International Scholars Journals

International Journal of Irrigation and Water Management ISSN 5423-5294 Vol. 3 (7), pp. 001-006, July, 2016. Available online at www.internationalscholarsjournals.org © International Scholars Journals



*Full Length Research Paper*

# Interaction effects of deficit irrigation and row spacing on sunflower (*Helianthus annuus* L.) growth, seed yield and oil yield

**Seyed Abdolreza Kazemeini*, Mohsen Edalat and Avat Shekoofa**

Crop Production and Plant Breeding Department, College of Agriculture, Shiraz University, Shiraz, Iran.

Accepted 29 September, 2015

**Productivity of sunflower is strongly regulated by the availability of water. In order to study the influence of deficit irrigation ($I_1$:100% FC, $I_2$ and $I_3$: 75 and 50% FC during stem elongation period, respectively; $I_4$ and $I_5$: 75 and 50% FC at flowering stages) and two row spacings (45 - 50 and 75 cm) on growth, yield and oil yield of sunflower, an experiment was conducted using a split plot design with three replications in the 2007 - 2008. Results indicated that Maximum (374.67 gm$^{-2}$) and minimum (198.5 gm$^{-2}$) grain yield was obtained from $I_1$ and $I_3$ treatments. Compared to $I_1$, grain yield was reduced significantly under deficit irrigation treatments ($I_2$, $I_3$ and $I_5$). Interaction effects of row spacing and deficit irrigation indicated that the highest seed yield (458.0 gm$^{-2}$) and oil percentage (31.66%) was obtained from $I_1$ and 75 cm row spacing. Reduction of grain yield due to deficit irrigation ($I_4$) was not significant (374.6 vs. 340.1 gm$^{-2}$), compared to full irrigation. Therefore, we confirm that irrigation levels significantly affected seed yield and oil percentage. Our results indicated that deficit irrigation, during the critical growth period should be avoided.**

**Key words:** Sunflower, deficit irrigation, seed yield, oil yield, row spacing.

## INTRODUCTION

Sunflower (*Helianthus annuus* L.) is one of the most important oil crops in the world, because it offers advantages in crop rotation systems, such as high adoption capability, suitability to mechanization and low labor needs. Sunflower is the world's fourth largest oil-seed crop (FAO, 2000). Sunflower is categorized as a low to medium drought sensitive crop (Stone et al., 1996; Tolga and Lokman, 2003; Turhan and Baser, 2004). Data on the effect of the agronomic techniques and irrigation on sunflower oil quality and seed yield are scarce and controversial.

Both quantity and distribution of water has a significant impact on yield and oil yield in sunflower (Krizmanic et al., 2003; Reddy et al., 2003; Iqbal et al., 2005). Previous investigations have shown that water stress at various growth stages affect seed yield of sunflower (Tolga and Lokman, 2003; Turhan and Baser, 2004). While maximum yields were obtained with full irrigation, they were generally obtained only when irrigation was used to provide adequate water during flowering and yield formation periods (Stone et al., 1996). However, adequate water for initial plant growth is important for providing a plant capable of responding to later irrigations (Stone et al., 1996; Tolga and Lokman, 2003).

Water stress during the yield formation period reduced yields when compared to full irrigation, but the reduction was much less than when stress occurred during flowering period (Stone et al., 1996; Tolga and Lokman, 2003). The optimization of irrigation water, particularly in seasons where there is insufficient water for crop demand, is essential for water resource management.

Optimum use implies not only an efficient irrigation system capable of providing good uniformity, but also a proper timing of irrigation so as to conform to the critical stages of growth of the crop concerned. With good planning, design and operation of irrigation schemes, it is possible to analyze the effect of water supply on crop yields (Tolga and Lokman, 2003).

Because of limited irrigation water, it is generally acceptable that deficit irrigation should be used in dryland conditions (Anonymous, 1999; Flagella et al., 2002). How-

*Corresponding author. E-mail: kazemin@shirazu.ac.ir. Tel +98-711-613-8374. Fax +98-711-228-6134.

**Table 1.** Some physical and chemical properties of experimental site soil.

| Clay (%) | Silt (%) | Sand (%) | O.M. (%) | Cu | Mn | Zn | Fe | P (ppm) | N (%) | Ec (µmos/s) | pH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 18 | 60.72 | 21.28 | 2.85 | 2.48 | 6.75 | 2.31 | 6.4 | 21.8 | 0.091 | 2.61 | 7.83 |

**Table 2.** Ten day averages of climatic data measured daily in the research area.

| Months | Temperature (°C) | Relative humidity (%) | Wind speed ($m\ s^{-1}$) | Evaporation (mm) |
|---|---|---|---|---|
| **May** | | | | |
| 22 - 31 | 21.3 | 33.7 | 1.12 | 8.7 |
| **June** | | | | |
| 01 - 10 | 22.2 | 32.1 | 1.18 | 10.2 |
| 11 - 20 | 23.6 | 38.8 | 1.16 | 10 |
| 21 - 30 | 24.6 | 34.1 | 1.24 | 10.8 |
| **July** | | | | |
| 01 - 10 | 24.3 | 36.6 | 1.13 | 9.7 |
| 11 - 20 | 26.2 | 33.5 | 1.07 | 11.6 |
| 21 - 30 | 25.7 | 39.9 | 0.84 | 7.4 |
| **August** | | | | |
| 01 - 10 | 25.9 | 40.9 | 0.82 | 7.9 |
| 11 - 20 | 22.9 | 39.2 | 0.65 | 7.8 |
| 21 - 30 | 20.2 | 46 | 0.64 | 6.5 |
| **September** | | | | |
| 01 - 10 | 21.7 | 44.7 | 0.85 | 7.7 |
| 11 - 20 | 20.2 | 47.2 | 0.70 | 6.1 |
| 21 - 30 | 18.4 | 49.2 | 0.77 | 6.2 |

However, before introducing this cultural practice, its effects on yield and oil quality of sunflower should be investigated.

The objective of this research was to study the effects of full and deficit irrigation applied at different growth periods of sunflower, on yield, yield components and oil percentage to determine the most critical growth period(s) of sunflower for water usage and the influence of irrigation level under in southern Iran conditions.

## MATERIALS AND METHODS

This study was conducted in a silty clay loam soil at the experimental farm of the College of Agriculture, Shiraz University, Shiraz. Iran, located at bajgah (1810 m above the sea level with longitude of 52° 35' and latitude 39° 4'). The experimental design was split plot with three replications. The treatments were composed of row spacing in two levels (75 cm and 45 - 50 cm) as main plot and deficit irrigation in four levels ($I_2$ and $I_3$: 75 and 50% soil water content in field capacity (FC) level during stem elongation period until maturity stage and $I_4$ and $I_5$: 75 and 50% FC from flowering until maturity) compared to control ($I_1$: full irrigation and increasing soil moisture content in root depth to field capacity). In each plot during growing period and irrigation interval was fixed at 10 days for all treatments. Some physical and chemical properties of experimental site soil are shown in Table 1 and ten day averages of climatic data measured daily in the study area are shown in the Table 2. The soil water content was monitored in each plot by using the gravimetric method at 30 cm intervals down to 90 cm. Time-volume technique (Grimes et al., 1987) is an irrigation technique in which irrigation water is applied by polyethylene pipes set in each plot and the time of each plot irrigation is calibrated by a timer and a standard container. Then, irrigation water amount of each plot (measured by gravimetric method) was converted to time (min) and applied. The amount of applied water was measured by time-volume technique. Amounts of seasonal irrigation water applied ($m^3$) for different treatments are shown in Table 3. Land preparation included plowing, disking and ridging the plots (5 × 3 m). The fertilizers consisted of 100 kg triple super phosphate and 100 $kha^{-1}$ urea as preplant and 100 kg urea $ha^{-1}$ as topdressing at 6-leaf growth stage. Weeds chemically controlled by triflouralin (2 l $ha^{-1}$) as preplant and soil incorporated. The sunflower seeds (var. Euroflor, semi dwarf and early maturing) were sown in plots by planter, expecting 75000 plants $ha^{-1}$, in mid June in both years, Row spacing, plant density in each treatment was constant. In

**Table 3.** Amounts of seasonal irrigation water applied ($m^3$) for different treatments.

| Row spacing (cm) | Irrigation treatments | | | | |
|---|---|---|---|---|---|
| | I1 | I2 | I3 | I4 | I5 |
| 75 | 7989.4 | 6351.3 | 3822.4 | 6620.7 | 4698.8 |
| 45 – 50 | 7655.4 | 6737.5 | 3895.2 | 6517.9 | 4698.8 |

$I_1$: full irrigation and increasing soil moisture content in root depth to field capacity (FC), $I_2$ and I3: 75 and 50% FC from stem elongation till maturity; $I_4$ and $I_5$: 75 and 50% FC from flowering, to maturity.

**Table 4.** Effect of deficit irrigation on growth, yield and yield components of sunflower.

| Irrigation | Seed yield ( g $m^{-2}$) | 100 seed weight (g) | Seed per plant | Seed weight per head (g) | Oil (%) | Oil yield ( g $m^{-2}$) | Head weight (g) | Head diameter (cm) | Biological yield ( g $m^{-2}$ ) | Height (cm) |
|---|---|---|---|---|---|---|---|---|---|---|
| $I_1$ | 374.67a | 5.0a | 552.38a | 38.67a | 29.00a | 139.0a | 762.5a | 11.33a | 1424.00a | 146.0a |
| $I_2$ | 283.50b | 4.2b | 392.00c | 31.83b | 24.66b | 94.83b | 543.33c | 10.33ab | 1174.83b | 126.0cd |
| $I_3$ | 198.50c | 4.0b | 353.67d | 29.33b | 22.83b | 69.67c | 723.33ab | 10.00b | 849.33c | 124.6d |
| $I_4$ | 340.17a | 4.5ab | 438.50b | 36.00a | 29.00a | 129.0a | 595.83bc | 10.66ab | 1285.67ab | 137.3b |
| $I_5$ | 258.50b | 4.5ab | 324.50d | 30.83b | 25.00ab | 92.67b | 592.50bc | 10.33ab | 1198.00b | 132.6bc |
| LSD (0.05) | 41.111 | 0.05806 | 31.302 | 3.5648 | 3.8445 | 21.641 | 134.2 | 0.9281 | 186.45 | 6.9443 |

$I_1$: full irrigation and increasing soil moisture content in root depth to field capacity (FC), $I_2$ and $I_3$: 75% and 50%FC from stem elongation till maturity; $I_4$ and $I_5$: 75% and 50% FC from flowering, to maturity. Means with the same letters in each column are not significantly different using LSD (0.05).

75 cm and 45-50 cm row spacings, 4 rows with 17.7 cm plant spacing and 6 rows with 26.5 cm plant spacing were in each plot respectively. Some traits such as plant height and head diameter were measured by randomly selecting four plants in each plot. The central two row of each plot were harvested in early November in both years to determine seeds per head, 100 seed weight, total dry mater and seed yield. Seed oil percentage was determined according to Association of Official of Analytical Chemists (AOAC, 1970).The experimental data were statistically analyzed for variance using the SAS system (Version 8 ). Analysis of variance showed significant treatments effects, LSD Test was applied to compare the means at $p < 0.05$.

## RESULTS AND DISCUSSION

Results of statistical analysis showed that water deficit levels significantly affected all studied parameters (Table 4). Deficit irrigation levels applied significantly decreased the seed yield, seed per plant, oil yield compared with the 100% FC (Table 4). Result revealed that all the growth, yield contributing and oil content of seed were highly significantly affected by deficit irrigation. Similar results have been observed by Kazi et al. (2002) and Tolga and Lokma (2003).

The data presented in Table 4 revealed that different deficit irrigation levels significantly affected the yield components. Under $I_1$ treat-ment, head diameter (11.33 cm) and head weight (762.5 g) were maximum. Strong cor-relation of irrigated water and obtained biomass and yield was observed before the different deficit irrigation levels significantly ($p < 0.05$) influenced biomass and yield of sunflower (Table 4). These results are in agreement with Bakhsh et al.(1999) have repor-

**Table 5.** Effect of row spacing on growth, yield and yield components of sunflower.

| Row spacing (cm) | Seed yield ( $g\ m^{-2}$) | 100 seed weight (g) | Seed per plant | Seed weight per head (g) | Oil (%) | Oil yield ( $g\ m^{-2}$) | Head weight (g) | Head diameter (cm) | Biological Yield ( $g\ m^{-2}$) | Height (cm) |
|---|---|---|---|---|---|---|---|---|---|---|
| 75 | 356.27a | 4.60a | 415.53a | 35.73a | 28.06a | 130.26a | 690.67a | 10.93a | 1403.80a | 145.80a |
| 45 - 50 | 225.87b | 4.26a | 409.07a | 30.93a | 24.13a | 79.80b | 596.33b | 10.13b | 968.93b | 120.86b |
| LSD (0.05) | 46.093 | 1.2503 | 41.97 | 7.995 | 4.0158 | 31.942 | 30.357 | 0.4968 | 95.49 | 11.02 |

Means with the same letters in each column are not significantly different using LSD (0.05).

ted reductions in plant height, yield and biomass of sunflower when irrigation levels were reduced.

Maximum seed per plant were recorded under full irrigation and minimum under I5. Between row spacings, maximum seed yield was recorded when spacing was 75 cm (Table 5). Increased 100 seed weight and seed per plant in 75 cm row spacing have been correlated with increased grain yield (Table 5). Similar attributions have been made by others such as Karami (1977). Decreasing row spacing (45 - 50 cm) of sunflower decreased head diameter, head weight, seed number and weight per plant (Table 5). This finding was in agreement with the results of Mojiri and Arzani (2003). With increasing row spacing from 45 - 50 cm to 75 cm, seed yield was increased from 225.87 - 356.27 g $m^{-2}$ (Table 5). The increase in seed yield (g $m^{-2}$) with increasing row spacing might be attributed to the increase in head diameter, number of seed per plant and 1000 seed weight which were increased with the increase in row spacing. Similar results were also reported by other researchers (e.g., Allam and Galal, 1996; Mojiri and Arzani, 2003) . Among yield components, seed number per plant take the most effects from deficit irrigation treatments, while this yield attribute decreased up to 31% compared with $I_1$ treatment. Oil percentage decreased with narrow row spacing (45 - 50 cm) in comparison to wide row spacing (75 cm), but this reduction was not significant (28.06 vs. 24.13%). The highest oil yield was obtained from 75 cm row spacing, this is could be attributed to higher seed yield in this row spacing. Water deficit levels also affected the oil percentage in all the irrigation treatments from $I_1$ to $I_5$. But, the oil percentage in $I_4$ (75% FC from flowering to maturity) and both of row spacing showed better response to water deficit level (Table 6). These results are in agreement with the findings of Ravishankar et al. (1990) and Tolga and Lokman (2003).

The interaction between deficit irrigation levels and row spacing significantly affected seed yield, 100 seed weight, and oil percentage (Table 6). Increasing in water deficit levels was associated with decreasing in seed oil yield and oil percentage. The highest oil yield was obtained from $I_1$ and the lowest one from $I_3$. With decreasing water deficit level from $I_1$ to $I_3$, oil yield was decreased from 139 to 69.67 g $m^{-2}$ and when I4 and I5 treatments were applied oil yield decreased from 129 to 92.67 g $m^{-2}$ respectively. It seems that deficit irrigation level, I4 (75% FC from flowering to maturity) and row spacing 75 cm with high seed yield (401 g $m^{-2}$) and oil percentage (30%) are an acceptable strategy for sunflower in southern Iran and particularly in seasons where there is insufficient water for crop demand.

Our results indicate that seed yield reduced with decreasing water application in both row spacing (Table 6). In sunflower seed yield is the ultimate product of many physiological processes occurring throughout the development of the plant till it die. Seed yield per plant depends on the number of yield per head, head diameter, seed size and seed weight etc. Furthermore, seeds with maximum amount of oil content are considered better. This study showed that reducing amount of irrigation water from 100% FC to 50% FC from flowering to maturity seed yield reduced seed yield, significantly.

Results indicate that flowering is the most important stage for irrigation of sunflower, because, sunflower is more sensitive to water stress at flowering than at other growth stages. Our results support the previous work of Rinaldi (2001) who reported that when seasonal irrigation water was limited, one or two irrigations in the central phase (heading and flowering stages) is profitable, for irrigation use efficiency and net income. On the other hand, the same researcher reported that in case of limited irrigation, water stress should be scheduled on critical growth stages such as flowering, heading and milking stages (Reddy et al., 2003; Tolga and Lokman, 2003). Khaliq (2004) observed the response of sunflower hybrids to deficit irrigation practice and obtained near-maximum yield when sunflower was irrigated during the reproductive phase.

## Conclusion

Any restriction in the supply of irrigation water is likely to induce a decrease in crop yield. However, the is likely to induce a decrease in crop yield.

**Table 6.** Interaction effect of irrigation deficit and row spacing on yield and yield components and oil percent of sunflower.

| | Seed yield (g m$^{-2}$) | 100 seed weight (g) | Seed per plant | Oil (%) |
|---|---|---|---|---|
| | | Row spacing 75 (cm) | | |
| $I_1$ | 458.00a | 5.00a | 536.66a | 31.66a |
| $I_2$ | 317.00c | 4.00b | 372.43c | 26.46ab |
| $I_3$ | 247.00d | 4.33ab | 355.00c | 24.00b |
| $I_4$ | 401.00ab | 5.00a | 447.76b | 30.00a |
| $I_5$ | 357.00bc | 4.66ab | 365.61c | 28.00ab |
| LSD | 58.14 | 0.8210 | 44.27 | 5.473 |
| | | Row spacing 45-50 (cm) | | |
| $I_1$ | 291.00a | 5.00a | 569.00a | 26.35ab |
| $I_2$ | 250.00a | 4.33ab | 411.33ab | 22.66ab |
| $I_3$ | 150.00b | 3.66b | 352.33b | 21.59b |
| $I_4$ | 278.00a | 4.00b | 429.45b | 28.00a |
| $I_5$ | 159.00b | 4.33ab | 283.35ab | 22.00b |
| LSD (0.05) | 58.14 | 0.8210 | 44.27 | 5.473 |

$I_1$: full irrigation and increasing soil moisture content in root depth to field capacity (FC), $I_2$ and I3: 75 and 50% FC from stem elongation till maturity; $I_4$ and $I_5$: 75 and 50% FC from flowering, to maturity. Means with the same letters in each column are not significantly different using LSD (0.05).

However, the impact of deficit irrigation on crop yield can be insignificant where the water stress is applied to the crop during specific growth stages that are less sensitive to moisture deficiency. Results from the present study indicated that sunflower seed yield, yield components and oil percentage had been significantly affected by deficit irrigation and row spacing. It seems that sowing sunflower with 75 cm row spacing and the application of deficit irrigation level, $I_4$ (75% FC from flowering to maturity) were the recommended treatments to raise sunflower seed and oil yields compared with the other deficit irrigation levels under the environmental conditions of this study. In case of deficit irrigation, reduced irrigation water during the flowering period should be avoided. But when seasonal irrigation water was limited, it seems that deficit irrigation, ($I_4$) should be applied for the irrigation efficiency.

## ACKNOWLEDGMENTS

This project was funded by a grant from Shiraz University, Shiraz, Iran. The authors express appreciation to Shiraz University Experimental Station staff for their assistance in field research.

## REFERENCES

Allam AY, Galal AH (1996). Effect of nitrogen fertilization and plant density on yield and quality of sunflower. Assiut J. Agric. Sci. 27 (2): 169-177.

Anonymous (1999). Sunflower crude and refined oils. In: Agribusiness Handbooks. Food and Agric. Organization, Eur. Bank Reconstruction Dev. pp. 17–26.

Association of Official of Analytical Chemists (AOAC). (1970). Official method of analysis. 11th edition, Washington D.C., USA.

Bakhsh I, Awan IU, Baloch MS (1999). Effect of various irrigation frequencies on the yield and yield components of sunflower. Pakistan J. Appl. Sci. 2: 194–195.

FAO (2000). http//www.fao.org.

Flagella Z, Rotunno T, Tarantino R, Di Caterina R, De Caro A (2002). Changes in seed yield and oil fatty acid composition of high oleic sunflower (*Helianthus annuus* L.) hybrids in relation to the sowing date and the water regime. Eur. J. Agron. 17: 221–230.

Grimes DW, Yamada H, Hughes SW (1987). Climate-normalized cotton leaf water potentials for irrigation scheduling. Agric. Water Manage. 12: 293-304.

Iqbal N, Ashraf M, Ashraf MY, Azam F (2005). Effect of exogenous application of glycinebetaine on capitulum size and achene number of sunflower under water stress. Int. J. Biol. Biotechnol. 2(3): 765– 771.

Karami E (1977). Effect of irrigation and plant population on yield and yield components of sunflower. Indian J. Agric. Sci. 47: 15–17.

Kazi BR, Oad FC, Jamro GH, Jamali LA, Oad NL (2002). Effect of water stress on growth, yield and oil content of sunflower. Pakistan J. Appl. Sci. 2 (5): 550–552.

Khaliq A (2004). Irrigation and nitrogen management effects on productivity of hybrid sunflower (*Helianthus annuus* L.). Ph.D. Thesis. University of Agric., Faisalabad.

Krizmanic M, Liovic I, Mijic A, Bilandzic M, Krizmanic G (2003). Genetic potential of OS sunflower hybrids in different agroecol conditions. Sjemenarstvo 20(5/6): 237–245.

Mojiri A, Arzani A (2003). Effects of nitrogen rate and plant density on yield and yield components of sunflower. J. Sci. Technol. Agric. Nat. Resour 7 (2): 115-125.

Ravishankar KV, Shanker RU, Kumar U. (1990). Relative stability of seed kernel oil content under moisture stress in sunflower evolutionary adaptations. Indian J. Plant Physiol. 33: 214-218.

Reddy GKM, Dangi KS, Kumar SS, Reddy AV (2003). Effect of moisture stress on seed yield and quality in sunflower, Helianthus annuus L. J. Oilseeds Res. 20(2): 282–283.

Rinaldi M (2001). Application of EPIC model for irrigation scheduling of sunflower in Southern Italy. Agric. Water Manage. 49:185–196.

Stone LR, Schlegel AJ, Gwin RE, Khan AH (1996). Response of corn, grain sorghum and sunflower to irrigation to the High Plains of Kansas. Agric. Water Manage. 30: 251-259.

Tolga E, Lokman D (2003). Yield response of sunflower to water stress under Tekirdag conditions. Helia. 26(38): 149–158.

Turhan H, Baser I (2004). In vitro and In vivo water stress in sunflower (*Helianthus annuus L.*). Helia 27(40): 227-236.