

Sunflower (*Helianthus annuus* L.) production for oil in Turkey has greatly increased in recent years. Most of the production occurs in Thrace region and an estimated area of 320 000 ha is used for this purpose. Mostly sunflower is grown without irrigation, but sometimes grown in sub - humid and semi - arid regions where off-season precipitation storage and subsequent spring rainfall are limited as in Thrace Region. Sunflower yields are usually highest when it is adequately irrigated to avoid plant water stress (Stegman and Lemert, 1981).

The value of consumptive water use of sunflower vary widely ranging from 200 mm to more than 900 mm. The wide range in ET is attributed to irrigation levels used, climatic regions involved and length of growing season. High ET occurred in USA and European countries, while it is reverse in Asian countries (Unger, 1990; Stone *et al.*, 1996).

In the previous studies, water stresses at various growth stages have been shown to markedly influence yields. While maximum yields were obtained with full irrigation, nearly maximum yields were generally obtained when irrigations were made to provide adequate water during flowering and yield formation periods (Connor *et al.*, 1985 ; Unger, 1986,). Also, irrigation level significantly affects sunflower yield. Patel and Singh (1983) reported that yields were nearly maximized when irrigation was made to maintain soil water content above 0.7-0.8 available levels. But, the limited irrigation conserved irrigation water and resulted in higher water use efficiency (WUE) in regions, where water is limited such as in Thrace Region (Unger, 1983 ; Connor *et al.*, 1985).

The objective of this study was to compare full irrigation and four deficit irrigation amounts based on the percentages of full irrigation for sunflower. Thus, total water use, water use efficiency and relationships between water use and seed yield were also determined.

Materials and Methods

The research was conducted at the Viticultural Research Institute of Tekirdag, Turkey (40°59' N latitude, 27°29' E longitude and 4 m altitude) during 1998-2000 growing seasons. Climate in this region is semi - arid with annual precipitation averaging 575 mm and April through October precipitation averaging 180 mm. Soil type in the plot area is generally clay and well drained. The gravimetric water content at the field capacity, wilting point and available water holding capacity of the soil at experimental site are shown in Table 1. Irrigation water quality was C_2S_1.

Experiments were arranged in a randomized block design with five irrigation treatments replicated three times. Full irrigation (T_1) was applied when approximately 50 % of available soil moisture was consumed in 0.90 m root zone during irrigated growth period. Other irrigation amount treatments designated as T_2, T_3, T_4 and T_5 received 75, 50, 25 and 0 % of the fully irrigated treatments on the same day. The plots were irrigated by furrow irrigation.

Each experimental plot took up an area of 10.5 m^2 (3.50 x 3.00 m), including 50 plants with 0.7 x 0.3 m^2 planting spacing. The gap between the plots was 3.0 m. The plots were situated on furrow-irrigated land having a uniform slope of about 0.5 %. On 4th May 1998, 8th June 1999 and 17th May 2000, 'Sunbro' variety of sunflower was planted in plots. Before planting, beds and furrows were formed with a disk bedder and trifluralin at a rate of 2 kg/ha was applied to control the weeds. Fertilizer applications were based upon soil test data and a composed fertilizer including 50 kg/ha N and 50 kg/ha P_2O_5 was applied.

Table 1: Some physical characteristics of soils at the experimental site.

Year	Soil Depth (cm)	Bulk Density (g/cm^3)	Field Capacity (%)	Wilting Point (%)	Available water holding capacity (mm /0.3 m)
1998	0-30	1.48	27.13	17.92	40.90
	30-60	1.51	27.57	18.10	42.90
	60-90	1.55	27.10	20.01	32.97
	90-120	1.58	27.90	21.02	32.61
1999	0-30	1.60	27.07	16.34	51.51
and 2000	30-60	1.64	24.17	15.31	43.59
	60-90	1.58	23.62	15.97	36.26
	90-120	1.61	23.90	13.76	48.98

Table 2: Water use factors of sunflower at different treatments and years

Year	Irrigation treatments (mm)	Deficit rate (%)	Soil water depletion (mm)	Rainfall (mm)	Irrigation water use (mm)	Seasonal ET (mm)	Water use efficiency (kg/da-mm)	Irrigation water use efficiency (kg/da-mm)
1998	T_1	0	110		555	800	0.65	0.94
	T_2	25	144		416	695	0.64	1.07
	T_3	50	211	135	277	623	0.62	1.39
	T_4	75	246		138	519	0.66	2.47
	T_5	100	256		-	391	0.71	-
1999	T_1	0	152		560	762	0.66	0.90
	T_2	25	152		420	622	0.75	1.11
	T_3	50	193	50	280	523	0.77	1.44
	T_4	75	215		140	405	0.80	2.32
	T_5	100	255		-	305	0.83	-
2000	T_1	0	88		690	852	0.65	0.80
	T_2	25	79		517	670	0.77	0.99
	T_3	50	105	74	345	524	0.79	1.20
	T_4	75	122		172	393	0.85	1.95
	T_5	100	188		-	324	0.94	-

ET = Evapotranspiration

Table 3: Summaries of vegetative growth parameters, yield, and yield components data of sunflower at different treatments and years

Year	Irrigation treatments (mm)	Plant height (cm)	Head diameter (cm)	Stem diameter (cm)	Seed yield (kg/da)	Seed weight (g)	Seed test weight (kg/hl)	Total dry matter (%)	Total oil (%)
1998	T_1	173NS	26.3NS	2.6a**	521.5a**	63.5NS	41.5NS	94.5NS	
	42.3NS								
	T_2	174	24.9	2.4ab	444.1b	62.4	41.3	95.3	40.9
	T_3	161	23.2	2.3b	285.8c	60.1	40.1	95.5	41.5
	T_4	170	23.9	2.4ab	341.4c	55.8	40.9	96.0	41.7
	T_5	165	22.4	2.3b	277.0d	57.1	39.9	95.6	40.4
1999	T_1	192a*	26.2a**	2.4NS	506.3a**	72.0NS	39.4NS	94.3NS	
	48.8NS								
	T_2	188a	23.2ab	2.2	465.0ab	65.1	37.9	94.2	48.2
	T_3	184a	23.8ab	2.1	402.7b	66.5	38.6	94.9	46.4
	T_4	174ab	21.5ab	2.1	324.8c	65.8	38.9	95.1	44.6
	T_5	160b	19.4b	1.9	254.4d	60.2	37.8	95.7	45.7
2000	T_1	200a**	23.6NS	2.6a*	552.2a**	79.9a*	45.3NS	85.5c*	47.7NS
	T_2	194a	23.6	2.6a	511.8a	77.0ab	45.0	86.9bc	47.1
	T_3	196a	23.0	2.6a	414.2b	74.1ab	43.5	88.9abc	47.3
	T_4	195a	23.3	2.4ab	335.9bc	71.2ab	43.6	89.8ab	46.5
	T_5	172a	21.1	2.2b	303.7c	64.3b	43.6	91.0a	44.0

*, ** Significant at the 0.05 and 0.01 level, respectively. NS : Non- significant

Soil moisture content in each plot was monitored by neutron probe (CPN, 503 DR Hydro probe). The measurement in 0.9 m were done daily and irrigation water was applied when 50 % available holding capacity was consumed in the T_1 treatment. Evapotranspiration for ten-day period were calculated according to method of water balance in 1.20 m soil depth (Heerman, 1985).

Plant height, head diameter and stem diameter were measured before harvesting. After physiological maturity, head samples for yield were harvested from three rows per plot on 31st August 1998, 21st September 1999 and 11th September 2000. The seeds were separated from the heads, oven dried at 65^{0}C and weighed to determine total dry matter Yields were adjusted to 9% moisture content. Seed oil percent, seed weight (based on 1000 seeds) and test weight were measured (Unger, 1982).

The relationship between seed yield and evapotranspiration (yield response factor) was determined according to Stewart model (Stegman and Lemert, 1981). While WUE was calculated from seed yields and total water use. Irrigation

WUE was calculated from seed yields and irrigation water use (Unger, 1982). Data were analyzed by analysis of variance and relationship between water use and seed yield were evaluated using regression analysis.

Results and Discussion

The amount of total irrigation water, rainfall and seasonal evapotranspiration during the experimental years are presented in Table 2. The magnitude of applied irrigation water to the treatments during three years varied between 138 and 690 mm. The highest irrigation water was applied to T_1 treatment in the experimental years as 555, 560 and 690 mm, respectively. During the first two years the values were close to each other, while that of last year's was found to be slightly higher. This may be attributed to the differences in climatic conditions, planting date and total growing season. Considering the seasonal ET for the treatments, the higher the deficit rate, the lower the water use was observed. In non – deficit treatment, (T_1), the seasonal ET were 800, 762 and

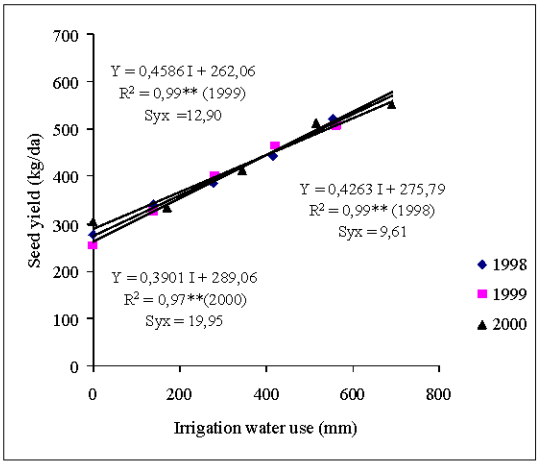

Fig. 1: Sunflower seed yield related to irrigation water use

852 mm (avg: 805 mm) and were 391, 305 and 324 mm in no – irrigation treatment, (T_5), for the years 1998, 1999 and 2000, respectively. The average value (805mm) is consistent with the ones obtained in Kİrklareli region as 845 mm by Yakan and Kamburoğlu (1989) and as 897 mm by Karaata (1993), In Ankara, this value was determined as 847 mm by Kadayifci (1996).

After adjusting the obtained yield for the seed moisture content of 9 %, the highest and lowest values were recorded in T_1 and T_5 treatments, respectively (Table 3). For the other treatments, they were placed between these two. While the deficit rates were 25 % (T_2), 50 % (T_3), 75 % (T_4) and 100 % (T_5) of T_1, the rate of decreases in seed yield was found to be 10, 24, 37 and 48 % of T_1, respectively. So, the ratio of decrease in seed yield for each percent of deficit rate was not constant. Applying different deficit rates in different growth periods of sunflower, other investigators also reported similar results (Rawson and Turner, 1982; Connor *et al.*, 1985, Khan and Muhawar, 1996). Statically significant differences were observed between the treatments for each three years according to the variance analysis at confidence level of 1%.

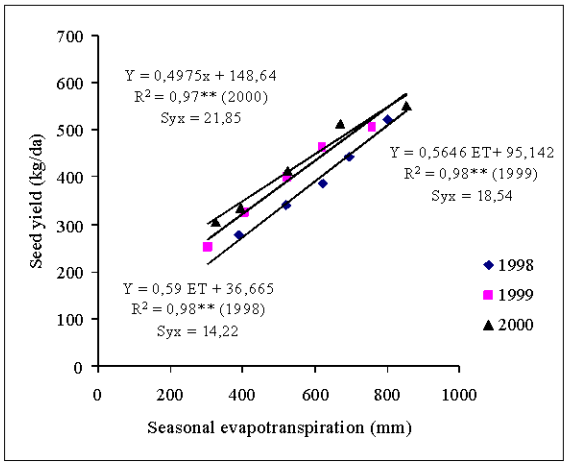

Fig. 2: Sunflower seed yield as related to seasonal evapotranspiration

In case of relationship between the treatments and vegetative growth parameters, an increase in applied irrigation water increased the plant height. There was no significant difference in plant height during first year, however, a significant difference was found in second and third year for the confidence level 1 % and 5 %, respectively. The reason for non- significant differences in the first year may be attributed to the precipitation occurred during vegetative growth period. Also, head and stem diameter were recorded to be the maximum in T_1 and minimum in T_5 treatment (Table 3). These results are in accordance with those of El-Wakil and Gaafar (1988) and Perniola *et al.* (1989).

While evaluating the yield components, seed weight, text weight and total oil content were increased with the amount of applied irrigation water and the total dry matter was vice versa. After the variance analysis of results, statistically no significant difference was found between the treatments during years in 1998 and 1999, however seed weight and total dry matter for the treatments differed significantly in 2000 at 1 % and 5 %, respectively (Table 3).

Seed yield as a function of applied irrigation water and ET for the treatments are plotted in Figure 1 and 2, respectively. Based on multiple regression analyses, seed yield was best correlated with applied irrigation water and ET. The regression coefficients for the treatments were highly significant ($p < 0.01$), and the data are similar to that summarized by Stegman and Lemert (1981) and Karaata (1994).

Relative seed yields (1-Ya/Ym) as related to corresponding estimates of relative growing seasonal evapotranspiration (1-ETa/ETm) are plotted in Figure 3 for each three years and average of years. As a result, the yield response factor (k_y) for total growing periods was determined as 0.98, 0.77 and 0.69 for the years 1998, 1999 and 2000, respectively. Average yield response factor was 0.78. While, Doorenbos ve Pruitt (1979) estimated k_y factor as 0.95 and it was determined as 0.91 and 0.81 for Kirklareli (Karaata, 1994) and Ankara (Kadayifçi ,1996) conditions, respectively.

Irrigation water use efficiency (IWUE) and (WUE) are listed in Table 2. IWUE was higher in 25 % (T_4) water consumption replenishment as compared with 50, 75 and 100 % water

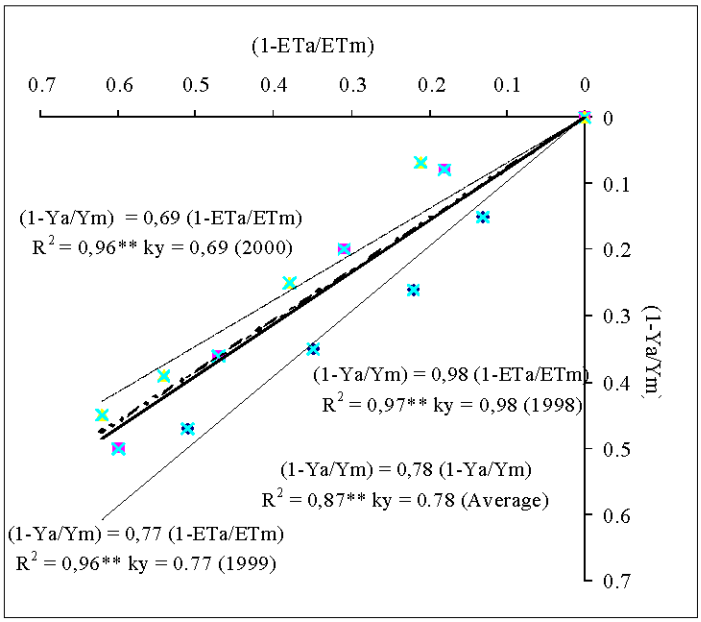

Fig. 3: Relationship between relative yield decrease (1-Ya/Ym) and relative evapotranspiration deficit (1-ETa/ETm) in total growth period of sunflower.

consumption replenishment and this value ranged from 1.95–2.47 kg/da-mm in T_4 treatment. WUE varied between 0.62 – 0.94 kg/da-mm for treatments and the highest values were recorded in no – irrigation treatment, (T_8). Unger (1990) also reported that WUE increased as water consumption decreased. The average water requirement of sunflower, which is commonly planted in Thrace Region, was obtained as 805 mm. Under deficit irrigation, seed yield was affected by different treatments and the highest yield was observed in non – deficit treatment with an average value of 526.67 kg/da. In addition, statically significant difference and a linear relationship between the seed yield and applied irrigation water and measured water consumption were determined. A negative correlative was seen between WUE and consumed water. Under experimental conditions, the water deficiency is evenly distributed during the growing season and the yield response factor (k_y) that is important factor in planning irrigation and quantifying the effect of deficit water on the yield, was found to be 0.78.

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