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EFFECTS OF IRRIGATION REGIME ON GROWTH AND SEED YIELD OF SUNFLOWER (*HELIANTHUS ANNUUS* L.)

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Abstract

Field experiments were conducted at National Agricultural Research Center Islamabad Pakistan to study the response of sunflower hybrids to irrigation levels. Four irrigation levels (control, heading stage, heading + flowering stages, and heading + flowering + grain filling stages) were applied to two sunflower hybrids (Parsun-1 and SF-187). Randomized complete block design in split plot arrangement having 5 replications were used. Irrigation levels were kept in the main plots while hybrid in the sub plots. Plant height, number of leaves plant^{-1} and head diameter was significantly ($p \leq 0.05$) affected by irrigation, hybrids and year. The effect of irrigation was non significant on 100 seed weight, seed yield ha^{-1} and oil content (%) due to rainfall at the experimental site during both growing seasons. The effect of the year was significant on 100 seed weight, seed yield (kg ha^{-1}), and oil content. Taller plants, bigger heads, maximum 100 seed weight and high seed yield was produced during 2002 when sunflower crop received three irrigations at heading stage, heading + flowering stages, and heading + flowering + grain filling stages compared with other treatments.

Introduction

Sunflower is the most important oil seed crop of the world due to its wide range of adaptability and highest seed oil contents. The oil contents of sunflower seeds ranged between 34.26-39.13% in non-irrigated environment and 38.50-42.73% in irrigated environment (Erdemoglu *et al.*, 2003). In recent years, sunflower planted area has increased because of moderate cultivation requirements and high oil yield. Hybrid cultivars give highest yield only when irrigated (Unger, 1982; Flagella *et al.*, 2002). Even limited irrigation water applied at different growth stages of sunflower can significantly increase seed yield especially during three growth stages: heading, flowering and milking (Unger, 1983; Stone *et al.*, 1996). Karaata, (1991) found that the highest seed yield and seasonal evepo-transpiration were obtained after irrigation at heading, flowering and milking stage with no water stress. It has also been investigated by several research workers that the crop is sensitive to water stress conditions in the phases between flowering and achenes filling (Quaglietta *et al.*, 1991; Quaglietta & Andria, 1994; Hedge & Havangi, 1990). Sunflower cultivars markedly differ in their growth characters, seed and oil yield (Sharif & Sais, 1993; Salama, 1996; El-Karamity & El-Serougy, 1997; Hammad *et al.*, 1999 and Abu Ghazalla *et al.*, 2000). Ghazy & Abu Ghazala, (1999) found that seed yield, seed oil contents (%) and WUE increase in proportion to increase in the amount of irrigation given to sunflower. Rawson & Turner, (1983) reported that frequently irrigated hybrids resulted in maximum yield. Similarly Vasiliu, (1986) reported that seed yield ranged from 2.64 tons ha^{-1} with no irrigation (control) to 3.34 tons ha^{-1} with irrigation at 50% field capacity.

Research trails revealed that the soil and climatic conditions of Pakistan are quite suitable for the cultivation of sunflower. Moreover, it is a short duration crop and can be grown twice a year as a spring and summer crop successfully (Bakhsh *et al.*, 1999). Keeping in view the role of water and genotypes in the yield of sunflower, the present study was designed to investigate the optimum water requirements of sunflower crop with the objectives to examine the effect of irrigation regimes on the yield and oil contents of sunflower hybrids (i.e. Parsun-1 and SF-187).

Materials and Methods

Field experiments on the effect of frequency of irrigations at different growth stages on the yield and oil contents of sunflower hybrids were conducted at National Agricultural Research Centre (NARC) Islamabad, Pakistan. National Agricultural Research Center, Islamabad is located at 33° ′42 N latitude, 73 ′08 E longitudes and altitude of 518 m above sea level in Islamabad, Pakistan. The area is mostly leveled with a gentle slope. Climatically it falls under sub humid to humid type and form a part of Pothar land. (Table 1). The soils are alkaline (pH, 7.0 to 8.2), non saline (EC, 0.09-0.76 ds m^{-2}) and slightly to moderately calcareous. In spring 2001 and 2002 the experimental sites showed 1.04 to 2.86 mg kg^{-1} NO_3–N, 2.36 to 3.37 mg kg^{-1} P and 0.84 to 1.22% organic matter. Textural class was loam of the experimental sites.

The crop was planted during February (spring 2001) and February (spring 2002). Experiments were carried out in randomized complete block design (RCBD) with spilt plot arrangements replicated five times. Irrigation levels (No irrigation, Irrigation at heading stage (R1), Irrigation at heading + flowering stages (R1 + R4), Irrigation at heading (R1) + flowering (R4) + seed filling stages (R6) were kept in main plots while hybrids (PARSUN-I and SF-187) were assigned to sub plots. Three treatments of surface irrigation, triple, double and single in addition to one dry conditioned treatment were used. In triple application, water was applied at heading stage (R1), flowering stage (R4) and seed filling stages (R6). In double, water was applied at heading (R1) and flowering while single irrigation was applied at heading stage (R1). Standard agronomic practices were followed during the course of experiment.

Table 1. Climate data of National Agricultural Research Center Islamabad, Pakistan.

Monthly average	2001			2002		
	Max temp. (°C)	Min temp. (°C)	Rainfall (mm)	Max temp. (°C)	Min temp. (°C)	Rainfall (mm)
January	19.0	1.1	0	19.0	1.5	17.9
February	23.3	4.3	19	20.5	4.5	23.9
March	27.5	9.2	27	26.9	9.5	41.4
April	31.5	15.1	10	32.6	15.1	10.5
May	39.0	21.3	46	39.9	19.7	3.1
June	35.6	23.5	157	38.4	23.2	130.4
July	33.2	23.7	591	37.9	23.7	64.8
August	33.9	23.7	141	32.6	23.5	407.9
September	33.6	18.8	29	31.0	18.3	125.7
October	31.4	13.9	23	29.8	14.4	49.7
November	26.1	7.5	4	25.5	8.1	0
December	21.2	3.9	1	20.0	4.4	25.80

Table 2. Effect of irrigation on plant height (cm) of sunflower hybrids (Parsun-I and SF-187) during spring 2001 and 2002.

Irrigation treatments	Parsun-1			SF-187			Mean (irrigation)
Number of irrigation	Year 2001	Year 2002	Mean (Parsun-1)	Year 2001	Year 2002	Mean (SF-187)	
00 (Control)	112.2	151.6	131.9	100.6	127.2	113.9	122.9
01	106.6	152.8	129.7	91.6	128.8	110.2	120.0
02	126.8	158.4	142.6	92.8	132.2	112.5	127.6
03	116.8	165.4	141.1	95.8	134.0	114.9	128.0

LSD value for irrigation treatments at $p \leq 0.05 = 8$

	Hybrids		
	Parsun-I	SF-187	Means (Y†)
Year 2001	116.7	93.4	105.1b
Year 2002	158.9	131.7	145.3a
Means (H††)	137.8a	112.6b	

† Years †† Hybrids

Means of the same category followed by different letters are significantly different using LSD test ($p \leq 0.05$)

All data are presented as mean values of five replicates. Data were analyzed statistically for analysis of variance (ANOVA) following the method described by Gomaz & Gomaz, (1984). MSTATC computer software was used to carry out statistical analysis (Russel & Eisensmith, 1983). The significance of differences among means was compared by using Least Significant Difference (LSD) test (Steel & Torrie, 1997).

Results and Discussion

Plant growth: Hybrids, irrigation and year had a significant effect ($p \leq 0.05$) on plant height of sunflower (Table 2). Taller plants (145.3 cm) were produced during 2002 as compared with 105.1 cm of 2001 growing season. Parsun-1 achieved significantly ($p \leq 0.05$) maximum height (137.8 cm) when compared with SF-187 (112.6 cm). Among irrigations, plant height of 128.0 cm was recorded in the treatment of three irrigations which showed significant ($p \leq 0.05$) increase in plant height compared with other irrigation levels. Prasad *et al*., (1999); Taha *et al*., (2001); Damdar *et al*., (2003); Khot & Patil, (2002) reported that plant height was increased with increase in irrigation levels. Aziz & Soomro, (2001) found maximum plant height up to four numbers of irrigations; whereas Bakhsh *et al*., (1999) observed plant height up to six numbers of irrigations. Similarly, Yasin & Rashid, (2000) reported marked reduction in average plant height under deficit irrigation. Thakuria *et al*., (2004) found that the sunflower crop irrigated at seedling, buttoning, flowering

and seed developing stages recorded better results in respect of plant height. Full and limited irrigation applied at different growth stages significantly increased plant height in sunflower (Tan *et al.*, 2000).

Significant differences ($p \leq 0.05$) were observed for number of leaves plant^{-1} due to irrigations, hybrids and year (Table 3). Maximum number of leaves plant^{-1} (25.9) was observed for Parsun-1 compared with SF-187 (24.6 leaves plant^{-1}). During 2001 significantly highest number of leaves (25.8) was recorded as compared with (24.7) in 2002. Treatments which received three irrigations produced maximum (25.7) number of leaves plant^{-1}, statistically at par with treatments receiving two irrigations (Fig. 1). Karaata, (1991); Gajri *et al*., (1997) reported that irrigation increases the number of leaves plant^{-1} and leaf area index (LAI) as a related character. Similarly, Thakuria *et al.*, (2004) observed that crop growth rate in sunflower was improved under irrigation condition. Head diameter was significantly ($p \leq 0.05$) affected by hybrids, years and irrigations (Table 4). Crop sown during 2002 recorded maximum head diameter (15.7 cm) compared with (14.2 cm) in 2001 growing season. Head diameter increased with increase in irrigation frequency. Treatments receiving maximum irrigations produced significantly ($p \leq 0.05$) bigger heads (15.9 cm) compared with other irrigation treatments (Fig. 1). These results are in line with Tomar *et al.*, (1999), Bakhsh *et al.*, (1999); Khot & Patil, (2002) reported that head diameter of sunflower was increased with increase in number of irrigations. Similarly, Taha *et al.*, (2001) concluded that head diameter of sunflower was linearly related to the amount of irrigation levels. On the contrary, Gajendra *et al.*, (2001) concluded that irrigation did not significantly affect the yield attributes of sunflower crop. Aziz & Soomro, (2001) revealed that all the growth and yield contributing components (i.e. plant height, days to maturity, head diameter, seed yield and oil content) were significantly affected by different irrigation frequencies.

Table 3. Effect of irrigation on number of leaves plant^{-1} of sunflower hybrids (Parsun-I and SF-187) during spring 2001 and 2002.

Irrigation treatments	Parsun-1			SF-187			Mean (irrigation)
Number of irrigation	Year 2001	Year 2002	Mean (Parsun-1)	Year 2001	Year 2002	Mean (SF-187)	
00 (Control)	24.0	25.0	24.5	23.0	25.4	24.2	24.4
01	25.6	25.4	25.5	22.8	24.2	23.5	24.5
02	25.4	26.4	25.9	24.0	26.6	25.3	25.5
03	26.2	26.4	26.3	24.2	25.8	25.0	25.7

LSD value for irrigation treatments at $p \leq 0.05 = 1.193$

	Hybrids		
	Parsun-I	SF-187	Means (Y†)
Year 2001	25.7	23.7	24.7b
Year 2002	26.1	25.5	25.8a
Means (H††)	25.9a	24.6b	

† Years †† Hybrids

Means of the same category followed by different letters are significantly different using LSD test ($p \leq 0.05$)

Table 4. Effect of irrigation on head diameter (cm) of sunflower hybrids (Parsun-I and SF-187) during spring 2001 and 2002.

Irrigation treatments	Parsun-1			SF-187			Mean (irrigation)
Number of irrigation	Year 2001	Year 2002	Mean (Parsun-1)	Year 2001	Year 2002	Mean (SF-187)	
00 (Control)	13.3	13.5	13.4	14.6	14.4	14.5	14.0
01	14.9	14.4	14.6	12.8	15.3	14.1	14.4
02	14.6	15.4	15.0	15.2	16.8	16.0	15.5
03	13.2	17.7	15.5	14.8	17.8	16.3	15.9

LSD value for irrigation treatments at $p \leq 0.05 = 1.017$

	Hybrids		
	Parsun-I	SF-187	Means (Y†)
Year 2001	14.0	14.4	14.2b
Year 2002	15.2	16.1	15.7a
Means (H††)	14.6	15.3	

† Years †† Hybrids

Means of the same category followed by different letters are significantly different using LSD test ($p \leq 0.05$)

Yield and oil contents: Hundred seed weight was significantly ($p \leq 0.05$) affected by years and interaction while the effect of irrigation was non-significant due to rainfall effect in both growing seasons (Table 5). Crop planted during 2002 produced bigger seeds with hundred seed weight (5.1 g) compared with (4.4 g) in 2001 growing season. Hundred seed weight was increased with increase in irrigations frequency (Fig. 2). Significantly, ($p \leq 0.05$) maximum 100 seed weight (5.0 g) was observed for treatments applied with three irrigations when compared with other irrigation frequencies (Bakht *et al*., 2010). Seed weight was significantly ($p \leq 0.05$) maximum (4.8 g) in Parsun-1 compared with SF-187. Karaata, (1991) found that 1000 seed weight increased with irrigations applied at flowering and milking periods. Similarly, Bakhsh *et al*., (1999); Aziz & Soomro, (2001), Tomar *et al*., (1999); Taha *et al*., (2001) reported that 100 seed weight was linearly related to the amount of irrigations. However our results are contradicted by Khot & Patil, (2002) and concluded that 100 seed weight was not significantly affected by irrigations. Three irrigations applied in spring season produced comparatively higher seed yield (2680 kg ha^{-1}) but the difference was non significant due to rainfall at the experimental site during growing season (Table 6). The rainfall has masked the effect of irrigation on seed yield of sunflower during the growing season. Seed yield was significantly ($p \leq 0.05$) affected by years while the effect of hybrids was non significant. Maximum seed yield (2920 kg ha^{-1}) was produced during 2002 compared with (2009 kg ha^{-1}) in 2001. These results are in an agreement with Baldev *et al*., (1999); Mehendar *et al*., (2000); Prasad *et al*., (1999) they investigated that seed yield was enhanced with increase in number of irrigations. Velu & Palanisami, (2001) reported that water stress at the flowering stage could reduce the seed yield up to 29%. Miller *et al*., (1984) observed that yield in irrigated trials was more than in the dry land trial.

Table 5. Effect of irrigation on 100 seeds weight (g) of sunflower hybrids (Parsun-I and SF-187) during spring 2001 and 2002

Irrigation treatments	Parsun-1			SF-187			Mean (irrigation)
Number of irrigation	Year 2001	Year 2002	Mean (Parsun-1)	Year 2001	Year 2002	Mean (SF-187)	
00 (Control)	4.7	4.2	4.5	4.4	4.5	4.5	4.5
01	4.9	4.5	4.7	4.2	4.8	4.5	4.6
02	4.6	4.8	4.7	4.0	5.2	4.6	4.7
03	4.4	5.5	5.0	4.3	5.6	5.0	5.0

	Hybrids		
	Parsun-I	SF-187	Means ($Y^{\dagger}$)
Year 2001	4.6	4.2	4.4b
Year 2002	4.9	5.2	5.1a
Means ($H^{\dagger\dagger}$)	4.8	4.7	

† Years †† Hybrids

Means of the same category followed by different letters are significantly different using LSD test ($p \leq 0.05$)

Table 6. Effect of irrigation on seeds yield (kg ha^{-1}) of sunflower hybrids (Parsun-I and SF-187) during spring 2001 and 2002.

Irrigation treatments	Parsun-1			SF-187			Mean (irrigation)
Number of irrigation	Year 2001	Year 2002	Mean (Parsun-1)	Year 2001	Year 2002	Mean (SF-187)	
00 (Control)	1540	2460	2000	2053	2533	2293	2147
01	1653	2480	2067	2033	2647	2340	2203
02	1900	2940	2420	2240	2960	2600	2510
03	2087	3593	2840	2140	2900	2520	2680

	Hybrids		
	Parsun-I	SF-187	Means ($Y^{\dagger}$)
Year 2001	1880	2138	2009b
Year 2002	3004	2836	2920a
Means ($H^{\dagger\dagger}$)	2442	2487	

† Years †† Hybrids

Means of the same category followed by different letters are significantly different using LSD test ($p \leq 0.05$)

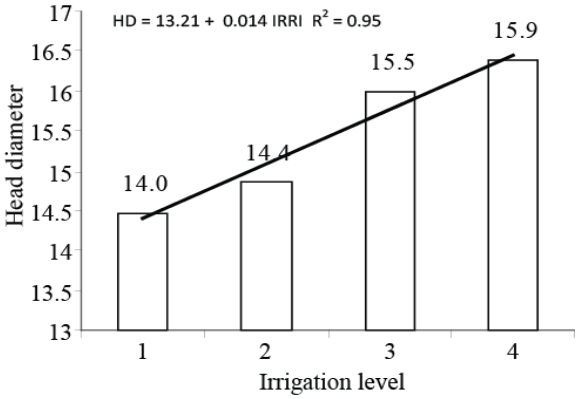

Fig. 1. Effect of irrigation on head diameter (cm) of sunflower during spring 2001 and 2002

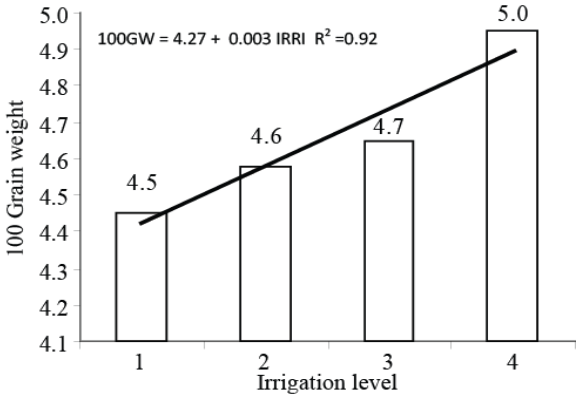

Fig. 2. Effect of irrigation on 100 grain weight (g) of sunflower during spring 2001 and 2002.

Table 7. Effect of irrigation on oil content (%) of sunflower hybrids (Parsun-I and SF-187) during spring 2001 and 2002.

Irrigation treatments	Parsun-1			SF-187			Mean (irrigation)
Number of irrigation	Year 2001	Year 2002	Mean (Parsun-1)	Year 2001	Year 2002	Mean (SF-187)	
00 (Control)	45.71	41.50	43.61	40.92	38.78	39.85	41.73
01	45.35	39.87	42.61	40.00	39.15	39.58	41.09
02	45.68	40.15	42.92	41.76	39.51	40.64	41.78
03	44.99	39.90	42.45	42.10	37.04	39.57	41.01

	Hybrids		
	Parsun-I	SF-187	Means (Y†)
Year 2001	45.34	41.29	43.32a
Year 2002	39.97	38.57	39.27b
Means (H††)	42.66a	39.93b	

† Years †† Hybrids

Means of the same category followed by different letters are significantly different using LSD test ($p \leq 0.05$)

Significant ($p \leq 0.05$) differences were observed for oil contents due to hybrids and years while the effect of irrigation was non significant (Table 7). Our results suggested that crop planted during 2001 produced significantly ($p \leq 0.05$) more oil content (43.325%) compared with (39.27%) from crop raised during 2002. Among hybrids Parsun-1 produced significantly ($p \leq 0.05$) maximum oil content (42.66%) compared with (39.93%) from SF-187. Irrigation frequencies showed non- significant effect on oil content of sunflower. Miller *et al.*, (1984) observed that the average seed oil concentration was 1.8% higher in the dry land trial than irrigated trial. However, seed yield was 172 kg ha^{-1} greater than the rainfed trial. On the contrary, Aziz & Soomro, (2001); Tan *et al.*, (2000); Flagella *et al.*, 2000; Santonoceto *et al.*, (2003) reported an increase in oil content due to increase in irrigation frequency.

Conclusions

According to the results obtained, it is concluded that the effect of irrigation levels, hybrids and years had significant effect on plant height, number of leaves $plant^{-1}$ and head diameter. Maximum plant height (128 cm), maximum number of leaves $plant^{-1}$ (25.7) and maximum head diameter (15.9 cm) was recorded from the treatment of three irrigations applied at heading stage, heading + flowering stage and heading + flowering stage +seed filling stage respectively. Hybrid (Parsun-I) produced highest plant height (137.8 cm) and highest number of (25.9 leaves $plant^{-1}$). The effect of the year was significant and produced highest plant height (145.3 cm), highest number of leaves $plant^{-1}$(25.8) and highest head diameter (15.7 cm) during 2002 spring season. The effect of irrigation levels was non significant on 100 seed weight, seed yield (kg ha^{-1}) and oil content (%) due to rainfall at the experimental site during both growing seasons. However maximum hundred seed weight (5.0g) and maximum seed yield (2680 kg ha^{-1}) was recorded with the application of three irrigations at heading stage, heading + flowering stage and heading + flowering stage +seed filling stages. The effect of hybrids on hundred seed weight and seed yield was non-significant. High oil content (41.78%) was recorded with the application of two irrigations applied at heading stage and heading + flowering stages respectively.

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