INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
1560–8530/2005/07–6–920–924
http://www.ijab.org

Effect of Irrigation Regimes on Some Agronomic Traits and Yield of Different Sunflower (*Helianthus annuus* L.) Hybrids

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ABSTRACT

Field experiments were conducted during 1995 and 1996 to study the response of three spring planted sunflower hybrids as HS-33, NK-265 and SF-270, to timing of irrigation application viz. I_5 = 5 irrigations (at early vegetative growth, at head visible, at floral initiation, at floral completion and during grain development), I_4 = 4 irrigations (at head visible, at floral initiation, at floral completion and during grain development), I_3 = 3 irrigations (at floral initiation, at floral completion and during grain development), I_0 = no irrigation; Dry (maturity on residual moisture, rainfed). The experiment was laid out in randomized complete block design keeping irrigation treatments in main and hybrids in sub plots. Irrigation increased total dry matter (TDM) for all hybrids with the increase being greater for the later maturity hybrid HS-33. Commencement of irrigation early in the season resulted in more total dry matter production in all the hybrids but application of first irrigation 40 (I_4) and 60 (I_3) days after sowing produced TDM that was lower by 5.0 and 6.5% for HS-33, 12 and 22% for NK-265 and 21 and 26% for SF-270 hybrids, respectively. Highest achene yields were recorded with the irrigation applied at head visible, at floral initiation, at floral completion and during grain development. The early maturity hybrid SF-270 had the highest harvest index but because of reduced total dry matter production achene yields were lower for this hybrid. Different agronomic traits as plant height stem diameter, head diameter, number of achenes per head and 1000-achene weight varied with irrigation treatments. Number of achenes per head varied among hybrids while differences in 1000-achene weight were non-significant between HS-33 and NK-265 during 1995 but during 1996 NK-265 produced heavier achenes. SF-270 exhibited lighter achenes during both the years.

Key Words: Sunflower; *Helianthus annuus* L.; Irrigation; Hybrids; Agronomic traits

INTRODUCTION

Pakistan is facing an acute shortage of edible oil. Domestic edible oil production from all sources has grown @ 2.56% annually over last 24 years, whereas the domestic consumption is increasing at an annual rate of 7.7% (Anonymous, 1995). Total availability of edible oils in 2002-03 was 2.199 million tons. Local production stood at 0.641 million tons, which accounted for 29.15% of the domestic requirement while remaining 70.85% of the country's requirement was met through imports (GOP, 2003). This shows an import growth rate of 12.5% since 1970-71. Among different non-conventional oilseed crops sunflower has emerged as a promising crop. It was cultivated on an area of 150.2 thousand hectares with a total production of 260 thousand tons and an average yield of 1731 kg ha^{-1} (GOP, 2003). Although from experimental fields yield as high as 2289 kg ha^{-1} has been reported (PARC, 1994) yet it is below its potential yield of 2600 kg ha^{-1} (Anonymous, 1995). The yield realized at the farmer's fields is still much lower.

In Pakistan diverse sunflower genotypes, i.e. synthetic, open-pollinated and hybrids are being grown. The new range of hybrid cultivars varies in their relative maturity and morphological characters such as leaf area and plant height. Research efforts have been underway to define plant characters and management strategies that confer sunflower with adaptation to Pakistan's high temperature and moisture limited environments. Much of the previous work continued to be confined to single genotypes. The absence of genotype comparison from many studies limits the extension of the interpretation of the work to the new hybrid cultivars of different maturity and morphological characters. The introduction of semidwarf and dwarf sunflower plant types has prompted the initiation of research to provide answers for sunflower producers in the country. The availability of cultivars of different maturity has also raised the possibility of yield stability by the selection of hybrids of maturity appropriate to specific environmental conditions.

Where precipitation and soil water supply are limited sunflower respond positively to irrigation with respect to growth and yield (Unger, 1990). Timing of irrigation is important for efficient use of applied water and for maximizing yields. Devising management strategies, which maximize the amount of water available to the crop, may bring about yield improvement under dry land conditions (Turner & Begg, 1981). Sunflower responds to irrigation, and yield increases exceeding 100% are common on drought affected soils (Robinson, 1971). Hybrids with contrasting morphological, and possibly, physiological characters in particular are available under different sets of macroclimatic conditions. Yield increases can be obtained by selecting superior agronomic characteristics or by reducing the factors, which reduce yield such as stress. In view of immense importance of irrigation timing for maximizing sunflower productivity, present studies were carried out to study the impact of different timing of irrigation on some agronomic traits and yield and yield components of diverse sunflower hybrids.

MATERIALS AND METHODS

Studies were carried out at the Agronomic Research Area, University of Agriculture, Faisalabad (31.25° N, 73.09° E, & 184 m) for two years during 1995 and 1996. The soil was a sandy clay loam in texture and with good drainage. Before sowing soil test showed a pH of 7.7 - 8.1, organic matter content from 0.72 to 0.81% and N 0.036 - 0.037%, P_2O_5 6.3 to 6.4 ppm and K_2O 145 - 148 ppm in the two growing seasons. Four irrigation treatments as I_5 = 5 irrigations (at early vegetative growth, at head visible, at floral initiation, at floral completion and during grain development, I_4 = 4 irrigations (at head visible, at floral initiation, at floral completion and during grain development), I_3 = 3 irrigations (at floral initiation, at floral completion and during grain development), I_0 = no irrigation; Dry (maturity on residual moisture, rainfed) were placed as main plots and three sunflower hybrids viz. H_1 (HS - 33), H_2 (NK - 265) and H_3 (SF - 270) in sub plots. The experiment was laid out in randomized complete plot design with split arrangement and quadruplicated. Net plot size was 4.5 x 7.0 m. Buffer plots of 1.2 m between the sub plots were maintained to avoid the seepage/border effect of irrigation among various treatments. The seed of all the three cultivars was obtained from National Oilseed Development Project, National Agricultural Research Centre, Islamabad.

In each season the experimental field was wetted to field capacity by heavy irrigation (*rouni*) and seedbed was prepared when the field was at proper moisture condition. In each experiment sunflower was sown in February. A seed rate of 8 kg ha^{-1} was used during both the years. The crop was sown in 75 cm a part rows and each sub plot had six rows. Planting was done by dibbling and placing 3 seeds per hill at 25 cm distance from each other. After crop establishment, at 2 - 4 leaf stage one plant per hill was maintained.

Fertilizer was applied @ 100 kg ha^{-1} each of N and P_2O_5. All P_2O_5 and half N was applied at sowing, remaining N was applied either with first irrigation in the plots to be irrigated or incorporated at the same time in plots not to be irrigated. Urea and single super phosphate were used as a source of fertilizer. Crop was irrigated as per schedules suggested. Irrigation water was applied using a cutthroat flume (90 cm x 20 cm size). Time for the application of measured quantity of water was calculated using the following formula as T = Ad/ Q, where t = application time (hours), A = field area (ha, m^2), d = depth of irrigation application (m) and Q = discharge, flow rate (m^3 sec^{-1}; Buland *et al.*, 1994). During growing season, two hoeing were done to control weeds. The crop was then earthed up to protect it from lodging. Seedling count showed that uniform number of plants in each treatment was established during both the years. Data on agronomic traits as plant height at harvest (cm), stem diameter (cm), head diameter (cm), achenes per head, 1000-achene weight (g; 1000-AW) and achene yield (kg ha^{-1}) were recorded by following the standard procedures. Two central rows from each sub plot were harvested for recording the achene yield, converted to kg ha^{-1} and are reported at 8% moisture content. The harvest index (HI) was calculated as the ratio of the achene yield to total biological yield and was expressed in percentage. The data were statistically analyzed by using the computer statistical program MSTAT-C (Freed & Eisensmith, 1986). Analysis of variance technique was employed to test the overall significance of the data, while the least significance difference (LSD) test at P = 0.05 was used to compare the differences among treatments' means.

RESULTS AND DISCUSSION

Agronomic traits and yield components. Results revealed that different irrigation regimes significantly ($P \leq 0.05$) influenced plant height of sunflower during both the years (Table I). Maximum plant height of 181.8 cm (179.3 – 184.4 cm) was recorded under I_5 treatment. Plant height decreased gradually as the irrigation regimes decreased from I_4 to I_3. Minimum plant height was recorded for I_0 during both the years. Differences in plant height among different hybrids were significant ($P \leq 0.05$) during both the years (Table I). Tallest plants were recorded for HS-33 hybrid. Shahid *et al.* (1988), Bakhsh *et al.* (1999), Kakar and Soomro (2001) and Chaniara *et al.* (1989) have reported reductions in plant height of sunflower when irrigation regimes were reduced. However, Akhtar *et al.* (1993) reported a non-significant difference in plant height of sunflower when irrigated at different developmental stages. Rawson *et al.* (1980), Takami *et al.* (1981), Hang and Evans (1985) and Al-Ghamdi *et al.* (1991), also found a reduction in plant height of sunflower under moisture stress conditions. Unger (1983) reported that early season water stress resulted in shorter plants. Different irrigation treatments significantly ($P \leq 0.05$) influenced stem diameter of sunflower (Table I). Thickest stems were recorded under I_5 treatment. Stem diameters decreased gradually in the order $I_4 > I_3 > I_0$ treatments. Differences in stem diameter among the hybrids in these studies were non-significant (Table I). Kakar and Soomro (2001) have reported significant reduction in stem thickness when frequency of irrigation was reduced in sunflower. Shahid *et al.* (1998) reported that stem diameter was reduced with not only delayed commencement of irrigation but also in crop receiving irrigation at 7, 14, 28, 42, 56 and 70 days after sowing in sunflower hybrid HS-33. Different irrigation treatments significantly ($P \leq 0.05$) affected the head diameter of sunflower hybrids in the present studies (Table I). Maximum head diameter of 21.36 cm (20.49 - 22.24 cm) was recorded for I_5 treatment. Head diameters under I_4 and I_3 treatments were statistically similar during both the years of experimentation. Among hybrids, maximum head

Table I. Effect of irrigation on plant development and yield components of sunflower hybrids

Treatments	Plant height (cm)		Stem diameter (cm)		Head diameter (cm)		Achenes per head		1000-achene weight (g)	
Irrigations	**Year 1**	**Year 2**	**Year 1**	**Year 2**	**Year 1**	**Year 2**	**Year 1**	**Year 2**	**Year 1**	**Year 2**
I_5	179.3 a	184.4 a	2.26 a	2.32 a	20.49 a	22.24 a	1574 a	1697 a	50.73 b	55.10 b
I_4	153.9 b	158.9 b	2.08 b	2.15 b	18.18 b	20.14 b	1528 b	1620 b	51.11 ab	56.59 a
I_3	139.7 c	144.6 c	1.85 c	1.92 c	17.37 b	19.34 b	1516 c	1582 c	51.35 a	57.31 a
I_0	116.3 d	120.3 d	1.53 d	1.58 d	9.12 c	10.16 c	892 d	993 d	26.35 c	29.36 c
s.e.m	1.46	0.76	0.035	0.037	0.34	0.39	3.48	1.60	0.12	0.37
Hybrids										
HS-33	192.6 a	197.5 a	1.99^{NS}	2.04^{NS}	17.90 a	19.41 a	1507 a	1568 a	45.35 a	49.18 b
NK-265	135.9 b	141.1 b	1.88	1.95	15.78 b	17.91 b	1307 c	1374 c	45.73 a	52.08 a
SF-270	113.5 c	117.5 c	1.92	1.99	15.19 b	16.59 c	1319 b	1478 b	43.58 b	47.59 c
s.e.m	0.52	0.64	0.048	0.050	0.29	0.29	2.84	3.04	0.14	0.40
Interaction										
I x H	**	**	NS	NS	NS	*	**	**	**	**
Mean	147.33	152.03	1.93	1.99	16.29	17.97	1377	1473	44.88	49.61

Figures in the same column with different letters differ significantly at $P \leq 0.05$ by LSD test. I_5=5 irrigations (at early vegetative growth, at head visible, at floral initiation, at floral completion and during grain development, I_4=4 irrigations (at head visible, at floral initiation, at floral completion and during grain development), I_3=3 irrigations (at floral initiation, at floral completion and during grain development), I_0= no irrigation; Dry (maturity on residual moisture, rainfed)

diameter (18.6 cm) was recorded for HS-33. During 1995 head diameter for NK-265 and SF-270 was similar but during 1996 head diameter of NK-265 hybrid was higher than SF-270. Shahid *et al.* (1998) reported that maximum head diameter in sunflower was produced when crop was irrigated seven times with weekly intervals starting from 14 days after sowing. While weekly or fortnightly irrigations starting at 7 or 14 days after sowing resulted in minimum head diameter. Gimenez and Fereres (1987), Akhtar *et al.* (1993) and Chaniara *et al.* (1989) have also reported reduced head diameters in sunflower under limited moisture supplies. Tahir *et al.* (2002) reported significant differences in head diameter among different sunflower genotypes. Takami *et al.* (1981) reported that head growth in sunflower is at least as sensitive to water stress as is vegetative growth.

The number of achenes per heads was significantly ($P \leq 0.05$) higher in irrigated over Dry treatments (Table I). Highest number of achenes per head 1635 (1574 - 1697) was recorded in I_5 irrigation treatment. The number of achenes decreased as the irrigation regime shifted from I_4 to I_3 (1574 vs. 1549). Dry (I_0) treatment produced minimum (913) number of achenes per head. HS-33 produced maximum achenes per head that ranged from 1507–1568. SF–270 produced 1319 (1995) and 1478 (1996) achenes per head, which were significantly higher than those recorded for NK-265. A similar pattern was observed for both the years. There was a significant interaction between irrigation treatments and hybrids for number of achenes per head during both the year (Table I), thereby indicating that the response depended upon irrigation timing. During both the years HS-33 produced maximum number of achenes per head under I_5 treatment but under I_0 treatment the number of achenes per head was highest for SF-270 during 1995 and for NK–265 during 1996. HS-33 produced lowest number of achenes per head under I_0 treatment during both the years under experimentation. Reduction in number of achenes per head in sunflower as a consequence of reducing irrigation frequency has been reported by Kakar and Soomro (2001) and Chaniara *et al.* (1989). Akhtar *et al.* (1993) reported that number of achene per head decreased as the water stress occurred at flowering or seed setting. Shahid *et al.* (1998) also reported reductions in achenes per head with changing irrigation schedules in sunflower. Fereres *et al.* (1986) reported reduction in number of seeds per head under drought and also among different genotypes of sunflowers.

Differences in 1000-achene weight (TAW) were significant ($P \leq 0.05$) under different irrigation treatments (Table I). However, it was similar for I_5 and I_4 treatments during 1995 (50.73 vs. 51.11 g). I_4 and I_3 treatments in turn produced similar TAW. Almost same trend was observed during 1996 except that TAW was lower under I_5 treatment than the I_4 treatment. Dry treatment differed from irrigated treatments in having lighter seeds. Difference in TAW between HS-33 and NK-265 was non-significant during 1995 but during 1996 NK-265 produced heavier achenes. SF-270 produced lighter achenes during both the years in this study. Ravishankar *et al.* (1990) reported that test weigh in sunflower decreased under water stress and it was more so in late stress. Al-Ghamdi *et al.* (1991) reported low test weight values associated with long irrigation intervals. Bakhsh *et al.* (1999) reported that lighter seeds were produced when frequency of irrigation was reduced from six irrigations to two in sunflower.

Total dry matter, achene yield and harvest index. Total dry matter (TDM) at final harvest was significantly ($P \leq 0.05$) affected by irrigation regimes over Dry plots during both the years (Table II). TDM yield in I_4 and I_3 treatments was 2% (2.92 – 0.94) and 13.5% (14.9 - 12.7%) less than the I_5 treatment, respectively. On an average, TDM yield decreased by 11.38% in I_3 treatment over I_4 treatment (8592 vs. 7714 t ha^{-1}). HS-33 produced highest TDM during both the years. On an average HS-33 yielded 45.32 and 52.58% more TDM over NK-265 and SF-270, respectively. The interaction between irrigation regimes and sunflower hybrids was also highly significant ($P \leq 0.05$) during both the years (Table II), indicating that TDM yield response depended upon irrigation. HS-33 gave highest TDM yield in I_5 treatment during both the years. TDM yield of HS-33 decreased in I_4 and I_3 treatments by about 7 - 8 and 3 - 5% during 1995 and 1996, respectively. Reduction in TDM

Table II. Effect of irrigation on total dry matter, achene yield and harvest index of sunflower hybrids

Treatments	Total dry matter (kg ha^{-1})		Achene yield (kg ha^{-1})		Harvest index%	
Irrigations	**Year 1**	**Year 2**	**Year 1**	**Year 2**	**Year 1**	**Year 2**
I_5	8399 a	9109 a	2563 b	2780 c	30.63 c	30.63 c
I_4	8161 b	9024 a	2660 a	2941 a	32.64 b	32.64 b
I_3	7306 c	8122 b	2553 b	2839 b	35.13 a	35.13 a
I_0	1221 d	1399 c	227 c	262 d	18.70 d	18.82 d
s.e.m	11.54	50.70	7.87	17.34	0.11	0.13
Hybrids						
HS-33	8097 a	8782 a	2569 a	2787 a	28.87 b	28.88 b
NK-265	5433 b	6182 b	1730 b	1967 b	29.26 ab	29.35 a
SF-270	5285 c	5776 c	1704 b	1863 c	29.70 a	29.70 a
s.e.m	11.43	48.60	9.91	22.72	0.19	0.16
Interaction						
I x H	**	**	**	**	**	**
Mean	6272	6913	2000	2205	29.27	29.31

Figures in the same column with different letters differ significantly at $P \leq 0.05$ by LSD test. I_5=5 irrigations (at early vegetative growth, at head visible, at floral initiation, at floral completion and during grain development, I_4=4 irrigations (at head visible, at floral initiation, at floral completion and during grain development), I_3=3 irrigations (at floral initiation, at floral completion and during grain development), I_0= no irrigation; Dry (maturity on residual moisture, rainfed)

yield was more pronounced under I_3 treatment for both NK-265 (12 - 22%) and SF-270 (21 - 26%) over I_5 treatment. As for interactive response for TDM yield under I_3 treatment is concerned, HS-33 still gained TDM by 3 - 4% but NK-265 and SF-270 underwent loss of TDM by 14 - 17 and 33 - 36%, respectively, as irrigation regime shifted from I_4 to I_3. Total dry matter yield under Dry treatment for the three hybrids was in the order of SF-270 > NK-265 HS-33 > during both the years. Values of TDM yield in these studies were similar to those reported earlier (e.g., Anderson *et al.*, 1978; Rawson & Turner, 1983). Connor *et al.* (1995) have reported the reduction in TDM yield when sunflower was grown under dry-land conditions without supplemental irrigation. The maintenance of TDM yield by HS-33 under I_4 and I_3 treatments is in accordance with the findings of Connor *et al.* (1985) who suggested that if watering was commenced at or before budding, the crop still has the capacity to grow and accumulate substantial biomass. Rawson and Turner (1982) have ascribed this capacity to the ability to gain leaf area on commencement of irrigation which, in turn, depended on the time of commencement of irrigation. Differential response of dry matter production has been reported by Fereres *et al.* (1986) who suggested that late maturing hybrid Sungro produced higher TDM over the early maturing hybrid Guadalete. Maximum TDM for HS-33 type hybrids should of the order of 10 - 12 t ha^{-1}. The maximum TDM yields from irrigated treatments (8 - 9 t ha^{-1}), therefore indicate scope for improvement. Increased achene yield could be expected if total biomass was increased. The differences between hybrids in TDM yields in these studies were essentially the result of the shortened crop duration. Fereres *et al.* (1986), Dubbelde (1990) and Schneiter (1992) have also attributed the differences in biomass production among genotypes to crop genotypes to crop duration and maturity ranking of sunflowers. Highest achene yield (2660 - 2941 kg ha^{-1}) was recorded in I_4 treatment during both the years. Achene yield was similar in I_5 and I_3 treatments during 1995; however, it was higher in I_3 treatment during 1996. On an average I_4 treatment gave 3.86% (4.19 – 3.59%) higher achene yield than I_3 treatment. HS-33 produced achene yield of 2678 kg ha^{-1} (2569 – 2787 kg ha^{-1}) that was on an average, 45 and 50% higher than the achene yields realized from NK-265 and SF-270 hybrids, respectively. A highly significant interaction among the irrigation treatments and hybrids during both the yeas (Table II) indicated that the response depended on irrigation treatments. When irrigated, HS-33 produced higher achene yield during both the years. However, the achene yields under Dry (I_0) treatment were in the order of SF-27 > NK-265 > HS-33. Achene yield of HS-33 was highest in I_3 treatment during both years while for NK-265 and SF-270 highest achene yields were recorded in I_4 treatment during both the years. In these studies achene yield of the irrigated treatments was on an average 11 times that of the Dry treatments. The average achene yields of the present study at 2000 kg ha^{-1} (1995) and 2205 kg ha^{-1} (1996) were similar to the average experimental yields in Pakistan of about 1500-2000 kg ha^{-1} (PARC, 1993 & 1994) under similar environments. Maximum achene yield for the hybrids under irrigated conditions were similar to those reported elsewhere (Nazir *et al.*, 1992; Akhtar *et al.*, 1993). The range of achene yield obtained in these studies also highlights the commonly encountered large variation in yields of sunflowers under various irrigation regimes (Bakhsh, 1999; Kakar & Soomro, 2001) and also owing to differences in genetic variability among sunflower cultivars (PARC, 1994). Several other authors (e.g., Connor *et al.*, 1985; Connor & Sadras, 1992; Nandhagopal *et al.*, 1996; Mercau *et al.*, 2001) have reported a positive response of achene yield of sunflowers under different strategies of irrigation Similarly, Zafforani and Schneiter (1989) and Schneiter (1992) have reported variation in achene yield of standard height (tall), semidwarf (SD) and dwarf (D) sunflower hybrids. Sunflower is cultivated during spring, autumn and winter seasons in Pakistan. Higher yields are obtained when planting is made on specific dates. During spring season severe yield reductions in non-irrigated crop occur due primarily to high evaporative demand and lack of winter rainfall, especially under Faisalabad conditions. Highest HI (35.13%) was recorded under I_3 treatment. Among irrigated plots harvest indices decreased as the frequency of irrigation was increased. However, lowest harvest indices (18.70 - 18.82%) were recorded for Dry (I_0) treatment during both the year. Higher and significantly similar HIs (29.26 - 29.70%) were recorded for SF-270 and NK–265 hybrids, during both the years under study (Table II). HS-33 exhibited lower (28.87%) HI. A highly significant interaction among irrigation regimes and hybrids indicated that the response was dependent upon irrigation timing. All the hybrids in this study exhibited highest harvest indices under I_3 treatment. During both the years the harvest indices under various irrigation regimes decreased in order of $I_0 < I_5 < I_4 < I_3$. The average HI ranged 29.31-35.13% under irrigated treatments in these studies, which compares favorably to the values 0.29, 0.25, 0.30, 0.33 and 0.45 reported by Guiducci (1988), Sangoi and da Silva (1988), Rawson and Turner (1982), English *et al.* (1979) and Connor *et al.* (1985), respectively under well-watered conditions. Increase in HI in irrigated treatments over non-irrigated treatments has also been reported by Connor *et al.* (1985). Dubbelde (1989) reported HI values of as low as13% in non-irrigated sunflowers under the environments prevailing in Australia. Results of this study are contradictory to those cited by Dubbelde (1989) who reported that HIs of different sunflower cultivars increased as the number of irrigations were increased. However, Rawson and Turner (1982) reported that HI increased the longer irrigation was delayed, so that it was highest when irrigation commenced 54 days after sowing in their experiments. Fereres *et al.* (1986) reported that harvest index was generally higher in short season genotypes under irrigated conditions, which are in confirmatory to the results of present studies.

It is concluded from these studies that for higher yield the irrigation should be commenced at early vegetative stage in the early and mid season hybrids as SF-270 and NK-265 but late maturing hybrids as HS-33 can still give good yields even if irrigation is delayed in the growing season. Frequent irrigation during the vegetative growth period in the late maturing hybrids may results in reduced yields owing primarily to the lower harvest indices.

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(Received 01 July 2005; Accepted 09 September 2005)