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YIELD RESPONSE OF SUNFLOWER TO WATER STRESS UNDER TEKIRDAG CONDITIONS

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SUMMARY

This study was carried out to determine yield response factors (k_y), under the conditions where 0%, 25%, 50%, 75% and 100% of the water requirement was supplied over the groving season. Relative water requirements were also supplied during the individual growth periods; namely, early vegetative, late vegetative, total vegetative, flowering and yield formation periods of sunflower (*Helianthus annuus* L.) under Tekirdag conditions. In the experiment, total of 554 and 560 mm irigation water were applied and 799 and 762 mm seasonal evapotranspiration were measured in T_1 treatment in which adequate irrigation water was applied during irrigated growing season in the year 1998 and 1999, respectively. The yield response factor (k_y) was obtained as 0.85 for total growing season and 0.67, 0.43, 0.40, 0.28 and 0.20 for flowering, total vegetative, yield formation, late vegetative and early vegetative period, respectively. Flowering period was more sensitive to water deficit than the other periods.

Key words: **sunflower (*Helianthus annuus* L.), yield response factor, irrigation, evapotranspiration**

INTRODUCTION

The optimum use of irrigation water, particulary in seasons where there is insufficient water for crop demand, is an essential for water resource management. Optimum use implies not only an efficient irrigation system capable of providing good uniformity, but also a proper timing of irrigation so as to conform to critical stages of growth of the crop concerned. Provided planning, design and operation of irrigation schemes, it is possible to analyze the effect of water supply on crop yields. When water supply does not meet crop water requirements, actual evapotranspiration (ET_a) will fall below maximum evapotranspiration (ET_m). Under this condition, water stress will develop in the plant, which adversely affects crop growth and ultimately crop yield. The effect of water stress on growth and yield depends on the

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crop species, variety, magnitude and time of occurrence of water deficit. The effect of the timing of water deficit on crop growth and yield is of major importance in scheduling available but limited water supply over growing periods of the crops and in determining the priority of water supply amongst cropst during the growing season (Doorenbos and Kassam, 1979).

Sunflower (*Helianthus annuus* L.) is an important oilseed crop in Turkey and its productions has greatly increased with the introduction of hybrids. Most of the production is from the Trakya region with an estimated area of 320,000 ha. Usually sunflower is grown without irrigation, but it is irrigated in sub humid and semi arid regions where precipitation is limited as in Trakya region.

Previous investigations have shown that water stress due to irrigation at various growth stages affected seed yield of sunflower. While maximum yields were obtained with full irrigation, almost maximum yields were generally obtained when irrigation was used to provide adequate water during flowering and yield formation periods. However, adequate water for initial plant growth was important for providing a plant capable of responding to later irrigations. Water stress during the yield formation period reduced yields as compared with full irrigation, but the reductions was much less than when stress occured during flowering period (Stegman and Lemert, 1981; Rawson and Turner, 1983; Connor *et.al.*, 1985; Stone *et.al.*, 1996; Unger 1986).

The objective of this study was to determine the yield response factor of sunflower during the total groving season and the individual stages of development under Tekirdag climatic conditions, one of the major sites of sunflower growing Trakya region.

MATERIALS AND METHODS

The experiment was conducted during the summers of 1998 and 1999 at the Viticultural Researche Institute of Tekirdag, Turkey (40°59' N latitude, 27°29'E longitude and 4m altitude). The climate in this region is semi-arid with annual precipitation averaging 575 mm, and April through October precipitation averaging 180mm. Soil type in the plot area is generally clay and well drained. 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.

"Sunbro" variety of sunflower was planted on 4th May 1998 and 8th June 1999. Before planting, beds and furrows were formed with a disk bedder, and trifluralin at a rate of 0.2 kg da^{-1} was applied to control weed. Fertilizer application was based upon the soil test data and fertilizers including 5 kg da^{-1} N and 5 kg da^{-1} P_2O_5 were applied.

The experiment was designed as a randomized block design with three replications for each treatment. There were 50 plants (3.50 × 3.00 m) in each plot and plant spacing was 0.70 m between the rows and 0.30 m within the row. Plots were cultivated in beds and furrows to ensure uniform water distribution. Irrigation water was applied by the furrow irrigation method and total water to each plot was measured with a flow meter. Soil moisture content in each plot was monitored by neutron probe (CPN, 503 DR Hydroprobe). To do this, aluminum access tubes were installed in 120 cm soil depth. The neutron probe was calibrated at the beginning of growing season and the calibration equation was PW=76.506, CR=25.969 R^2=0.85** (PW: volumetric soil water content, CR: count ratio) (Evett *et al.*, 1993). Evapotranspiration was calculated according to the method of water balance in 1.20 m soil depth (Heerman, 1985).

Table 1: Some physical characteristics of soil at the experiment site

Year	Soil depth (cm)	Bulk density (g cm^{-3})	Field capacity (mm)	Wilting point (mm)	Available water holding capacity (mm)
1998	0-30	1.48	120.46	79.56	40.90
	30-60	1.51	124.89	81.99	42.90
	60-90	1.55	126.02	93.05	32.97
	90-120	1.58	132.25	99.64	32.61
	0-90		371.37	254.60	116.77
	0-120		503.62	354.24	149.38
1999	0-30	1.60	129.94	78.43	51.51
	30-60	1.64	118.92	75.33	43.59
	60-90	1.58	111.96	75.70	36.26
	90-120	1.61	115.44	66.46	48.98
	0-90		360.82	229.46	131.36
	0-120		476.26	295.92	180.34

The experiment included 25 treatments in order to determine yield response factor, k_y, during the total growing season and individual growth periods. Establishment (0), early vegetatie (1a), late vegetative (1b), total vegetative (1), flowering (2), yield formation (3) and ripening (4) were consided as the growth periods of sunflower (Doorenbos and Kassam, 1979). But soil water deficit was not applied in establishment (0) and ripening (4) periods. The irrigation treatmens were based on the soil water replenishment. Control treatment "T_1" was designated to receive 100% soil water depletion and irrigation was applied when approximately 50% of available soil moisture was consumed in the 0.90 m root zone at T_1 treatment during the irrigated periods, namely, 1a, 1b, 2 and 3. The other treatments were arranged to receive 100, 75, 50, 25 and 0% of the soil water depletion measured in treatment T_1 for total growing season and the same application was repeated for each individual growth period. These 25 treatments were summarized in Table 2. In this Table, "+" and "–"represents the full irrigation (100%) and non-irrigation (0%), respectively. Because of excessive rainfall after planting, soil water deficit was not replenished in early vegetative period in 1998. Therefore, yield response factor for early (1a) and total (1) vegetative periods were not determined in the first year.

After physiological maturity, head samples for seed yield were harvested from three rows in each plot on the 31st August 1998 and 21st September 1999. The seed were separated from the heads, oven dried at 65°C and adjusted to 9% moisture content (Unger, 1982). Seed yield data were analyzed statically. The relationship between seed yield and evapotranspiration were evaluated according to Stewart equation (Doorenbos and Kassam, 1979).

Table 2: Irrigation treatments

Treatment	Growth period			
	Early vegetative (1a)	Late vegetative (1b)	Flowering (2)	Yield formation (3)
T_1	+	+	+	+
T_2	-	+	+	+
T_3	+	-	+	+
T_4	-	-	+	+
T_5	+	+	-	+
T_6	+	+	+	-
T_7	-	-	-	-
T_8	0.25+	0.25+	0.25+	0.25+
T_9	0.50+	0.50+	0.50+	0.50+
T_{10}	0.75+	0.75+	0.75+	0.75+
T_{11}	0.25+	+	+	+
T_{12}	0.50+	+	+	+
T_{13}	0.75+	+	+	+
T_{14}	+	0.25+	+	+
T_{15}	+	0.50+	+	+
T_{16}	+	0.50+	+	+
T_{17}	0.25+	0.25+	+	+
T_{18}	0.50+	0.50+	+	+
T_{19}	0.75+	0.75+	+	+
T_{20}	+	+	0.25+	+
T_{21}	+	+	0.50+	+
T_{22}	+	+	0.75+	+
T_{23}	+	+	+	0.25+
T_{24}	+	+	+	0.50+
T_{25}	+	+	+	0.75+

RESULTS AND DISCUSSION

The amount of applied irriogation water and evapotranspiration measured for each treatment during the individual growth periods are presented in Tables 3 and 4. The largest amount of irrigation water was applied in treatment T_1 in both experiment years, 554 mm in 1998 and 560 mm in 1999. Seasonal ET increased with amount of irrigation water applied. The highest evapotranspiration for the total growing period was measured in T_1, 799 mm in 1998 and 762 mm in 1999 (aver-

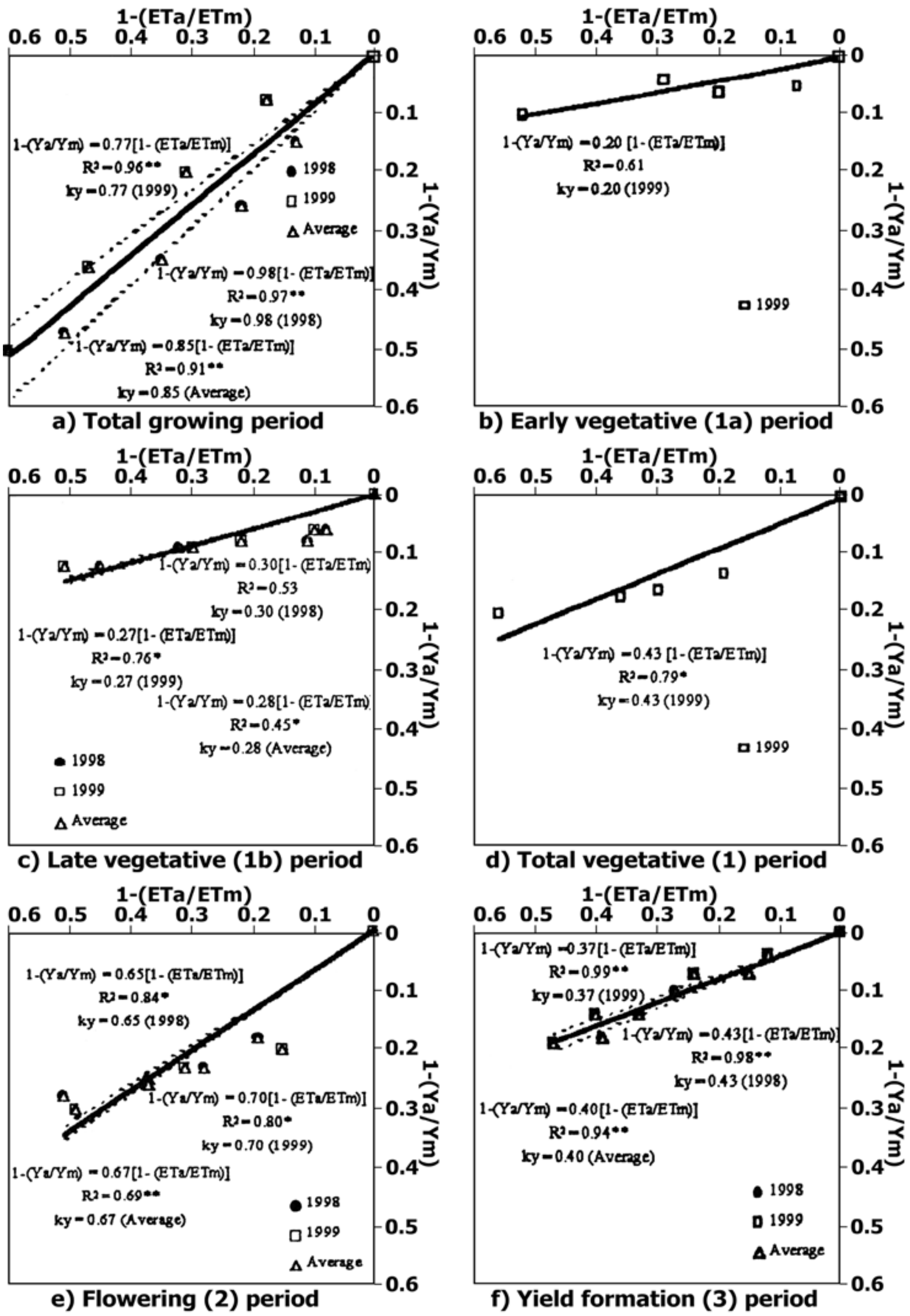

Figure 1: Yield response factor, k_y

age 781 mm) and the lowest ET occurred in the continuous stress treatment (T_1). The seasonal ET in 1998 was higher than that in 1999. Some climatic factors may have caused this difference in as much as the rainfall was higher in 1998 (135 mm) than in 1999 (50 mm). The maximum ET rates were generally obtained during the flovering period of crop growth. The seasonal ET value (781 mm) is consistent with the ones obtained in Kirklareli region, which is a city very close to Tekirdag, 845 mm by Yakan and Kamburoglu (1989) and 897 mm by Karaata (1991).

Table 3: Relative yield decrease versus relative evapotranspiration deficit in total growing period

Year	T	I (mm)	ET_m (mm)	ET_a (mm)	Ym (kg da^{-1})	Ya (kg da^{-1})	$1-(Y_a/Y_m)$	$1-(ET_a/ET_m)$	k_y
1998	T_1	554	799		521.46				
	T_7	-		392		277.03	0.47	0.51	0.92
	T_8	139		520		341.40	0.35	0.35	1.00
	T_9	278		623		385.78	0.26	0.22	1.18
	T_{10}	417		695		444.13	0.15	0.13	1.15
1999	T_1	560	762		506.26				
	T_7	-		306		254.41	0.50	0.60	0.83
	T_8	139		406		324.75	0.36	0.47	0.77
	T_9	281		524		402.68	0.20	0.31	0.65
	T_{10}	420		622		464.95	0.08	0.18	0.44

The seed yields obtained in each treatment are given Tables 3 and 4. Seed yield ranged from 277.03 to 521.46 kg da^{-1} in 1998 and from 254.41 to 506.26 kg da^{-1} in 1999. The highest seed yield was obtained in treatment T_1 in which crop water requirement was applied during the total growing oeriod and the lowest seed yield was obtained in treatment T_7 where no irrigation water was applied during the total groving period. For the other treatmens, they varied between these two. Statically significant differences were observed among the treatmens for both years assording to the variance analysis at confidence level of 1%. Sunflower seed yields in this study were comparable with the ones obtained in previous experiments in Thrace region.

The results of relative yield and relative evapotranspiration deficit for total growing period are shown in Table 3 and plotted in Figure 1a for years and average of the years. According to the regression analysisd, yield response factor, k_y, was 0.98 and 0.77 for the years and 0.85 for average of the years.

This result confirmed that sunflower was not sensitive to soil water deficit during the total growing period as Doorenbos and Kassam (1979) reported. While Doorenbos and Kassam (1979) estimated the yield response factor, k_y, as 0.95, it was determined as 0.91 and 0.81 for Kirklareli (Karaata, 1991) and Ankara conditions (Kadayifci and Yildirm, 2000) in Turkey, respectively.

Relative yield decreases and relative evapotranspiration deficits for individual growth periods are presented in Table 4 and plotted in Figure 1b-1f. As shown in the Figures, the yield response factor, k_y, was 0.20 for early vegetative, 0.28 for late vegetative, 0.43 for total vegetative, 0.67 for flowering and 0.40 for yield formation.

Table 4: Relative yield decrease versus relative evapotranspiration deficit in individual growth periods

Year	T	I_a (mm)	I^2 (mm)	ET^2 (mm)	$ET_m{}^1$ (mm)	$ET_a{}^1$ (mm)	Y_m (kg da^{-1})	Ya (kg da^{-1})	1-(Y_a/Y_m)	1-(ET_a/ET_m)	k_y
					Early vegetative (1a)						
1999	T_1	73	560	762	56		506.26				
	T_2	-	542	730		28		455.63	0.10	0.52	0.19
	T_{11}	18	548	738		40		484.43	0.04	0.29	0.14
	T_{12}	37	551	743		45		475.42	0.06	0.20	0.30
	T_{13}	55	557	741		52		482.48	0.05	0.07	0.71
					Late vegetative (1b)						
1998	T_1	211	554	799	201		521.46				
	T_3	-	434	700		110		459.49	0.12	0.45	0.27
	T_{14}	53	464	752		138		472.24	0.09	0.32	0.28
	T_{15}	106	483	777		180		478.41	0.08	0.11	0.73
	T_{18}	159	522	772		186		490.32	0.06	0.08	0.75
1999	T_1	145	560	762	175		506.26				
	T_3	-	486	671		85		445.21	0.12	0.51	0.24
	T_{14}	36	511	724		123		458.29	0.09	0.30	0.30
	T_{15}	73	534	729		137		465.74	0.08	0.22	0.36
	T_{16}	109	554	743		157		475.29	0.06	0.10	0.60
					Total vegetative (1)						
1999	T_1	218	560	762	231		506.26				
	T_4	-	467	677		101		405.74	0.20	0.56	0.36
	T_{17}	54	498	742		147		419.24	0.17	0.36	0.47
	T_{18}	110	517	733		161		422.75	0.16	0.30	0.53
	T_{19}	164	546	742		187		439.28	0.13	0.19	0.68
					Flowering (2)						
1998	T_1	137	554	799	165		521.46				
	T_5	-	467	711		81		377.86	0.28	0.51	0.55
	T_{20}	34	486	731		105		392.17	0.25	0.37	0.68
	T_{21}	68	508	739		118		400.35	0.23	0.28	0.82
	T_{22}	102	533	763		133		428.14	0.18	0.19	0.95
1999	T_1	196	560	762	194		506.26				
	T_5	-	463	712		98		352.29	0.30	0.49	0.61
	T_{20}	49	503	728		122		375.29	0.26	0.37	0.70
	T_{21}	98	518	731		135		391.48	0.23	0.31	0.74
	T_{22}	147	540	754		165		405.26	0.20	0.15	1.33
					Yield formation (3)						
1998	T_1	206	554	799	216		521.46				
	T_6	-	348	690		132		429.08	0.18	0.39	0.46
	T_{23}	52	400	704		144		449.73	0.14	0.33	0.42
	T_{24}	104	451	727		159		469.19	0.10	0.27	0.37
	T_{25}	156	504	755		184		483.78	0.07	0.15	0.47
1999	T_1	146	560	762	168		506.26				
	T_6	-	414	642		89		410.20	0.19	0.47	0.40
	T_{23}	36	450	667		101		433.80	0.14	0.40	0.35
	T_{24}	73	487	710		127		469.21	0.07	0.24	0.29
	T_{25}	109	523	734		148		488.49	0.04	0.12	0.33

These results that flowering period was the most sensitive period to soil water deficit, total vegetative period and yield formation period following this period. It was also shown that these values were lower compared with the values obtained by Doorenbos and Kassam (1979), which were 0.25 for early vegetative, 0.50 for late vegetative, 1.00 for flowering and 8.80 for yield formation. This may be attributed to the differences in climatic condition, planting date and the length of total growing season. According to yield response factort equations for individual growth shown in figures, relative yield reductions of 10, 14, 22, 34, 20% were obtained when 50% water deficit was created periods, respectively.

CONCLUSION

The yield response to water deficit of different crops is of major importance in production planning. In this study, yield response factor, k_y, of sunflower was determined as 0.85 during the total growing period. Consequently, when such crops are grown within the same project area and maximum production per unit volume of water is being aimed at, sunflower would not have the priority for water supply.

Similary, the yield response to water deficit in individual growth periods is of major importance in the schedulingof irrigation. Sunflower is more sensitive to water deficit during flowering, total vegetative and yield formation periods than during early and late vegetative periods. Planning of seasonal water supply must take into consideration the optimum allocation of water supply to the crop over the total growing period, but limited supply would be directed towards the full water requirements of ther crop during the most sensitive growth periods than spreading the available limited supply over the total growing period (Doorenbos and Kassam, 1979). As a result, sunflower is grown under limited water supply as in Thrace region; supplemental irrigation must be programmed so that sufficient water is made available in the soil during the flowering period.

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INFLUENCIA DEL ESTRÉS HÍDRICO EN EL RENDIMIENTO DE GIRASOL EN LAS CONDICIONES DE LA LOCALIDAD DE TEKIRDAG

RESUMEN

El objetivo de este estudio ha sido determinar los factores de reacción de rendimiento (k_y) en las condiciones en las cuales, durante la temporada de vegetación, se ha satisfecho 0, 25, 50, 75 y 100% de las necesidades de agua de la planta. También se satisfacían las necesidades de agua relativas para la localidad de Tekirdag, durante las fases de crecimiento particulares, como son el inicio de vegetación, terminación de vegetación, la vegetación completa, floración y formación de rendimiento de girasol (*Helianthus annuus* L.). En el ensayo realizado durante los años 1998 y 1999 en la variante T_1 con el riego óptimo, se aplicó respectivamente 554 y 560 mm de agua para el riego, y se midió la evapotranspiración de 799 y 762 mm respectivamente. El factor de reacción de rendimiento fue 0,85 para la temporada completa de vegetación y 0,67 para la floración; 0,43 para la vegetación completa; 0,40 para la formación de rendimiento; 0,28 para la terminación de vegetación, y 0,20 para el inicio de vegetación. De todas las fases de crecimiento, el período de floración se ha mostrado el más sensible al déficit de agua.

EFFET DU STRESS DÛ À LA SÉCHERESSE SUR LE RENDEMENT DU TOURNESOL DANS LA LOCALITÉ DE TEKIRDAG

RÉSUMÉ

Le but de cette expérience était d'établir les facteurs de réaction du rendement (k_y) dans des conditions où 0, 25, 50, 75 et 100% des besoins de la plante en eau étaient satisfaits au cours de la saison de végétation. Les besoins en eau relatifs pour la localité de Tekirdag au cours de certaines phases de la croissance comme le début de la végétation, la fin de la végétation, la végétation entière, la floraison et la formation de la production du tournesol (*Helianthus annuus* L.) ont aussi été satisfaits. Au cours des années 1998 et 1999 dans la variante T_1 avec irrigation optimale, 554 et 560 mm d'eau ont été utilisés et 799 et 762 mm d'évapotranspiration ont été mesurés. Le facteur de réaction du rendement a été de 0,85 pour la saison de végétation entière, de 0,67 pour la floraison, de 0,43 pour la végétation entière, de 0,40 pour la formation de la production, de 0,28 pour la fin de la végétation et 0,20 pour le début de la végétation. De toutes les phases de la croissance, c'est la période de floraison qui s'est montrée la plus sensible au manque d'eau.