INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
ISSN Print: 1560–8530; ISSN Online: 1814–9596
09–054/RSA/2009/11–6–701–706
http://www.fspublishers.org

***Full Length Article***

# Role of Planting Pattern and Irrigation Management on Growth and Yield of Spring Planted Sunflower (*Helianthus annuus*)

JAVEED SHABBIR DAR[1], MUMTAZ AKHTAR CHEEMA, MUHAMMAD ASHFAQ WAHID[1], MUHAMMAD FARRUKH SALEEM[1], MUHAMMAD FAROOQ[1] AND SHAHZAD MAQSOOD AHMED BASRA†
*Department of Agronomy, University of Agriculture, Faisalabad, Pakistan*
†*Department of Crop Physiology, University of Agriculture, Faisalabad, Pakistan*
[1]Corresponding author's e-mail: javeedshabbir@hotmail.com

## ABSTRACT

Water stress is a major limiting factor for sunflower production in the arid and semi arid regions in the world. A field experiment was conducted to assess the impact of different planting pattern and irrigation levels on growth and yield of spring planted sunflower. Four planting patterns ($P_1$ = 60 cm spaced single row flat sowing, $P_2$ = 60 cm spaced single row ridge sowing, $P_3$ = 90 cm spaced double row strip flat sowing, $P_4$ = 90 cm spaced double row bed sowing) and four irrigation levels ($I_0$ = normal irrigations, $I_1$ = irrigation skipped at pre-anthesis stage, $I_2$ = irrigation skipped at anthesis stage, $I_3$ = irrigation skipped at post-anthesis stage) were used. Maximum LAI and CGR were recorded at $P_2$, whereas post anthesis stress treatment produced maximum crop growth. Maximum value of NAR was observed at $P_3$ treatment and at anthesis stress. Highest achene yield (kg ha$^{-1}$) was recorded at $P_2I_0$ (38% more yield than $P_3I_1$) treatment.

**Key Words:** Growth; Irrigation; Planting pattern; Sunflower; Yield
**Abbreviations:** LAI = Leaf area index, NAR = Net assimilation rate, CGR = crop growth rate

## INTRODUCTION

Rapid growth rate of population has resulted in a lot of pressure on food and fuel worldwide. Pakistan is chronically deficient in the production of edible oil and situation is getting worst day by day with alarming population increase. The indigenous edible oil production does not meet with the growing demand. The edible oil consumption in Pakistan during 2006-2007 was 2.796 million tons, where local production stood at 0.857 million tons, which accounted for only 28% of total requirement. So Pakistan has to spend huge foreign exchange to meet its requirements (Anonymous, 2008).

Sunflower is short duration crop and can be fitted well in our present cropping system with out much change in agriculture setup. Planting pattern plays a key role in increasing yield of sunflower (Hussain *et al*., 2001). Planting pattern not only affects plant growth and development by balancing the interplant competition (Malik *et al*., 1992), but also affects solar radiation interception, evaporation and indirectly affects water use efficiency. Narrow row spacing ensures more uniform distribution of plant over a given area and makes a plant canopy more effective in intercepting radiant energy (Saeed, 1994).

Irrigation is an important factor that directly influences the yield of sunflower (Kakar & Soomro, 2001), although sunflower is a crop well adapted to drought and consequently it is being grown with increasing success in many semi-arid environments. In Pakistan sunflower has the potential to be grown in both irrigated and rain fed areas (Ghani *et al*., 2000). Under limited precipitation and soil water supply, sunflower responds positively to irrigation with respect to growth and yield (Unger, 1990). Judicious and timely application of irrigation at critical growth stages of sunflower increases yield considerably. The sunflower crop uses only 20-25% of its total water needed during the first 30 days, but the peak demand is during reproductive stage (Ghani *et al*., 2000). The most critical period of sunflower yield determinants are anthesis and post anthesis (Chimenti & Hall, 1992).

Conventionally, the sunflower crop is grown at flat planting without taking care of its irrigation management. Some of the innovative farmers are testing ridge or bed sowing with reduced irrigation. The objective of this study was to enhance our understanding about planting pattern, stress at different growth stages and their impact on growth, yield and fatty acid content of spring planted sunflower.

## MATERIALS AND METHODS

**Site and soil.** A field experiment was conducted at the Agronomy Farm, University of Agriculture, Faisalabad (31.25°N, 73.09°E, & 184 m a.s.l). The experimental soil was sandy clay loam (64% sand, 17% silt & 19% clay) in

**To cite this paper:** Dar, J.S., M.A. Cheema, M.A. Wahid, M.F. Saleem, M. Farooq and S.M.A. Basra, 2009. Role of planting pattern and irrigation management on growth and yield of spring planted sunflower (*Helianthus annuus* L.). *Int. J. Agric. Biol.*, 11: 701–706

texture with good drainage. Experimental soil belonged to Lyallpur soil series (aridisol-fine-silty, mixed, hyperthermic Ustalfic, Haplarged in USDA classification & Haplic Yerrmosols in FAO Classification). Monthly average maximum and minimum temperature and rainfall (mm) data for the growing period during both the years are presented in Table I. Climatic conditions were favorable for high yield of sunflower during, 2005 as compared to 2006. Average monthly temperature was higher in 2006 than that of 2005. Total rainfall during growing season (15 February to 15 June) was 117 mm and 81 mm in 2005 and 2006, respectively.

Treatments include four planting patterns placed in main plots and four irrigation levels in sub-plots. Planting patterns include $P_1$ = 60 cm spaced single row (flat sowing), $P_2$ = 60 cm spaced single row (ridge sowing), $P_3$ = 90 cm spaced double row strip (flat sowing) and $P_4$ = 90 cm spaced double row (Bed sowing). Irrigation Levels includes $I_0$ = Control (normal irrigations), $I_1$ = Irrigation skipped at pre-anthesis stage, $I_2$ = Irrigation skipped at anthesis stage and $I_3$ = Irrigation skipped at post-anthesis stage.

The experiment was laid out in randomized complete plot design with split plot arrangement and replicated three times. Net plot size was 3.6 x 7.0 m. Buffer area of 1.2 m between the sub-plots was maintained to avoid the seepage/border effect of irrigation among various treatments.

Before seedbed preparation, pre-soaking irrigation of 10 cm was applied. When soil reached to proper moisture level seedbed was prepared by cultivating the soil 2-3 times with tractor mounted cultivator each followed by planking. Sunflower was sown on 14$^{th}$ February, with seed rate of 8 kg ha$^{-1}$ in both the years. Planting was done by a dibbler and 2 seeds per hill were placed at 25 cm apart from each other. At 2-4 leaf stage one plant per hill was maintained.

Fertilizers were applied at the rate of 150 kg N and 100 kg $P_2O_5$ ha$^{-1}$. Urea and Diammonium phosphate (DAP) were source of fertilizer. Half of N and full dose of phosphorus were applied at sowing, remaining N was applied with first irrigation as band placement. All other recommended agronomic practices were followed uniformly for all the treatments. Plant protection measures were adopted to keep the crop free from weeds, insect pests and diseases. Pre-emergence weedicide Dual Gold (S-metolachlor) at the rate of 2 L ha$^{-1}$ was used to control the weeds. Insecticide methamidophos was sprayed once 1 L ha$^{-1}$ for the control of aphids and white fly.

Five plants were randomly selected from each sub-plot to calculate average number of seeds per head. Crop was harvested at maturity. After sun drying crop was threshed manually. Seed yield from the whole plots were measured and converted into kg ha$^{-1}$. Seed yield data have been adapted from Dar *et al.* (2008). For leaf area index, five plants were selected from each plot leaving appropriate borders. The plants were cut at the ground level on all the harvest dates (30, 45, 60, 75 & 90 DAS) and taken to the laboratory for further processing. Leaf area was measured on an area meter (Licor, Model 3100). The leaf area index (LAI) was calculated as the ratio of leaf area to land area (Hunt, 1978). Crop growth rate and net assimilation rate were calculated using the formula proposed by Hunt (1978).

**Irrigation methodology.** Irrigation water was applied using a siphon tube (length=5 m, Diameter =3 inch). Time for the application of measured quantity of water was calculated using the following formula (Buland *et al*., 1994).

$$T = Ad/Q$$

Where,
t = application time (hours).
A = field area (ha).
d = depth of irrigation application (m).
Q = discharge, flow rate (m$^3$sec$^{-1}$).
Plot area = 3.6 m x 7.0 m = 25.2 m$^2$.
Depth of one irrigation = 50 mm = 0.05 m.
Volume of water required=25.2 m$^2$ x 0.05 m=1.26 m$^3$.
Quantity required (L) As1 m$^3$ = 1000 L.
For 50 mm (0.05 m) depth of water=1.26 x 1000=1260 L.
Length of siphon tube = 5 m.
Diameter of siphon tube = 3 inch.
Discharge from siphon (Length=5 m, Diameter=3 inch).
after calibration = 60 L/min.
Time required to discharge 60 L water = 1 min.
Time required to discharge 1260 L water = 21 min.
So one siphon (Length = 5 m, Diameter = 3 inch) takes 21 min to discharge 1260 L of water.

Six siphon tubes were calibrated and shifted into three different plots. Water control barrier was prepared at cross channel area to make and control the flow of water. Time measurement was done with the help of stop watch and at measured time siphons were shifted to the other field.

The data were statistically analyzed by using the computer statistical program MSTAT-C (Freed & Scott, 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

### Growth

**Leaf area index.** Planting pattern (Table II) showed significant difference among all treatments (75 DAS). During 2005, maximum Leaf area index (LAI) was produced by Ridge 60 cm (4.82) and that was reduced in order of flat sowing 60 cm > Bed Sowing 90/30 cm > Flat Sowing 90/30. Different trend was seen in second year. Bed sowing 90/30 cm (3.86) and flat sowing 90/30 cm (3.79) showed statistically similar results.

Normal irrigation and ridge sowing increased progressively with the advancement of the growth period and reached the maximum at 75 DAS. Maximum LAI was

**Table I. Fifteen day mean weather data for the growing season of the study during, 2005 and 2006**

| Date/month | Max. temp (°C) | | Min. temp (°C) | | Avg. temp (°C) | | Rain (mm) | | $ET_0$ (mm) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2005 | 2006 | 2005 | 2006 | 2005 | 2006 | 2005 | 2006 | 2005 | 2006 |
| 1-15 January | 20.8 | 20.2 | 7.6 | 5.3 | 14.2 | 12.8 | 20.0 | 8.20 | 1.7 | 1.2 |
| 16-31 January | 18.1 | 21.4 | 6.1 | 7.2 | 12.1 | 14.3 | 12.8 | 0.00 | 1.6 | 1.5 |
| 1-14 February | 19.6 | 27.0 | 11.2 | 11.3 | 15.4 | 19.2 | 29.5 | 0.00 | 1.4 | 2.3 |
| 15-28 February | 20.5 | 28.1 | 8.3 | 14.7 | 14.4 | 21.4 | 5.6 | 14.6 | 2.0 | 3.0 |
| 1-15 March | 27.2 | 28.3 | 14.7 | 14.7 | 21.0 | 21.5 | 6.2 | 8.40 | 2.5 | 2.9 |
| 16-31 March | 28.3 | 28.0 | 15.9 | 14.5 | 22.1 | 21.3 | 42.4 | 28.6 | 3.0 | 3.4 |
| 1-15 April | 33.4 | 35.2 | 16.8 | 18.5 | 25.1 | 26.9 | 0.0 | 0.00 | 5.2 | 6.4 |
| 16-30 April | 36.7 | 40.1 | 19.6 | 22.8 | 28.2 | 31.5 | 10.8 | 0.00 | 6.2 | 7.6 |
| 1-15 May | 36.4 | 43.5 | 21.9 | 26.7 | 29.2 | 35.1 | 18.4 | 0.60 | 6.0 | 8.4 |
| 16-31 May | 39.7 | 41.1 | 24.8 | 27.8 | 32.3 | 34.4 | 0.0 | 23.4 | 8.4 | 7.6 |
| 1-15 June | 41.6 | 41.7 | 27.0 | 27.2 | 34.3 | 34.5 | 4.5 | 5.60 | 7.8 | 9.0 |
| 16-30 June | 45.0 | 38.9 | 30.4 | 26.8 | 37.7 | 32.9 | 58.0 | 50.0 | 9.6 | 6.9 |

**Table II. Effect of planting pattern and water stress on average CGR and NAR of sunflower**

| Treatments | Leaf area index (75 DAS) | | Crop growth rate | | Net assimilation rate | |
|---|---|---|---|---|---|---|
| | 2005 | 2006 | 2005 | 2006 | 2005 | 2006 |
| **Planting Pattern (P)** | | | | | | |
| $P_1$=Flat 60 cm | 4.35 b | 4.26 b | 10.95 b | 11.09 b | 4.76 a | 4.91 b |
| $P_2$=Ridge 60 cm | 4.82 a | 4.75 a | 11.45 a | 11.81 a | 4.42 c | 4.65 c |
| $P_3$=Flat 90/30 cm | 3.86 d | 3.79 c | 10.23 c | 10.55 c | 4.86 a | 5.15 a |
| $P_4$=Bed 90/30 cm | 3.98 c | 3.86 c | 10.02 c | 10.48 c | 4.60 b | 4.93 b |
| LSD (5%) | 0.11 | 0.09 | 0.44 | 0.37 | 0.11 | 0.15 |
| **Water stress (I)** | | | | | | |
| $I_0$=No Stress | 4.81 a | 4.72 a | 11.74 a | 11.96 a | 4.62 b | 4.83 bc |
| $I_1$=Pre Anthesis Stress | 3.23 c | 3.17 c | 9.07 d | 9.28 c | 4.79 a | 4.99 ab |
| $I_2$=Anthesis Stress | 4.14 b | 4.04 b | 10.50 c | 10.99 b | 4.66 b | 5.01 a |
| $I_3$=Post anthesis Stress | 4.73 a | 4.66 a | 11.35 b | 11.67 a | 4.56 b | 4.81 c |
| LSD (5%) | 0.13 | 0.09 | 0.23 | 0.34 | 0.11 | 0.17 |
| Interaction (PxI) | Ns | ns | ns | ns | ns | Ns |
| Year Mean | 4.25 | 4.17 | 10.66 | 10.98 | 4.66 | 4.91 |

Mean values sharing the same letter in a column do not differ significantly at P = 0.05

recorded from no stress (4.81) during first year. Post anthesis stress show statistically non-significant differences among no stress treatment. Lowest value of LAI was recorded from pre anthesis stress (3.23). Similar trend was observed during second year of experimentation.

**Crop growth rate (g $m^{-2}$ $day^{-1}$).** Data presented in Table II for average crop growth rate reveal that planting pattern and irrigation levels showed significant difference during both the years of experimentation. Maximum value for average CGR (11.45 g $m^{-2}$ $day^{-1}$) was recorded in ridge 60 cm. However, crop planted at Bed 90/30 cm produced the minimum average CGR of 10.02 g $m^{-2}$ $day^{-1}$ and was statistically at par with flat sowing 90/30 cm (10.23) during, 2005. Stress at different growth stages had significant effect on CGR. Significantly higher value (11.74 g $m^{-2}$ $day^{-1}$) of CGR was recorded at control treatment. Whereas, post-anthesis stress produced the CGR value of 11.35 g $m^{-2}$ $day^{-1}$ during, 2005 contrary to the lowest values (9.07 g $m^{-2}$ $day^{-1}$) of CGR recorded at pre-anthesis stress. Similar pattern was observed during, 2006. Sunflower planted at ridge 60 cm gave the maximum value (11.81 g $m^{-2}$ $day^{-1}$) of CGR. Whereas, minimum CGR (10.48 g $m^{-2}$ $day^{-1}$) was recorded at crop planted on bed 90/30 cm.

**Net assimilation rate (g $m^{-2}$ $day^{-1}$).** Planting pattern presented a significant difference among all the treatments. Highest value of NAR (Table II) was recorded in flat sowing 90/30 cm (4.86 g $m^{-2}$ $day^{-1}$). These results were at par with flat 60 cm (4.76 g $m^{-2}$ $day^{-1}$), whereas lowest value was recorded from ridge sowing 60 cm (4.42 g $m^{-2}$ $day^{-1}$). Different trend was observed during second year. Maximum NAR was observed in flat sowing 90/30 cm. Statistically similar results were recorded from bed sowing 90/30 cm (4.93 g $m^{-2}$ $day^{-1}$) and flat sowing 60 cm (4.91 g $m^{-2}$ $day^{-1}$).

The results for irrigation treatments were significant during both the years. In 2005, only pre-anthesis stress showed the maximum NAR of 4.79 g $m^{-2}$ $day^{-1}$, while rest of the treatments showed statistically similar results. Regarding second year maximum NAR was observed from anthesis stress (5.01 g $m^{-2}$ $day^{-1}$) and these results were at par with pre-anthesis stress (4.99 g $m^{-2}$ $day^{-1}$), which in turn remained at par with no stress (4.83 g $m^{-2}$ $day^{-1}$). No stress also showed statistically similar results with post-anthesis stress (4.81 g $m^{-2}$ $day^{-1}$). Interaction effect of different planting pattern and irrigation treatment for NAR was found to be non-significant.

**Yield Parameter**

**Number of achenes per head.** There was a significant interaction between planting pattern and irrigation treatments (Table III). In 2005, More number of achenes $head^{-1}$ 1185 was produced by ridge sowing 60 cm with no stress. Ridge 60 cm with anthesis stress (1038), flat 90/30 cm with no stress (1045) and Bed 90/30 cm with no stress (1044)

**Table III. Effect of planting pattern and water stress on number of achenes head$^{-1}$ and achene yield (kg ha$^{-1}$) of sunflower**

| Treatment | No. of achenes head$^{-1}$ | | Achene yield | |
|---|---|---|---|---|
| | 2005 | 2006 | 2005 | 2006 |
| **A. Planting Pattern (P)** | | | | |
| $P_1$= Flat 60 cm | 1015 b | 967 b | 2937 b | 2854 b |
| $P_2$ = Ridge 60 cm | 1084 a | 1068 a | 3293 a | 3199 a |
| $P_3$ = Flat 90/30 cm | 961 c | 945 c | 2603 d | 2529 d |
| $P_4$ = Bed 90/30 cm | 975 c | 961 a | 2734 c | 2657 c |
| LSD (5%) | 18 | 19 | 128 | 122 |
| **B. Water Stress (I)** | | | | |
| $I_0$ = No Stress | 1105 a | 1097 a | 3217 a | 3126 a |
| $I_1$ = Pre Anthesis Stress | 899 d | 880 d | 2525 d | 2453 d |
| $I_2$ = Anthesis Stress | 975 c | 954 c | 2756 c | 2677 c |
| $I_3$ = Post Anthesis Stress | 1057 b | 1037 b | 3069 b | 2982 b |
| LSD (5%) | 19 | 21 | 76.33 | 74.84 |
| **Interaction (P × I)** | | | | |
| $P_1$ $I_0$ | 1146 b | 1120 b | 3363 b | 3268 b |
| $P_1$ $I_1$ | 879 hi | 859 jk | 2480 h | 2410 h |
| $P_1$ $I_2$ | 967 f | 951 g | 2774 def | 2695 def |
| $P_1$ $I_3$ | 1070 c | 1056 cd | 3130 c | 3042 c |
| $P_2$ $I_0$ | 1185 a | 1167 a | 3674 a | 3569 a |
| $P_2$ $I_1$ | 966 f | 945 gh | 2842 de | 2761 de |
| $P_2$ $I_2$ | 1039 d | 1024 e | 3121 c | 3032 c |
| $P_2$ $I_3$ | 1147 b | 1127 b | 3535 a | 3435 a |
| $P_3$ $I_0$ | 1045 d | 1038 de | 2917 d | 2835 d |
| $P_3$ $I_1$ | 862 i | 846 k | 2269 i | 2205 i |
| $P_3$ $I_2$ | 933 g | 915 i | 2475 h | 2405 h |
| $P_3$ $I_3$ | 1002 e | 983 f | 2749 ef | 2672 ef |
| $P_4$ $I_0$ | 1044 d | 1062 c | 2912 d | 2830 d |
| $P_4$ $I_1$ | 889 h | 871 j | 2508 gh | 2437 gh |
| $P_4$ $I_2$ | 961 f | 928 hi | 2653 fg | 2578 fg |
| $P_4$ $I_3$ | 1007 e | 983 f | 2863 de | 2782 de |
| LSD (5%) | 24 | 23 | 153 | 150 |
| Year Effect | 1009 | 992 | 2892 | 2810 |

Mean values sharing the same letter in a column do not differ significantly at P = 0.05

produced statistically same number of achenes head$^{-1}$. Whereas minimum number of achenes head$^{-1}$ (862) were recorded from flat sowing 90/30 cm with pre-anthesis stress.

Treatment ridge 60 cm with no stress produced 27% more number of achenes head$^{-1}$ as compared to flat sowing 90/30 cm with pre-anthesis stress. Similar trend was observed in the next year. Regarding planting pattern ridge 60 cm produced 11.44% more number of achenes head$^{-1}$ than flat 90/30 cm. bed sowing 90/30 cm and flat sowing 90/30 cm revealed the statistically same results by producing 975 and 961 number of achenes head$^{-1}$. Irrigation treatments also showed the significant differences among all the treatments. Highest number of achenes head$^{-1}$ (1105) was obtained, where stress was not given and that was 18.73% more than pre-anthesis stress.

**Achene yield.** Interaction of planting pattern and irrigation treatment for achene yield showed the significant differences in both the years (Table III). Achene yield of 3674 was recorded in ridge 60 cm with no stress during first year. These results were at par with ridge 60 cm post-anthesis stress. In 2005, Results revealed that treatment combination of flat sowing 90/30 cm with no stress (2918 kg ha$^{-1}$), bed sowing 90/30 cm with no stress (2912 kg ha$^{-1}$), bed sowing 90/30 cm with post-anthesis stress (2863 kg ha$^{-1}$), ridge 60 cm with pre-anthesis stress (2842 kg ha$^{-1}$) and flat 60 cm with anthesis stress (2774 kg ha$^{-1}$) were statistically similar with each other. Minimum achene yield was recorded in treatment flat sowing 90/30 cm with pre-anthesis stress, which produced 2269 kg ha$^{-1}$. Same trend was observed in second year. On average basis 22% increase in achene yield was recorded, when crop was sown at ridge 60 cm with normal irrigation instead of pre-anthesis stress.

**Table IV. Correlation coefficients among different characters of spring sunflower**

| Characters | Achene yield | LAI | CGR | NAR |
|---|---|---|---|---|
| No of seeds head$^{-1}$ | 0.967** | 0.929** | 0.959** | -0.624** |
| Achene Yield | | 0.907** | 0.914** | -0.720** |
| LAI | | | 0.963** | -0.713** |
| CGR | | | | -0.563* |

*= significant at $P \leq 0.05$, ** = significant at $P \leq 0.01$

**Correlation.** Number of seeds head$^{-1}$, seed yield, LAI, CGR, showed the positive and significant correlation among each other (Table IV). NAR was significantly but negatively correlated with number of seeds head$^{-1}$, seed yield, LAI and CGR.

## DISCUSSION

**Growth.** The leaf area index of the crop at a particular growth stage indicates its photosynthetic potential or the level of its dry matter accumulation (Rasheed *et al*., 2003). Application of water under different irrigation treatments apparently had slight or no effect on the early sunflower development. Differences between treatments were mainly observed at anthesis stage in sunflower for LAI. Highest LAI was recorded with full irrigation treatment and water stress decreased leaf area and LAI (Hussain *et al*., 2000; Tahir *et al*., 2002; Goksoy *et al*., 2004). Rawson and Turner (1982) reported that leaf area increased with the number of irrigations supplied and in the irrigated treatments it was positively correlated with time to anthesis.

The CGR express the high efficiency of sunflower crop among different planting pattern and irrigation treatments. Average CGR increased due to increase in dry matter accumulation, with the progressive increase in plant growth under different planting pattern and irrigation treatment. With time it reached its maximum value showing significant variation among different treatments and there after decline up to harvest of crop in other study ridge sowing presented significant difference on CGR than the other methods and was followed by flat planting in sunflower crop (Khaliq *et. al.*, 1988; Ardakani *et al*., 2005). The results corroborate the findings of Arnon (1972) that better growth of sunflower could be attained by sowing the crop in a suitable pattern. The NAR of a crop represents the net photosynthetic production per unit leaf area duration (Hunt, 1978). Hussain *et al.* (2000) tested three moisture levels i.e., 100, 50 and 25% of field capacity and concluded that water stress increased the NAR. Ardakani *et al.* (2005)

reported that effect of water stress on NAR was significant. The possible explanation could be that ridge sowing facilitates more light penetration of the canopy thereby providing better conditions for establishment, growth and development. One of the other benefits of ridge sowing is to change from flood irrigation to irrigation in a partial areas decreased irrigation amount and controlled evaporation from top soil.

**Yield related traits.** The ridge sown crop with no stress achieve the highest yield due to more leaf area index, better crop growth rate and higher number of achenes per head. Number of achenes per head showed the similar trend to achene yield under different planting patterns and irrigation levels. High seed yield of sunflower could be attained by sowing the crop in suitable pattern. Maximum number of achenes per head was recorded from no stress treatment against the minimum from pre-anthesis stress. Reduction in number of achenes per head in sunflower as a consequence of reduced irrigation frequency has been reported by Kakar and Soomro (2001). Achene number and yield was decreased by water stress during the vegetative and flowering period (Fereres *et al*., 1986; Akhtar *et al*., 1993; Debaeke *et al*., 1998).

Final achene yield is the function of combined effect of all the yield components under the influence of a particular set of environmental conditions (Calvino *et al*., 2004). For crop with more severe water deficit, yield response ranged from a 25% reduction (Browne, 1997; Andrade *et al*., 2002). Supporting results were reported by Malik *et al*. (2001), who recommended that the planting patterns ridge sowing (60 cm apart) produced the maximum seed yield (2600 kg $ha^{-1}$) among various planting patterns (60 cm apart single rows, 90 cm apart double row strip planting, 60 cm apart ridge sowing & 90/30 cm bed sowing) used for evaluation.

Aiken and Lamm (2006) reported that supplemental irrigation scheduled by the water balance method results in higher yields. Yield reductions depend on the degree of plant water stress at critical stages of growth. When supply of water limits crop water use, seed yields are frequently limited as well. The possible reason could be that the ridge sowing provided aerated fertile soil to the plants and gave favorable environment to the plants, which helped in the absorption of more nutrients and hence more yield was produced (Ahmad *et al.*, 2000).

The possible explanation could be that ridge planting created favorable soil environments for plant growth due to loose surface fertile soil (Saleem *et al.*, 2008).

## CONCLUSION

The results suggested that ridge sowing is the best planting pattern for better growth and yield production of sunflower. Crop showed the maximum potential with normal irrigation. Yield of the crop was significantly decreased at early growth stage water stress.

## REFERENCES


Ahmad, G., Z. Quresh and H. Ullah, 2000. Effect of different sowing methods on the performance of sunflower. *Pakistan J. Biol. Sci.*, 3: 1829–1830

Aiken, R.M. and F.R. Lamm, 2006. Irrigation of oilseed crops. *In*: Thompson Colby, K.S. (ed.), *Proc. Central Plains Irrigation Conf., February 21-22, 2006*, pp: 162–172. Available from CPIA, 760N

Akhtar, M., M. Zubair, M. Saeed and R. Ahmad, 1993. Effect of planting geometry and water stress on seed yield and quality of spring planted sunflower (*Helianthus annus* L.). *Pakistan J. Agric. Sci.*, 30: 73–76

Andrade, F.H., P. Calvino, A. Cirilo and P. Barbieri, 2002. Yield response to narrow rows depend on increased radiation interception. *Agron. J.*, 94: 975–980

Anonymous, 2008. *Economic Survey of Pakistan, 2006-2007*. Ministry of Food, Agriculture and Livestock, Finance Division, Economic Advisor's Wing, Islamabad, Pakistan

Ardakani, M.R., A.H.S. Rad, D. Habibi and S. Jahed, 2005. Effect of drought stress on quantitative and qualitative characteristics of oilseed rape (*Brassica napus* L.). *Interdrought-II, the Second Int. Conf. on Integrated Approaches to Sustain and Improve Plant Production Under Drought Stress*, p: 132. Rome, Italy, September, 24-28, 2005

Arnon, I., 1972. *Sunflower, Crop Production in Dry Regions*, Vol. 2, pp: 399–406. National book foundation of Pakistan, Islamabad, Pakistan

Browne, C.L., 1997. Effect of date and final irrigation on yield and yield components of sunflowers in a semi-arid environment. *Australian J. Exp. Agric. Anim. Husb.,* 17: 482–488

Buland, A., A. Hussain, A.H. Ahmad, M. Saleem, N. Mehmood, M. Aslam and K. Ali, 1994. Optimizing irrigation requirements for maximizing yields of mungbean crop. An experimental study. *Pakistan J. Agric. Sci.*, 31: 331–335

Calvino, P., V. Sadras and M.M. Canepa, 2004. Yield responses to narrow rows as related to interception of radiation and water deficit in sunflower hybrids of varying cycle. *Field Crops Res.*, 88: 261–267

Chimenti, C.A. and A.J. Hall, 1992. Sensibilidad del numero de frutos por capitulo de girasol (*Helianthus annuus* L.) a cambio en el nivel de radiacion durante la ontogenia del cutivo. *In*: *19th Reunion Nacional De Fisiologia Vegetal*, pp: 27–28. Huerta Grande, Argentina

Dar, J. S., M. A. Cheema, R. S. Kanwar, A. Wahid and N. S. Dar, 2008. Impact of planting pattern and water stress on yield and oil quality of sunflower (*Helianthus annuus* L.). *Int. Agric. Eng. J.,* 17:9-18.

Debaeke, P., M. Cabelguenne, A. Hilaire and D. Raffaillac, 1998. Crop management systems for rainfed and irrigated sunflower (*Helianthus annuus* L.) in South Western France. *J. Agric. Sci. Cambridge*, 131: 171–185

Fereres, E., C.G. Gimenez and J.M. Fernandez, 1986. Genetic variability in sunflower cultivars under drought I. yield relationships. *Australian J. Agric. Res*., 37: 573–582

Freed, R.D. and D.E. Scott, 1986. *MSTATC, Crop and Soil Science Department*, Michigan State University, Michigan, USA

Ghani, A., M. Hussain and M.S. Qureshi, 2000. Effect of different irrigation regimens on the growth and yield of sunflower. *Int. J. Agric. Biol.*, 2: 334–335

Goksoy, A.T., A.O. Demir, Z.M. Turan and N. Dagustu, 2004. Response of sunflower (*Helianthus annuus* L.) to full and limited irrigation at different growth stage. *Field Crop Res.*, 87: 167–178

Hunt, R., 1978. *Plant Growth Analysis, Studies in Biology No. 96*, pp: 26–38. Edward Arnold, London

Hussain, M.K., E. Rasul and S.K. Ali, 2000. Growth analysis of sunflower (*Helianthus annuus* L.) under drought conditions. *Int. J. Agric. Biol.*, 2: 136–140

Hussain, N., M.B. Khan and M. Asif, 2001. Growth and yield of spring sunflower (*Helianthus annuus* L.) as influenced by planting geometry. *Pakistan J. Biol. Sci.*, 1: 48–49

Kakar, A.A. and A.G. Soomro, 2001. Effect of water stress on the growth, yield and oil content of sunflower. *Pakistan J. Agric. Sci.*, 38: 73–74

Khaliq, A., M. Munir and J. Asif, 1988. Effect of different planting methods on some agronomic and physiological traits of maize. *Pakistan J. Agric. Res.*, 9: 145–148

Malik, M.A., M. Akram and A. Tanvir, 1992. Effect of planting geometry and fertilizer on growth yield and quality of a new sunflower cultivar "SF-100". *J. Agric. Res.*, 30: 59–63

Malik, M.A., S.H. Shah, S. Mahmood and M.A. Cheema, 2001. effect of various planting geometries on the growth, seed yield and oil contents of New Sunflower hybrid (SF-187). *Int. J. Agric. Biol*., 3: 55–56

Rasheed, M., A. Hussain and T. Mahmood, 2003. Growth analysis of hybrid maize as influenced by planting techniques and nutrient management. *Int. J. Agric. Biol.*, 5: 169–171

Rawson, H.M. and N.C. Turner, 1982. Recovery from water stress in five sunflower (*Helianthus annuus* L.) cultivars I. Effects of the timing of water application on leaf area and seed production. *Australian J. Plant Physiol*., 9: 437–448

Saeed, M., 1994. Crop water requirements and irrigation systems. *In*: Bashir, E. and R. Bantel (eds.), *"Crop production"*, pp: 48–83. National Book Foundation, Islamabad, PAkistan

Saleem, M.F., B.L. Ma, M.A. Malik, M.A. Cheema and M.A. Wahid, 2008. Yield and quality response of autumn-planted sunflower (*Helianthus annuus* L.) to sowing dates and planting patterns. *Canadian J. Plant. Sci*., 88: 101–109

Tahir, M.H.N., M. Imran and M.K. Hussain, 2002. Evaluation of sunflower (*Helianthus annuus* L.) inbred lines for drought tolerance. *Int. J. Agric. Biol.*, 4: 398–400

Unger, P.W., 1990. Sunflower. *In*: Stewart, B.A. and D.R. Nielson (eds.), *Irrigation of Agricultural Crops*, pp: 775–791. ASA Monograph No. 30, ASA, CSSA, SSSA, Madison, Wisconsin

**(Received 12 February 2009; Accepted 16 March 2009)**