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Influence of Irrigation and Nitrogen Management on Some Agronomic Traits and Yield of Hybrid Sunflower (*Helianthus annuus* L.)

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ABSTRACT

Influence of irrigation application at various growth stages and nitrogen rates on spring planted sunflower hybrid NK-265 was studied under field conditions for two years. Irrigation treatments were 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) while nitrogen was applied @ 0, 100 and 200 kg ha^{-1}. The experiment was laid out in randomized complete block design keeping irrigation treatments in main and nitrogen rates in sub plots. Total dry matter (TDM) production varied with irrigation timings and nitrogen application rates. Highest TDM was produced with the application of 200 kg ha^{-1} nitrogen. Highest achene and total dry matter yields were recorded with the irrigation applied at head visible, at floral initiation, at floral completion and during grain development. Different agronomic traits as plant height stem diameter, head diameter, number of achenes per head and 1000-achene weight varied with irrigation and nitrogen application rates. Higher nitrogen application rates resulted in reduction in harvest indices.

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

INTRODUCTION

Pakistan will have to look beyond the long established oilseed sources of cottonseed, rapeseed and mustard and groundnut to significantly increase domestic production of vegetable oil. For this, the most promising crops are sunflower, soybean and safflower. Although soybeans contain a lot of production benefits but due to processing at conventional expeller plants, soybean and safflower contribute a little (less than 1% towards filling the oil gap). Among different non-conventional oilseed crops sunflower has emerged as a promising crop. It has the potential to produce the highest oil yield per hectare. Sunflower oil is generally considered a premium oil because of its light color, high level of un-saturated fatty acids and lack of linolenic acid, bland flavor and high smoke points. Sunflower can be grown almost all over Pakistan. 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.

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). Biomass accumulation in sunflower is correlated with nutrient uptake throughout its life span. Irrigation and nitrogen application affects the uptake of nutrients (Singh & Singh, 1980). Protein and oil contents in sunflower are influenced due to variation in water and nitrogen supply (Tripathy & Sawhney, 1989). Hybrids with contrasting morphological, and possibly, physiological characters in particular are available under different sets of macroclimatic conditions. Potential areas for future progress include nitrogen-water interactions on leaf area, growth and seed production and drought adaptation. Continued increases in yield are needed for sunflower to remain a competitive crop. In view of immense importance of irrigation timing and nitrogen application for maximizing sunflower productivity, investigations were carried out to determine the effect of timing of irrigation and nitrogen management on agronomic traits of hybrid sunflower.

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. 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 nitrogen levels (0, 100 & 200 kg ha^{-1}) 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. Sunflower hybrid NK-265 was sown and the seed 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 at the respective rates. 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. 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. Maximum plant height of 158.0 cm (156.4 – 159.6 cm) was achieved under I_5 treatment (Table I). Plant height decreased gradually as the irrigation regimes decreased. Minimum plant height was recorded for Dry (I_0) treatment during both the years. Nitrogen application at 200 kg ha^{-1} resulted in tallest plants (153.0 cm), while nitrogen at 100 kg ha^{-1} gave a plant height of 137.7cm (136.8 vs 138.6 cm). The response of plant height to N application was quadratic during both the years. Application of 200 kg ha^{-1} N under I_4 treatment resulted in maximum plant height during both the years. A delay in irrigation (I_3) resulted in decreased plant height during both the years. Application of N without irrigation (Dry) resulted in smallest plants of hybrid sunflower. The reduction in plant height under various irrigation regimes is in confirmatory to the pervious findings (Rawson *et al.,* 1980; Takami *et al.*, 1981; Kakar & Soomro, 2001). The increase in plant height in response to N fertilization in this study is accordance with the findings of Nazir *et al.* (1987), and Bakht *et al.* (1989). The thickest stems were recorded under I_5 treatment during both years. Stem diameter decreased gradually in the order $I_4 > I_3 > I_0$. Nitrogen fertilization significantly ($P \leq 0.05$) increased the stem diameter (Table I). Application of N at 200 kg ha^{-1} gave maximum stem diameter (2.82 cm) during both the years. The response to applied N for stem diameter was quadratic in nature. Application of 200 kg ha^{-1} N under I_5 treatment resulted in maximum stem diameter during both the years. Application of nitrogen fertilizer without irrigation did not increase stem diameter. The reduction in stem thickness under reduced frequency of irrigation in sunflower has been reported by Kakar and Soomro (2001). While Steer and Hocking (1984) reported that stem growth was positively influenced by N application in sunflower. Ahmad *et al.* (1992) also reported increase in stem girth of sunflower as a consequence of nitrogen application. Maximum but similar ($P \leq 0.05$) head diameter was recorded for I_5 and I_4 treatments (19.46 vs 19.92 cm). Head diameter was reduced to 16.75 cm under I_3 treatment. Heads could grow to a diameter of only 9.36 cm (5.59 – 9.12 cm) under Dry (I_0). Maximum head diameter of 18.36 cm (18.33 – 1840 cm) was achieved with the application of 200 kg ha^{-1} N (Table I). The response to N fertilization was quadratic in nature. Interactive effect of irrigation timing and nitrogen application on head diameter was significant ($P \leq 0.05$) during both the years. Application of 200 kg ha^{-1} N at all levels of irrigation produced larger heads during both the years as compared with N application at 100 kg ha^{-1}. Crop grown with out irrigation failed to achieve remarkable size of heads. These values are similar to those reported elsewhere (PARC, 1994). Takami *et al.* (1981) reported that head growth in sunflower is as sensitive to water stress as in vegetative growth. These results in agreement with those reported by Gimenez and Fereres (1987), Chaniara *et al.* (1989) and Akhtar *et al.* (1993), who quoted that head diameter in sunflower is reduced under limited soil moisture supplies. The increase in head diameter in response to N application in this study confirms the findings of El-Sayed *et al.* (1988) who found that nitrogen increased head diameter of sunflower. Maximum number of

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

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	156.4 a	159.6 a	2.29 a	2.36 a	18.99 a	19.94 a	1383 a	1445 a	40.07 b	41.52 b
I_4	153.9 b	157.1 b	2.16 a	2.19 a	19.61 a	20.22 a	1347 b	1390 b	42.13 a	43.52 a
I_3	125.1 c	130.6 c	1.96 b	2.20 a	16.45 b	17.05 b	1329 c	1379 b	41.79 b	43.62 a
I_0	95.9 d	95.3 d	1.40 c	1.54 b	5.59 c	9.12 c	796 d	753 c	20.80 c	19.64 c
s.e.m	0.345	0.392	0.026	0.026	0.033	0.019	0.011	0.142	0.053	0.114
Nitrogen (kg ha^{-1})										
0	111.5 c	112.6 c	1.22 c	1.34 c	13.20 c	13.82 c	804 c	842 c	15.35 c	16.02 c
100	136.8 b	138.6 b	1.87 b	1.99 b	16.95 b	17.53 b	1358 b	1401 b	45.71 b	47.38 b
200	150.3 a	155.7 a	2.76 a	2.87 a	18.33 a	18.40 a	1480 a	1482 a	47.52 a	47.82 a
s.e.m	0.303	0.389	0.017	0.020	0.018	0.012	0.010	0.012	0.033	0.062
Linear	**	**	**	**	**	**	**	**	**	**
Quadratic	**	**	*	*	**	**	**	**	**	**
Interaction										
I x N	**	**	**	**	**	**	**	**	**	**
Mean	132.8	135.6	1.95	2.07	16.16	16.58	1214	1242	36.19	37.07

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)

achenes per head 1414 (1383 - 1445) were recorded in I_5 irrigation treatment. The number of achenes per head declined gradually as the irrigation regimes were reduced from I_4 to I_3 (1369 vs 1354). Minimal number of achenes per head (775) was recorded for non-irrigated (Dry) treatment during both the years. Application of 200 kg ha^{-1} N resulted in more number of achene per head as compared with 100 kg ha^{-1} (1481 vs 1380). Crop grown without N developed very low (823) number of achenes per head. During both the years maximum number of achenes per head were recorded where 200 kg ha^{-1} N was applied in I_5 irrigation treatment. Number of achenes per head decreased as irrigation was delayed (I_4 & I_3 treatments) and the effect was more pronounced when sunflower was grown without nitrogen application. Crop grown without both irrigation (Dry) and nitrogen (N_0) produced minimum number of achenes per head. The 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). Connor and Sadras (1992) reported that shortage of N affects the development and growth of both sinks (florets & seed) and source (leaves). Palmer and Steer (1985) reported that floret number was reduced from 690 florets plant^{-1} for 42 mg N plant^{-1} day^{-1} to 370 florets plant^{-1} for 9 mg N plant^{-1} day^{-1}. Bakht *et al.* (1989) and Ahmad *et al.* (1992) reported that nitrogen application increased number of filled seeds per head in sunflower. Nazir *et al.* (1987) also reported a positive influence of N application on number of achenes per head in sunflower. Differences in 1000–achene weight (TAW) were significant ($P \leq 0.05$) among the irrigation treatments (Table I). During 1995 maximum TAW (42.12 g) was recorded for I_4 treatment while it was similar under I_5 and I_3 treatments (40.07 vs 41.79 g). However, during 1996 I_4 and I_3 treatments gave similar TAW (43.52 vs 43.62 g), which was significantly higher than that recorded for I_5 treatment. Dry (I_0) treatment produced lighter seeds during both the years. Maximum TAW (47.67 g) was recorded with application of 200 kg ha^{-1} N. Crop grown without and with 100 kg ha^{-1} N gave 15.69 and 46.55 g TAW, respectively. The response to TAW was quadratic in nature. During 1995 application of 200 kg ha^{-1} under I_4 treatment produced heaviest achenes. Maximum TAW during 1996 was recorded for 100 kg ha^{-1} N at I_3 treatment. Among irrigated treatments lowest TAW were recorded without nitrogen application during both the years.

Total dry matter, achene yield and harvest index. Data (Table II) revealed that highest TDM (6899 kg ha^{-1}) was produced under I_4 treatment which, on an average, was 10 and 20% higher than TDM produced under I_5 and I_3 treatments, respectively. I_4 and I_3^I treatments gave 81 and 78% higher TDM than Dry treatments (1264 kg ha^{-1}), respectively. Application of N fertilizer enhanced the TDM yield significantly ($P \leq 0.05$) over the un-fertilized plots (Table II). Application of N at 200 kg ha^{-1} resulted in maximum TDM of 7945 kg ha^{-1} (7751 – 8138 kg ha^{-1}) during both the years. On an average application of 200 kg N ha^{-1} gave 26.5% higher TDM than that realized with the application of 100 kg N ha^{-1}. During both the years the response to N application was quadratic in nature. Highest TDM (10350 – 10630 kg ha^{-1}) was recorded with the application of 200 kg N ha^{-1} under I_4 treatment. Response to N application decreased as irrigation was delayed (I_3). Crop grown without N application at either level of irrigation resulted in substantially lower TDM production as compared with the fertilized crop. Similarly application of N without irrigation failed to enhance TDM production during both the years. Anderson *et al.* (1978) and Rawson and Turner (1983) have also reported similar values of TDM for sunflower. Cox and Jollif (1986) reported that TDM in the well-irrigated sunflower averaged close to 1400 g m^{-2} whereas the dry land treatments produced about 100 g m^{-2}

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

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	6237 b	6350 b	2302 b	2334 b	36.23 a	36.09 a
I_4	6810 a	6988 a	2488 a	2568 a	35.40 b	35.56 b
I_3	5402 c	6142 c	1905 c	2161 c	34.25 c	34.12 c
I_0	1230 d	1298 b	408 d	427 d	33.09 d	32.92 d
s.e.m	1.185	1.241	20.03	14.28	0.068	0.163
Nitrogen (kg ha^{-1})						
0	895 c	1004 c	295 c	329 c	32.80 c	32.68 c
100	6112 b	6442 b	2243 b	2368 b	36.11 a	36.14 a
200	7751 a	8138 a	2788 a	2920 a	33.32 b	35.19 b
s.e.m	0.979	0.983	17.92	9.57	0.046	0.107
Linear	**	**	**	**	**	**
Quadratic	**	**	**	**	**	**
Interaction						
I x N	**	**	**	**	**	**
Mean	4919	5194	1775	1872	34.74	36.67

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)

TDM. Steer and Hocking (1984) reported that DM production in sunflower is positively influenced by N supply throughout the development. Unger (1990) reported that fertilizer requirements for sunflower rise with increased irrigation because of the higher yields obtained. Irrigation regimes significantly ($P \leq 0.05$) influenced achene yield of hybrid sunflower (Table II). During both the years maximum achene yield (2488 - 2568 kg ha^{-1}) was recorded in I_4 treatment. Achene yields under I_5 and I_3 treatments were 2302 – 2334 and 1905 – 2116 kg ha^{-1}, respectively, during 1995 and 1996. On an average, achene yield in I_4 treatment was 9 and 24% higher than that achieved under I_5 and I_4 treatments, respectively. Achene yield in Dry treatment could reach up to 427 kg h^{-1} only. Highest achene yield 2854 kg ha^{-1} (2788 – 2920 kg ha^{-1}) was realized in plots fertilized @ 200 kg ha^{-1} N (Table II). Application of nitrogen @ 100 kg ha^{-1} give 86% higher yield over the un-fertilized plots, which was 89% higher in case of N applied @ 200 kg ha^{-1}. During both the years of experimentation, the response of nitrogen application was quadratic in nature. A highly significant ($P \leq 0.05$) interaction was observed between irrigation regimes and nitrogen application rates (Table II), which indicated that response to nitrogen application depended upon irrigation regimes. Application of nitrogen @ 200 kg ha^{-1} under I_4 treatment resulted in higher achene yield during both the years. Nitrogen application at either level under Dry (I_0) treatment failed to give substantial yield increase as compared with plots to which irrigation was applied. Similarly application of irrigation without nitrogen fertilization also gave nominal yield increases over Dry treatment. Chaniara *et al.* (1989) reported that application of 4, 6 and 8 irrigations to sunflower gave average achene yields of 1.07, 1.28 and 1.37 t ha^{-1}, respectively. Increasing nitrogen application rate from 40 to 80 kg ha^{-1} increased achene yield from 1.04 to 1.37 t ha^{-1}. Hussain *et al.* (1998) reported that sunflower yield increase occurred with nitrogen levels up to 125 kg N ha^{-1}. Vivek *et al.* (1994) reported similar results quoting that mean achene yield of sunflower increased with increasing levels of irrigation and nitrogen fertilizer. They reported achene yield of 0.75 t ha^{-1} from the rainfed crop. Substantial achene yield increases have been reported following N fertilization at rates up to 180 kg ha^{-1} (Blamey & Chapman, 1981) and 200 kg ha^{-1} (Tomov, 1976 according to Robinson, 1978). Zubriski and Zimmerman (1974) found that fertilization with 112 kg N ha^{-1} increased achene yield from 2193 to 3043 kg ha^{-1}. Viveck *et al.* (1994) and Nazir *et al.* 1987) also reported substantial yield increase through N fertilization, and that the magnitude of the response was dependent on moisture supply. Khade *et al.* (1994) also reported interactive effect of nitrogen fertilization and irrigation on achene yield of sunflower. Highest harvest index of 36.16% (36.23 – 36.09) was recorded for I_5 treatment. Harvest indices declined as the frequency of irrigation declined. Highest harvest index (36.43%) was recorded with 100 kg ha^{-1} N which declined (35.26%) with increasing N rates to 200 kg ha^{-1} (Table II). The response of nitrogen application to harvest index was quadratic. During 1995 maximum harvest (37.74%) was recorded with 100 kg ha^{-1} N applied at I_5 irrigation treatment while during 1996 the same N level gave statistically similar harvest indices under I_4 and I_5 irrigation treatments. The maximum harvest indices in these studies are similar to those reported by Connor *et al.* (1985) and English *et al.* (1979) in Australia. Steer and Hocking (1984) reported that harvest index in sunflower was positively affected by N supply floret initiation and anthesis.

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