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Effect of Water Stress on Growth and Yield of Sunflower

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Abstract

Field study was carried out during the year 2012 at the experimental fields of Oil seeds Section, Agriculture Research Institute, Tandojam. The objective of the study was to investigate the effect of water stress on growth and yield of sunflower. Four irrigation regimes were tested to examine the effect of water stress on crop productivity which included T_1 = 2 irrigations (30 and 45 DAS), T_2 = 3 irrigations (30, 45 and 60 DAS), T_3 = 4 irrigations (30, 45, 60 and 75 DAS) and T_4 = 5 irrigations (30, 45, 60, 75 and 90 DAS). The experiment was laid out in a three replicated with Randomized Complete Block Design (RCBD) in a plot size of 3 x 5m (15m^2). The results indicated that days to 75% flowering and 90% maturity, plant height, stem girth, head diameter, seeds head^{-1}, seed index and seed yield ha-1 were significantly ($P < 0.05$) affected by the water stress by means of number of irrigations applied throughout the sunflower growing season. The crop irrigated five times (30, 45, 60, 75 and 90 DAS) resulted maximum values for growth and yield components and took 79.00 days to 75% flowering, 120.67 days to 90% maturity, 186.67 cm plant height, 5.59 cm stem girth, 27.69 cm head diameter, 1913.33 seeds head^{-1}, 78.91 g seed index and 2200.00 kg ha^{-1} seed yield. The crop receiving four irrigations (30, 45, 60 and 75 DAS) ranked 2nd and took 74.67 days to 75% flowering, 114.67 days to 90% maturity, 164.33 cm plant height, 4.94 cm stem girth, 26.39 cm head diameter, 1855.67 seeds head-1, 76.38 g seed index and 2032.00 kg ha^{-1} seed yield. The sunflower crop irrigated three times (30, 45 and 60 DAS) ranked 3rd and two irrigations (30 and 45 DAS) ranked least for all the growth and yield components studied. It was concluded that the differences in seed yield ha^{-1} and contributing characters of sunflower between five and four irrigations were statistically non-significant ($P > 0.05$); hence, 4 irrigations (30, 45, 60 and 75 DAS) was an optimum irrigation regime for achieving higher economical seed yields. The discontinuation of irrigation water after 45 or 60 DAS (under 2 and 3 irrigations) resulted in severe negative effects on seed yield ha^{-1}.

Keywords: *sunflower; water stress; growth and yield*

Introduction

Pakistan is an agricultural country, but unfortunately facing deficits in major commodities of domestic consumption including edible oil. More than 70% edible oil domestic demand is met by imports. The major crops that are source of edible oil are cottonseed, sunflower, canola and rapeseed/mustard. Although the cotton crop is grown for its lint, but its contribution to meet total edible oil production in the country is 50 to 60% [1]. Sunflower (*Helianthus annuus* L.) has the potential to bridge up the gap between demand and supply of edible oil and it is well adapted to agro-ecological conditions of Pakistan. Sunflower seed contains 25-48% oil and 20-27% protein. Its oil contains high% age of poly-unsaturated fatty acids (60%), accepted largely in diet to reduce cholesterol in blood and prevents heart diseases [2]. Sunflower oil is quite palatable and contains soluble vitamins A, D, E and K. It is used in manufacturing of margarine; and sunflower cake is used as cattle feed [3]. Sunflower being the most important oil crop and due to its high content of unsaturated fatty acids and a lack of cholesterol, the oil benefits are well recognized for human health [4]. Although sunflower is known as a drought tolerant crop or grown under dry land conditions, substantial yield increases are achieved by irrigation and many researchers have reported its performance decrease under water stress conditions [5]. During the year 2011-12, the total availability of edible oil was 2.748 million tons. Domestic production of edible oil is persist at 0.636 million tons while imports were 2.148 million tons. The import bill during 2011-12 stood at Rs. 216.4 billion. During the year 2012-13 (July-March), 1.738 million tons of edible oil valued at Rs. 153.3 billion has been imported. The local production during 2012-13 was 0.612 million tons. Total availability of edible oil from all sources is provisionally estimated at 2.35 million tons during 2012-13 [6].

At the time of independence, Pakistan was water surplus country due to huge water resources of Indus River system and now Pakistan is a water deficit country. In 1947, water availability per capita was about 5000 cubic meter; this will decrease to about 1200 cubic meter per capita by the year 2025 [7]. The immediate water shortage crisis in Pakistan is severe, and experts maintain that the long-term forecast is bleaker [8]. This indicates that the country is well short of the water requirements for routine agriculture. Hence, it becomes indispensable to plan strategies with concrete measures in order to properly manage irrigation water at all levels [9].

Proper water management is not only to reduce water deficit level, but also to obtain higher yields within existing water resources. The application of traditional flood irrigation methods is responsible for considerable loss of water, reduction in crop yields, and disturbance of eco-system, widespread salinity, and water logging problems. This has reduced the overall irrigation efficiency hardly up 30% [10]. Hence, these methods are not viable for small farms and are difficult to adopt by common farmer. Therefore, it is high time to introduce and practice efficient irrigation methods, which not only increase yields, and save water, but also be cheap and can easily be operated and maintained. One of those methods is raised bed planting method. This method helps in reducing irrigation requirements of crops and increase crop production even in soils having low permeability, seasonal water logging, salinity and shortage of water supply [4].

The objective of well-regulated deficit irrigation is to save water by subjecting crops to periods of moisture stress with minimal effects on yields. Under arid and semi arid climates, the drought stress is considered as one of the main problems of production. Water shortage is usually one of the important reasons for the reduction of performance in the unit area of these areas. Most of the regions have a rainfall of less than 250 mm in year; the danger of drought is considered serious. Low water potential caused by a soil water deficit is one of the major natural limitations of the productivity of natural and agricultural ecosystems, resulting in large economic losses in many areas. In the past, irrigation has been a key solution to resolving this problem, but due to the increasing societal demands to water, today it is not a reasonable alternative and it increase financial cost [11]. Thus, the implementation of research programs for planning proper irrigation management is essential. Causing stress in a stage of plant's growth without losing its performance from the point of view of saving water and irrigation is one of the favourite research areas for researchers. On the other hand, development of proper water management and irrigation methods can be a common solution for the sunflower cultivation [12]. Water saving techniques is the demand of the time that may increase the absorption capability and retention of water in soil and for the fight against water shortage conditions and the decrease of bad effects of drought stress [13]. Flagell., *et al*. [14] stated that need of the hour is to adopt management techniques and technologies available for increasing irrigation efficiency [15]. These techniques may include proper irrigation intervals to evaluate the proper amount of water to apply to the crop and the proper scheduling for application. Different principals are applied to estimate the proper water supply according to the crop requirement for maximum crop yield [16]. In view of the problems stated above, the study was carried out to evaluate the effect of water stress on growth and yield of sunflower at climatic condition of Tandojam.

Materials and Methods

The study was carried out during 2012 to investigate the effect of water stress on growth and yield of sunflower. The experiment was laid out in a three replicated Randomized Complete Block Design (RCBD) in a plot size of 3 x 5m (15m^2), at the experimental fields of Oil seeds Section, Agriculture Research Institute, Tandojam. The experimental land was prepared by giving two dry plowings followed by precision land levelling. After soaking dose, when soil came in condition two plowings with crosswise cultivator followed by planking was applied to achieve the fine seed bed. The sowing was done by means of single coulter hand drill at the row distance of 60 cm, keeping 45 cm distance between plants. The above row and plant spacing was maintained by thinning, 15 days after completion of the germination.

Treatments = 04 (Irrigation regimes)
T_1 = 2 irrigations (30 and 45 DAS)
T_2 = 3 irrigations (30, 45 and 60 DAS)
T_3 = 4 irrigations (30, 45, 60 and 75 DAS)
T_4 = 5 irrigations (30, 45, 60, 75 and 90 DAS)

Nitrogen was applied in the form of urea and P in the form of single super phosphate (SSP) and the crop was irrigated as per the treatment plan. All P along with 1/3rd of N (as urea) were applied at the time of sowing and remaining N was applied in two splits at first irrigation and at grain formation stage, respectively. Five plants from each plot were randomly selected and labelled for recording observations of various agronomical traits. The observations were recorded on the following parameters:

Observations recorded

a. Days to 75% flowering
b. Days to 90% maturity
c. Plant height (cm)
d. Stem girth (cm)
e. Head diameter (cm)
f. Seeds head^{-1}
g. Seed index (1000 seed weight, g)
h. Seed yield (kg ha^{-1})

Procedure for recording observations

Days to 75% flowering: The number of days from sowing to completion of 75 % flowering was recorded for the crop in each plot and average was calculated.

Days to 90% maturity: The number of days from sowing to completion of 90 % maturity was recorded for the crop in each plot and average was worked out.

Plant height (cm): Plant height was recorded at maturity of crop using measurement tape from bottom to top of the randomly selected plants in each plot and averaged in centimeters.

Stem girth (cm): Stem girth was measured from three positions of the stem i.e. bottom, middle and top by means of Vernier Caliper in centimetres and average was recorded.

Head diameter (cm): Head diameter was examined by crosswise measurement of the head exactly through center of the head in centimetres in the labelled plants and average was worked out.

Seeds head^{-1}: The seeds in the heads of the selected plants were counted in each plot and averaged head^{-1} was calculated.

Seed index (1000 seed weight, g): One thousand seeds from the seed lot threshed in each plot were collected and weighed to obtain seed index in grams.

Seed Yield (kg ha^{-1}): At maturity, the sunflower heads in each plot were harvested and threshed, and yield ha^{-1} was calculated by the following formula:

Statistical analysis: Data collected were subjected to statistical analysis through MSTATC computer software. The mean comparison values were determined through Duncan's Multiple Range Test (DMRT) according to the method developed by Gomez and Gomez [17].

Results and Discussion

Studies were carried out during the year 2012 at the experimental fields of Oilseeds Section, Agriculture Research Institute, Tandojam to investigate the effect of water stress on growth and yield of sunflower. Four irrigation regimes were tested to examine the effect of water stress on crop productivity which included T_1 = 2 irrigations (30 and 45 DAS), T_2 = 3 irrigations (30, 45 and 60 DAS), T_3 = 4 irrigations (30, 45, 60 and 75 DAS) and T_4 = 5 irrigations (30, 45, 60, 75 and 90 DAS). Agronomic observations were recorded to evaluate the effect of irrigation scheduling on crop growth and seed sunflower yield. This chapter describes the results (Figure 1 to Figure 8) on the basis of analysis of variance and DMRT.

Days to 75% flowering

The effect of water stress by means of irrigation scheduling on the number of days taken by sunflower crop to complete 75% flowering was examined and the results are presented in Figure 1. Sunflower crop receiving five irrigations (30, 45, 60, 75 and 90 DAS) took maximum number of days (79.00) to 75% flowering, while the crop receiving four irrigations (30, 45, 60 and 75 DAS) completed 75% flowering in 74.67 days. Similarly, the sunflower crop given three irrigations (30, 45 and 60 DAS) took 68.67 days to flowering; while minimum number of days (61.33) to 75% flowering was observed in sunflower crop receiving only two irrigations (30 and 45 DAS). This indicates that with increasing the number of irrigations, and continuing the water supply up to the later crop stages prolonged the period between sowing and 75% flowering. On the other hand, reducing the number of irrigations and discontinuing the water supply to the crop at early stages resulted in physiological changes in plant and earliness in completion of 75% flowering was observed. The DMRT suggested a linear difference among all the treatment means ($P < 0.01$). The coefficient of variation per plot (1.76%) suggested that the experimental soil was homogenous in fertility, so far the days to 75% flowering is concerned.

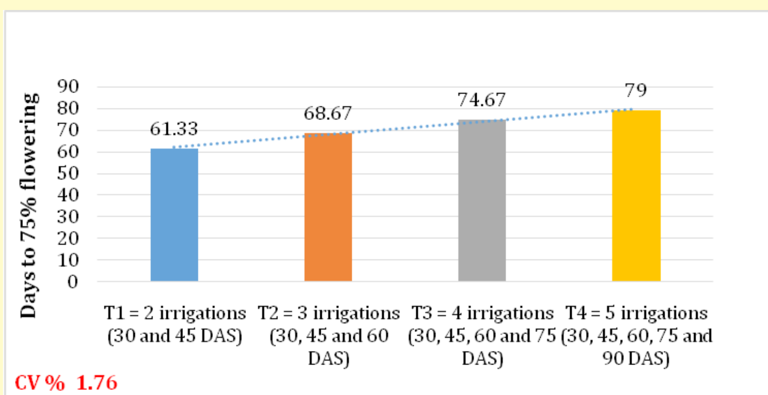

***Figure 1:** Number of days taken to 75% flowering of sunflower as influenced by water stress.*

Days to 90% maturity

The effect of water stress on the number of days taken by the crop to 90% maturity was investigated and the results are shown in Figure 2. The analysis of variance demonstrated that the sunflower crop receiving five irrigations (30, 45, 60, 75 and 90 DAS) took maximum number of days (120.67) to 90% maturity, while the crop receiving four irrigations (30, 45, 60 and 75 DAS) completed 90% maturity in 114.67 days. Similarly, the sunflower crop given three irrigations (30, 45 and 60 DAS) took 101.00 days to 90% maturity; while minimum number of days (93.00) to 90% maturity was noted in sunflower crop receiving only two irrigations (30 and 45 DAS). The

DMRT suggested a linear difference among all the treatment means (P < 0.01). The results suggested that with increasing the number of irrigations, and continuing the water supply up to the later crop stages prolonged the period between sowing and 90% maturity. On the other hand, curtailing the irrigation number and discontinuing the crop irrigation at early stages led the crop to physiological stress and earliness in completion of 90% maturity was noted. The coefficient of variation per plot (1.38%) suggested that the experimental soil responded homogenously to sunflower crop in all the plots for days to 90% maturity.

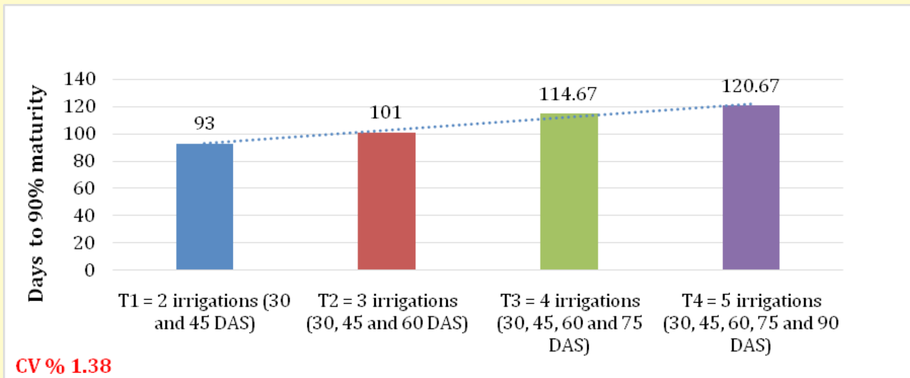

Figure 2: *Number of days taken to 90% maturity of sunflower as influenced by water stress.*

Plant height (cm)

The effect of water stress on the plant height of sunflower was evaluated and the results are presented in Figure 3. The analysis of variance illustrated a significant (P < 0.05) effect of number of irrigations on the plant height of sunflower. The results indicated that the sunflower crop irrigated five times (30, 45, 60, 75 and 90 DAS) produced the plants of maximum height on average (186.67 cm) and by decreasing the number of irrigations to four (30, 45, 60 and 75 DAS), the plant height followed an adverse direction (164.33 cm). Similarly, The sunflower crop irrigated three times (30, 45 and 60 DAS) resulted in average plant height of 138.67 cm; whereas the lowest plant height of 129.00 cm was recorded in sunflower crop irrigated two times throughout the growing season (30 and 45 DAS). The DMRT suggested a linear difference among all the treatment means (P < 0.01). It was noted that under 2, 3 and 4 irrigations (at 15 days interval) at different scheduling the sunflower crop was under-irrigated, while five irrigations proved to be necessary for achieving desired plant height. On the other hand, discontinuity of irrigation water to sunflower at early stage resulted in severe disadvantage for plant growth that caused poor plant height. The coefficient of variation per plot (2.50%) indicated that the experimental soil was homogenous in all the experimental plots and no uneven variation in plant height was observed.

Stem girth (cm)

The effect of water stress on the stem girth of sunflower was investigated and the data to this effect are presented in Figure 4. The analysis of variance suggested a significant (P < 0.05) effect of number of irrigations on the stem girth of sunflower. The sunflower crop given five irrigations (30, 45, 60, 75 and 90 DAS) resulted in thicker stems as compared to those under water stress and maximum stem girth (5.59 cm) while under reduced number of irrigations to four (30, 45, 60 and 75 DAS), the stem girth showed a simultaneous decrease (4.94 cm). The sunflower crop irrigated three times (30, 45 and 60 DAS) resulted in average stem girth of 4.29 cm; while the lowest stem girth of 3.59 cm was recorded in sunflower crop irrigated two times (30 and 45 DAS) throughout the growing season. The DMRT suggested a linear significance in stem girth difference among all the treatment means (P < 0.01). The results suggested that under 2, 3 and 4 irrigations (at 15 days interval) the sunflower crop was under stress, while under five irrigations they showed adequacy of water for maximum stem girth. On the other hand, termination of irrigation water to sunflower at early stage showed severe negative effects on stem girth. The coefficient of variation per plot (0.84%) suggested that the experimental soil was homogenous; and in all the experimental plots the experimental plants received opportunity to develop stem girth uniformly.

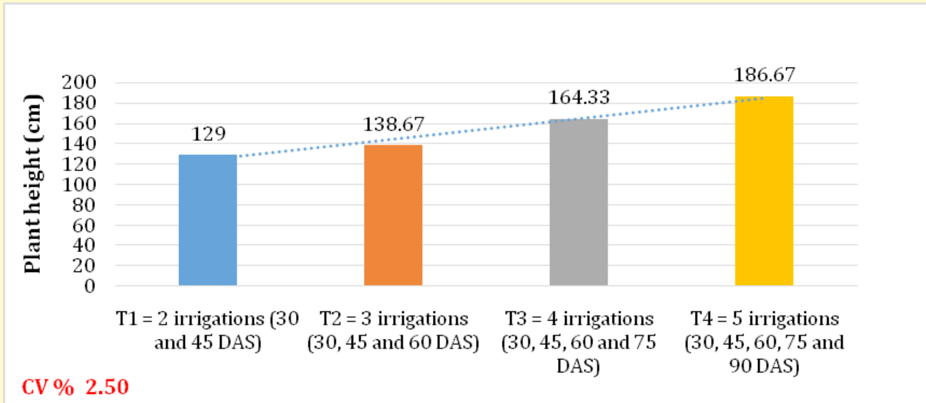

Figure 3: *Plant height (cm) of sunflower as influenced by water stress.*

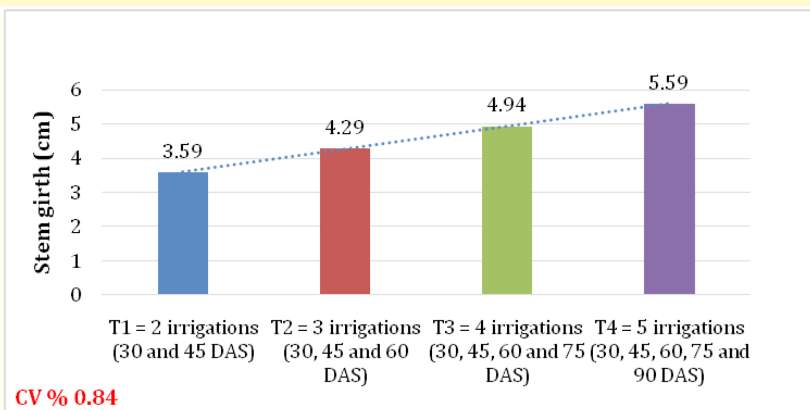

Figure 4: *Stem girth (cm) of sunflower as influenced by water stress.*

Head diameter (cm)

The head diameter of sunflower in response to different number of irrigations was measured and the results for this trait are shown in Figure 5. Analysis of variance validated a significant ($P < 0.05$) effect of number of irrigations on the head diameter of sunflower. The sunflower crop given five irrigations (30, 45, 60, 75 and 90 DAS) resulted in bigger heads (27.69 cm) as compared to those under water stress. The sunflower crop receiving four irrigations (30, 45, 60 and 75 DAS) resulted in a decreased head diameter (26.39 cm). The sunflower crop that received three irrigations (30, 45 and 60 DAS) resulted in average head diameter of 24.23 cm; while the minimum head diameter of 22.10 cm was observed fewer than two irrigations (30 and 45 DAS) throughout the sunflower growing season. The DMRT suggested that the differences in head diameter in plots given five and four irrigations were statistically non-significant ($P > 0.05$), while significant ($P < 0.05$) when compared with rest of the treatments. The results suggested that in case of 2 and 3 irrigations (at 15 days interval) the sunflower crop was under stress, while the differences in head diameter indicated that four irrigations would be adequate to be fulfilling the crop water requirement. However, discontinuation of irrigation after 45 days or 60 DAS resulted in marked reduction in head diameter. The coefficient of variation per plot (3.50%) indicated that the experimental soil was homogenous and no uneven variation in head diameter was associated with the treatments.

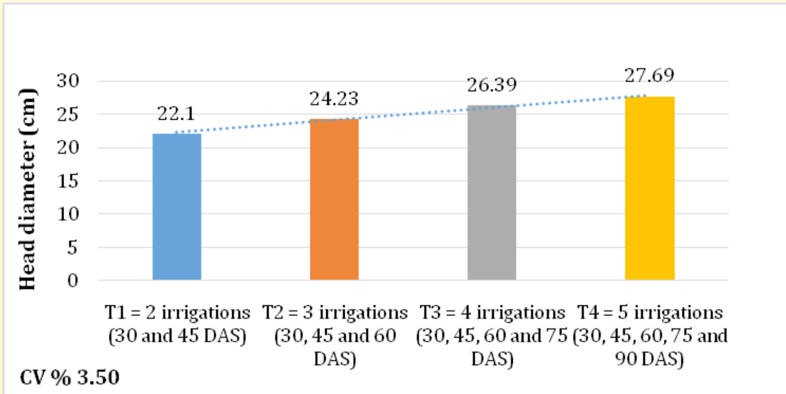

Figure 5: *Head diameter (cm) of sunflower as influenced by water stress.*

Number of seeds head^{-1}

The effect of different irrigations regimes on the number of seeds head-1 of sunflower was examined and the results for this parameter are shown in Fig. 6. The analysis of variance suggested that the number of seeds head^{-1} in sunflower was significantly ($P < 0.05$) affected by the number of irrigations. The crop receiving five irrigations (30, 45, 60, 75 and 90 DAS) resulted in maximum number of seeds (1913.33) as compared to rest of the irrigation regimes. The sunflower crop receiving four irrigations (30, 45, 60 and 75 DAS) resulted in a minor decrease in the number of seeds (1855.67) head^{-1}. The crop that received three irrigations (30, 45 and 60 DAS) suffered a marked reduction in the number of seeds (1362.33) head^{-1}; while the lowest number of seeds (1065.00) head^{-1} was observed under two irrigations (30 and 45 DAS). The DMRT suggested that the differences in number of seeds head^{-1} under five and four irrigations were statistically non-significant ($P > 0.05$), while significant ($P < 0.05$) when compared with rest of the irrigation regimes. It was further observed, that the sunflower crop was under water stress when given 2 and 3 irrigations (at 15 days interval), while results clearly suggested 4 irrigations as an optimum irrigation regime at 15 days interval, being 1st irrigation after 30 days of sowing. However, termination of irrigation after 45 days or 60 DAS resulted in severe adverse effects on number of seeds head^{-1}. The coefficient of variation per plot (6.38%) showed that the experimental soil was homogenous and no uneven variation for this trait was observed.

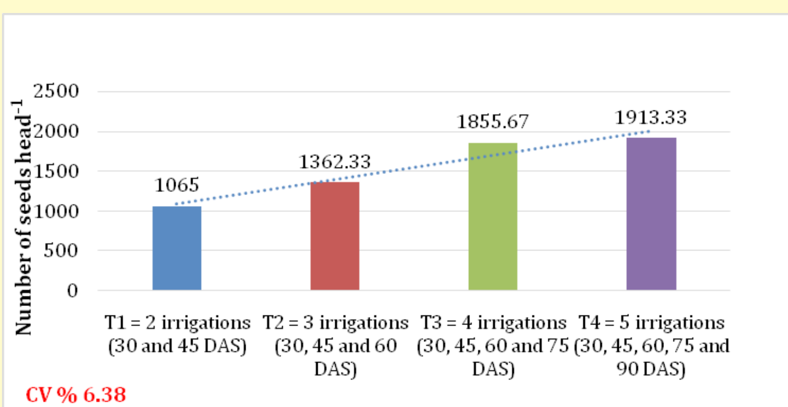

Figure 6: *Number of seeds head^{-1} of sunflower as influenced by water stress.*

Seed index (g)

The seed index of sunflower in response to different irrigation regimes was recorded on the basis of 1000 seeds weight and the results are presented in Figure 7. The crop given five irrigations (30, 45, 60, 75 and 90 DAS) resulted in bigger heads (78.91g) as compared to those under water stress. The sunflower crop receiving four irrigations (30, 45, 60 and 75 DAS) resulted in a nominal decrease in seed index (76.38g). The crop receiving three irrigations (30, 45 and 60 DAS) resulted in average seed index of 67.11g; while the minimum seed index of 60.03g was noted in case of two irrigations (30 and 45 DAS). The DMRT suggested that the differences in seed index in plots given five and four irrigations were statistically non-significant ($P > 0.05$), while significant ($P < 0.05$) when compared with rest of the irrigation regimes. The results showed that in case of 2 and 3 irrigations (at 15 days interval) the sunflower crop was under stress, while the differences in seed index between four and five irrigations indicated that four irrigations would be optimum for achieving desired results for seed index. It was also observed that termination of irrigation application after 45 or 60 days of sowing caused a marked reduction in seed index. The coefficient of variation per plot (3.17%) indicated that the experimental soil was homogenous.

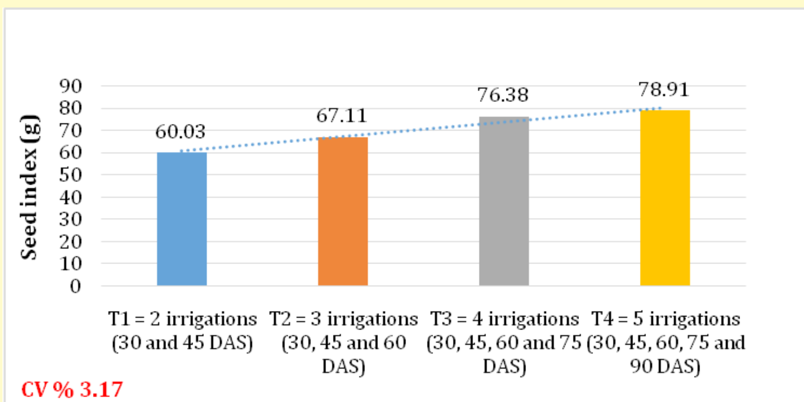

***Figure 7:** Seed index value (1000 seeds weight g) of sunflower as influenced by water stress.*

Seed yield (kg ha^{-1})

The effect of different irrigations regimes on the seed yield ha^{-1} of sunflower was examined and the results for this parameter are presented in Figure 8. The analysis of variance indicated that the seed yield ha^{-1} in sunflower was significantly ($P < 0.05$) affected by the number of irrigations. The crop receiving five irrigations (30, 45, 60, 75 and 90 DAS) resulted in maximum seed yield (2200 kg ha^{-1}), while the crop receiving four irrigations (30, 45, 60 and 75 DAS) resulted in a slight decrease in seed yield (2032 kg ha^{-1}) over 5 irrigations. The crop receiving three irrigations (30, 45 and 60 DAS) suffered a marked reduction in seed yield (1472.33 kg ha^{-1}); while the lowest seed yield (960.33 kg ha^{-1}) was noted under two irrigations (30 and 45 DAS). The DMRT suggested that the differences in seed yield ha^{-1} under five and four irrigations were statistically non-significant ($P > 0.05$), while significant ($P < 0.05$) when compared with rest of the irrigation scheduling. The results further showed that the sunflower crop was under water stress when given 2 and 3 irrigations (at 15 days interval) were applied, while results 4 irrigations proved to be an optimum irrigation regime. The stoppage of irrigation application after 45 days or 60 DAS resulted in severe negative effects on seed yield ha^{-1}. The coefficient of variation per plot (6.71%) showed that the experimental soil was homogenous and no uneven variation for this trait was observed.

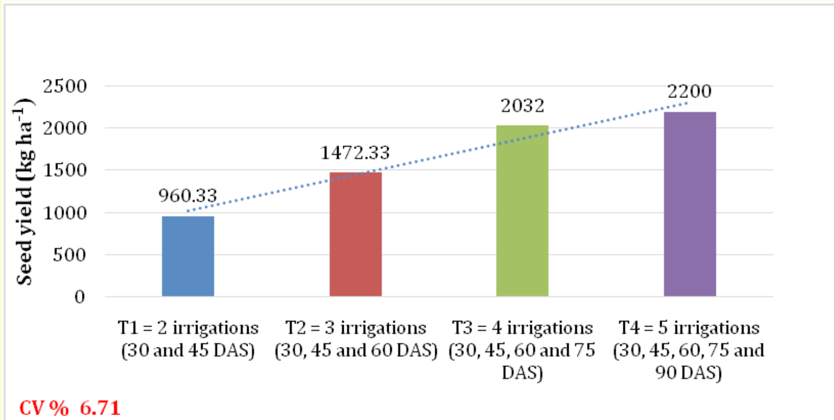

Figure 8: *Seed yield (kg ha^{-1}) of sunflower as influenced by water stress.*

Discussion

The yield response to water deficit of different crops is of major importance in production planning. Water deficit in crops and resulting water stress on plants affect crop evapotranspiration. Under the conditions of higher evapotranspiration water stress develops in plants, which adversely affects crop growth and ultimately crop yield. However, for a full evaluation of the effect of limited water supply on yield and yield component, consideration must be given to the effect of the limited water supply during individual growth stages of the crops. The response of yield to water supply is quantified through the yield response factor which relates to relative yield decrease and relative ET deficit [18]. The findings of the study showed that sunflower irrigated five times i.e. during all the growth stages, resulted maximum values for growth and yield components including highest seed yield of 2200.00 kg ha^{-1}. A substantial reduction in yield and yield components was noted by withdrawing irrigation number. The crop receiving four irrigations gave2032.00 kg ha^{-1} seed yield. The discontinuation of irrigation water after 45 or 60 DAS (under 2 and 3 irrigations) resulted in severe negative effects on seed yield ha^{-1}. Similar finding were earlier reported by Ghani., *et al*. [19] who reported that an irrigation interval of 10 days, corresponding to 60% depletion of available water, is optimum for reasonable sunflower production. Growth and yield attributes like, plant height, head diameter, number of grains per head, 1000-grain weight and grain yield per hectare were significantly affected by irrigation frequencies i.e. 0, 2, 4, 6 and 8 irrigation, six irrigations were found optimum for obtaining good yield of sunflower [20].

Our findings are also supported by Shekari [21], where according to him Deficit irrigation in mid flowering and after that has significant effect on CGR and seed filling period of sunflower. Erdem., *et al*. [22] demonstrated the effect of water stress on 58% yield reduction of sunflower. It seems that the budding and flowering stages are more susceptible to water stress in relation to seed yield [23].

Taha., *et al*. [24] also reported that proper scheduling of irrigation resulted in significantly maximum sunflower seed yield of 1391.7 kg ha^{-1} and response of plant height, diameter, seeds per head or seed weight of sunflower was found to be linearly related to the amount of irrigation. The results obtained by above researchers are in full support of our achievements. Prasa., *et al*. [25] found that water use efficiency were higher at 1 irrigation, however, 3 irrigations resulted in higher net returns and in our case 5 irrigations gave maximum net results and this may be due to high temperature during growth period of sunflower under climatic conditions of Sindh province of Pakistan for the period of development of canopy there may be maximum evapotranspiration which may have caused moisture stress to the sunflower crop.

Conclusions

Sunflower is sensitive to both excessive and deficit water which leads to decrease yield. Sunflower irrigated five (30, 45, 60, 75 and 90 DAS) and four times (30, 45, 60 and 75 DAS) resulted maximum values for growth and yield components and took more days to maturity. However, highest water stress to sunflower (two irrigations (30 and 45 DAS)) reduced sunflower days to flowering and maturity, plant height, stem girth, head diameter, seeds head-1, seed index and seed yield. It was therefore, concluded that four irrigations (30, 45, 60 and 75 DAS) was an optimum irrigation regime for achieving higher economical sunflower seed yield.

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