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Morpho-physiological responses of Sunflower (*Helianthus anuus* L.) hybrid to different irrigation and planting regimes

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Abstract

Judicious water management along with proper planting method plays key role in increasing sunflower yield. Sunflower occupies main role among oil seed crops in Pakistan in which mostly indigenous sunflower hybrid are cultivated, however due to low crop yield and return farmers are switching to high yielding sunflower hybrids. Hence, the research was carried out to determine the effect of planting methods and irrigation levels on the growth and yield of sunflower hybrid (SMH0907) and to find out the optimum irrigation level and most suitable planting method. Experiment comprised of five irrigation levels i.e., irrigation at seedling, buttoning, flowering, grain filling and near to maturity stage along with control (no irrigation) and two planting method i.e., ridge and flat. Randomized complete block design was followed with three replications. According to this research, the optimum irrigation for the highest achene yield is applying water at all four critical growth stages (from seedling to grain filling) (achene yield, 3184.2 kg ha^{-1}) compared with irrigation at all five growth stages (achene yield 2592.0 kg ha^{-1}). Similarly, number of achene head^{-1}, 100 achene weight was also increased with irrigation at four growth stages. An increased leaf area index (LAI), and harvest index (HI) was also recorded with irrigation at critical growth stages. In this study the crop grown on ridges had an increased LAI, and HI. Similarly, ridge sown crop produced more achene head^{-1} and greater 100 achene weight and achene yield than crops sown on flat. The findings of this studies economized water use by identifying critical growth stages where irrigation is important along with suitable planting method.

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Introduction

Edible oil, being an important commodity, is used in everyday life in many ways. Unfortunately, Pakistan has been facing edible oil deficiency because the local production has throughout remained lower than our total national requirement and consequently around 70-80 % of the domestic requirement is met through imports while only 20-30 % of edible oil is produced locally. In Pakistan, traditional (rapeseed-mustard, groundnut, sesame and linseed) and non-conventional (sunflower, soybean and safflower) oilseed crops are grown (Tolga and Lokman, 2003; Turhan and Baser, 2004). Sunflower has recently emerged as a major oilseed crop in the country due to its oil yield but it has the potential to narrow down the gap between production and consumption of edible oil because it contributes around 30% of our local edible oil production. It is well known fact that number of biotic and abiotic factors are responsible for potential yield of any crop such as the environmental factors i.e., soil fertility, soil moisture and plant population which have a paramount role on crop growth and its yield. By manipulating environmental conditions through proper management of irrigation and adopting suitable planting pattern, the sunflower yield can be increased.

Water is one of the important crop growth-limiting factors that directly affect biological yield and oil content of sunflower. Its quantity and distribution is equally important whose significance has been practically realized by most farmers (Krizmanic *et al.*, 2003; Reddy *et al.*, 2003; Iqbal *et al.*, 2005). It has also been reported that the cautious and judicious application of irrigation at critical growth stages significantly increases the yield of sunflower (Rawson and Turner, 1983 Ghani *et al.*, 2000). It has also been claimed that the optimum supply of water particularly at reproductive phase results in maximum yield of sunflower (Stone *et al.*, 1996). Nevertheless, ample supply of water at initial growth stage is essential for later response of crop to irrigations (Stone *et al.*, 1996; Tolga and Lokman, 2003). The sunflower consumes 20-25% of its total water requirement during the initial thirty days (Rawson and Turner, 1983) and the climax for water need is at reproductive stage. However, Blamey and Chapman (1981) viewed that the sunflower responded positively to irrigation both at vegetative and reproductive phase. Vasiliu (1986) observed 27% higher seed yield with irrigation at 50% field capacity than without irrigation. Not only the optimum levels of irrigation but also proper timing of irrigation is essential for obtaining maximum yield of crop at sustainable basis (Tolga and Lokman, 2003). By designing and operating a judicious irrigation schemes, the effect of water supply on crop yield and its proper timing of application can be determined. Various morpho-physiological methods are used to screened better plant genotypes both in stress and in normal conditions. However the traits response varies among different plant genotypes (Arif *et al.,* 2015; Jan *et al.,* 2017; Jan *et al.,* 2016; Khan *et al.,* 2016; Qadir *et al.,* 2017; Saleem *et al.,* 2017). Better developed root system of plants is one of the most important adaptation factors that has good ability to discover greater soil volume to make certain the adequate water and nutrient uptake (Horst *et al.,* 2001). Better root system can be achieved either by genetic improvement of the plants or by soil environmental manipulation. Improved plating methods like ridges and raised beds are used to manipulate soil environmental conditions. Planting methods play an important role to increase seed yield of sunflower due to well-developed root system. Khan *et al.* (2012) and Bakht *et al.* (2011) reported that loose fertile layer of soil enhanced rooting system and accordingly better nutrient and water uptake.

A variety of planting methods are in practice for sunflower cultivation. It is of paramount importance to dig out an appropriate planting method for sunflower cultivation for resource conservation and obtaining the highest yield on sustainable basis. The objectives of the present study were to find optimum level of irrigation and suitable planting method and it effect on important physiological and agronomic characters for yield enhancement of spring grown sunflower.

Materials and methods

The study was carried out at experimental area of Oilseed Program NARC, Islamabad during 2012 and 2013 to assess the effect of different irrigation levels and planting methods on the performance of sunflower hybrid. Experiment was laid out in a split plot design in which planting method was kept in main plots and irrigation levels in sub-plots with three replications. Two planting methods: Ridge, Flat with five irrigation levels were used at different growth stages (Table 1). All treatments were kept apart by making 1.5 m wide ridges between plots to check water seepage. A path of 2.5 m width was made between replications and water channels were made in the paths.

Field was irrigated before seed preparation. Field was prepared by ploughing 2-3 times followed by planking at proper soil moisture condition. The crop was sown during second week of February 2012 and 2013. A seed rate of 8 kg ha^{-1} was used. Dibbling was used for planting 3 seeds per hill keeping the distance of 25cm within and 75cm between rows. One plant per hill was maintained at 2-4 leaf stage. Nitrogen and phosphorus was applied @ 150 kg N and 100 kg P_2O_5 ha^{-1}. All phosphorus and half of nitrogen were applied at sowing and remaining half of nitrogen was applied during first irrigation in the plots to be irrigated. Second dose of fertilizer was applied by dibbling at control treatment. Meteorological data recoded during the months of studied are shown in Table 5. All other agronomic practices were kept uniform as per recommendations for all the treatments. Plants were protected from insects, pests and diseases by adopting protection measures. Data were recorded on following characters.

Physiological characters

Leaf area index (LAI)

Harvest index (HI)

Agro-morphological characters

100 achene weight (g)

Number of achenes $head^{-1}$

Achene yield (kg ha^{-1})

Leaf Area Index (LAI)

Leaf area index (LAI) measured with help of an electronic device MK_2 (Area measurement system, Delta T-Devices Ltd, Burwell Cambridge England). The dry weight was expressed in g per dm^2 per day (g m^{-2} d^{-1}) and was calculated using the following formula:

$$LAI = \frac{\text{Leaf area per plant } (dm^2)}{\text{Ground area covered by the plant } (dm^2)}$$

Harvest Index (HI)

The ratio of the seed yield to total biological yield (above ground biomass) was taken as HI. It was displayed in percentage as under:

HI % = Seed yield / Biological Yield

Achene yield (kg ha^{-1})

At maturity, all heads were threshed manually from each sub-plot. Fresh seed yield of sub-plot was recorded and converted into kg ha^{-1}. Samples of seeds from each plot were taken randomly to assess moisture contents. The seed was sun dried and weighed. The achene yield was determined by using following formula:

$$\text{Achene yield} = \frac{\text{Dry weight of sample} \times \text{total weight} \times 1333.33}{\text{Fresh weight of sample}}$$

Where 1333.33 is correction factor.

Statistical Analysis

For statistical analysis the program of Statistix 8.1 was adopted. Analysis of variance was used to measure variation among the treatments while the least significant difference was used to compare treatments.

Results and discussion

Response of physiological characters to planting methods and irrigation levels

Leaf area index at 40 and 65 days

All combinations of interaction except three way interaction (irrigation levels x planting methods x years) showed highly significant effect on leaf area index after 40 days of sowing whereas none of interactive combination had significant effect on LAI after 65 days of sowing (Table 2).

Main effect of years and planting methods showed highly significant effect on LAI after 40 and 65 days of sowing (Table 2). Both LAI (after 40 days & 65 days) was higher during year 2013 indicating the effect of environment on LAI (Table 3). Similar effect was also reported by Dar *et al.* (2009). Who claimed that year (environment) had significant effect on LAI.

In this study, LAI of plants was higher on ridges than at flats (Table 4) at both dates (40 and 65 days after sowing). This suggests that the ridge has comparatively better environmental conditions than the flats for growth of the sunflower. Similar effect of planting pattern on LAI has also been reported in previous studies (Dar *et al.,* 2009, Shahid *et al.,* 2012).

Table 1. Arrangement of treatments and growth stages.

Sowing Methods	Number of Irrigation	Irrigation Scheduling on different stages
Ridge	I_1 = 0	No irrigation
	I_2 = 01	Seedling VE (vegetative emergence)
	I_3 = 02	Seedling + Buttoning stage
	I_4 = 03	Seedling + Buttoning + Anthesis stage
	I_5 = 04	Seedling + Buttoning + Anthesis + Seed development stage
	I_6 = 05	Seedling + Buttoning + Anthesis + Seed development stage + seed setting stage
Flat	I_1= 0	No irrigation
	I_2 = 01	Seedling VE (vegetative emergence)
	I_3 = 02	Seedling + Buttoning stage
	I_4 = 03	Seedling + Buttoning + Anthesis stage
	I_5 = 04	Seedling + Buttoning + Anthesis + Seed development stage
	I_6 = 05	Seedling + Buttoning + Anthesis + Seed development stage + seed setting stage

Table 2. Mean square values of different parameters studied.

Source	DF	LAI 40 d	LAI 65 D	HI	100 AW	NO-ACH	ACY (kg)
Irrigation	5	1.5542**	5.8967**	137.572**	17.2333**	284755**	4193518**
planting methods	1	4.2292**	10.2001**	46.722**	16.0556**	141865**	640901**
year	1	0.29517**	3.9574**	18.809**	2.7222**	69192**	64142**
Irrigation × planting method	5	0.12861**	0.293-ns	0.422**	0.8556**	17**	12433**
Irrigation × year	5	0.0152**	0.2114-ns	0.326**	0.4556-ns	1807**	22108**
Planting method × year	1	0.1577**	0.1881-ns	1.076**	6.7222**	854^{ns}	8690-ns
Irrigation × planting method × year	5	0.0009-ns	0.7953-ns	0.154**	0.5222-ns	1294**	1256-ns
Error	48	0.00332	0.5114	0.015	0.2222	232	1579

The irrigation levels also expressed highly significant effect on LAI at both growth stages (Table 2). The lowest LAI after 40 days of sowing was exhibited by plants sown in plot of I_0 (no irrigation) followed by I_1 (one irrigation), whereas there was non-significant difference among plants for LAI in the remaining irrigation levels (Fig 1a). The irrigation levels showed increased LAI than the LAI showed by I_0 and I_1which indicated that the moisture stress at early growth stages had adverse effect on plant growth and consequently on LAI. Effect of irrigation also showed similar response on LAI after 65 days of sowing (Fig. 1b). These findings are in agreement with those of Connor *et al.* (1985), Ozer *et al.* (2004) and Beg *et al.* (2007) who claimed that the LAI was significantly increased due to application of water at critical growth stages.

Harvest index (HI %)

All the interactive effects as well as main effects were highly significant for HI of sunflower hybrid (Table 2). Comparatively higher HI was noted in year 2013 than 2012 (Table 3).

Table 3. Mean values of different parameters as affected by planting method.

Year	LAI 40 d	LAI 65 d	HI	100 ACW	NO ACH-	ACY (kg)
year 2012	1.01 b	2.05 b	20.64 b	5.72 b	752.06 b	2467.8 b
year 2013	1.14 a	2.51 a	21.66 a	6.11 a	814.06 a	2527.5 a

Table 4. Mean square values of different parameter studied.

Planting methods	LAI 40 day	LAI 65 day	HI	NO ACH-	100 ACW	ACY (kg)
Ridge	1.32a	2.66a	21.96a	827.44a	6.38a	2592.0a
Flat	0.83b	1.90b	20.35b	738.67b	5.44 b	2403.3b

This indicated favorable environmental conditions for higher HI in the year 2013. Lamm and Aiken (2005) also viewed that variation in environmental conditions (temperature, solar radiation, rain fall) has also significant effect on biological process of sunflower.

The plants grown on ridges showed significantly higher HI than the plants grown on flats (Table 4). These results are in agreement with those of Rasheed *et al.* (2003) who also reported that the sunflower grown on ridges displayed higher HI than the plants grown on flats.

Table 5. Meteorological data recoded during the months of studied (data was recorded at 08:00 Hrs.14:00 Hrs daily).

2012						2013				
Months	Max Temp (C°)	Min Temp (C°)	Pan Evap.	Rainfall (mm)	Avg. Relative Humidity (%)	Max Temp (C°)	Min Temp (C°)	Pan Evap. (mm)	Rainfall (mm)	Avg. Relative Humidity (%)
January	16.9	1.3	1.3	59.1	68.5	17.3	2.45	38.71	17.25	79.2
February	17.4	3.2	1.8	44.1	70.1	17.4	6.46	38.62	274.4	80.6
March	24.9	8.9	3.3	16.0	58.6	25.3	10.5	84.2	85.86	74
April	29.9	15.0	4.7	40.9	54.7	29.2	14.5	133.5	36.07	63.8
May	36.2	18.3	7.3	9.5	39.0	36.6	18.5	230.4	22.15	46
June	40.9	22.7	10.4	4.5	31.2	37.8	22.9	213.6	102.88	59
July	36.9	24.1	6.7	198.0	59.0	34.3	23.7	148.6	280.71	79

This higher HI might be due to the fact that ridges had favorable environmental conditions for sunflower that resulted in better yield and higher HI (Dar *et al.*, 2009). Similarly, increased number of irrigations at different critical growth stages had also significantly increased the HI of sunflower hybrid. The maximum HI was recorded in plots irrigated at all the five stages (I_5) followed by I_4 whereas the lowest HI was recorded in the plots that were not irrigated (Fig. 2).

These results are in agreement with those of Gholinezhad *et al.* (2009) who claimed that the highest HI was obtained by crop that received optimum level of irrigation. Mirshekari *et al.* (2012) also observed that the effect of drought was more on seed yield rather than biological yield thus decreased HI. As harvest index is ratio of grain yield to biological yield, thus higher the grain yield, the higher will be HI.

Harvest index indicates the relative distribution of photosynthetic production among economical and other sinks of plants. Provision of irrigation during all critical growth stages will result in better physiological activities of plants.

The plants will have higher CGR and higher NAR. Similarly, if there is water stress then at critical growth stages the process of distribution of photosynthetic products among different sink sources will be disturbed (Setter, 1990).

Thus, grain will receive fewer carbohydrates and plants will show less HI (Cox and Julliff, 1988).

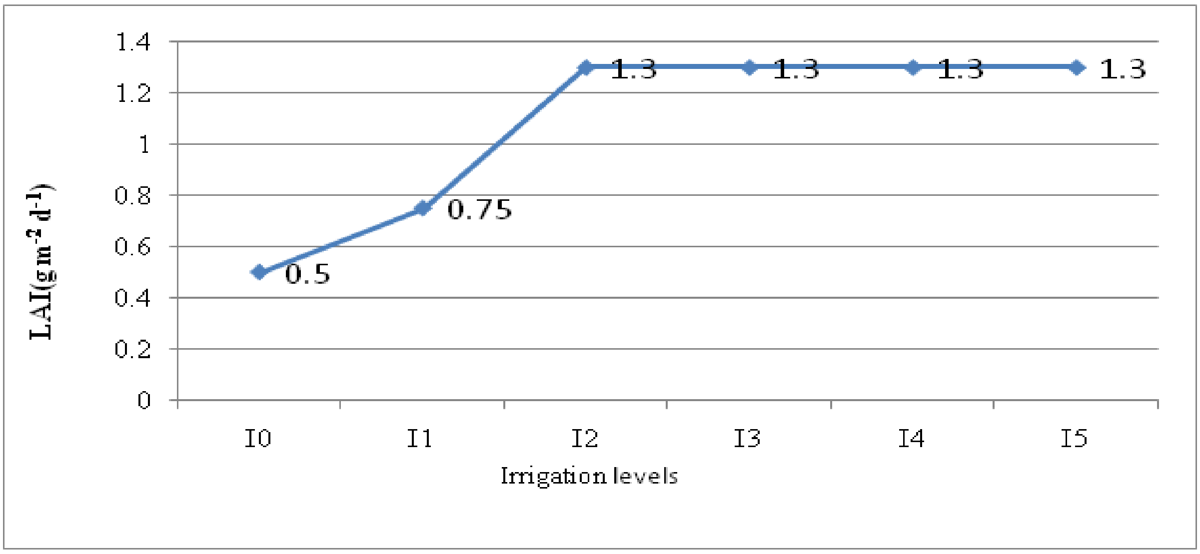

Fig. 1a. Effect of irrigation levels on LAI after 40 days of sowing.

Response of agronomical characters to planting methods and irrigation levels

100 achene weight (g)

Except years x irrigation levels interaction, all the interactive effects significantly affected the 100 achene weight (Table 2). Akhtar and Malik (2005) and Sincik *et al.* (2013) also reported non-significant effect of year x irrigation interaction on 100 achene weight. Shahid *et al.* (2012) also observed significant effect of sowing method x irrigation level interaction on 100 achene weight.

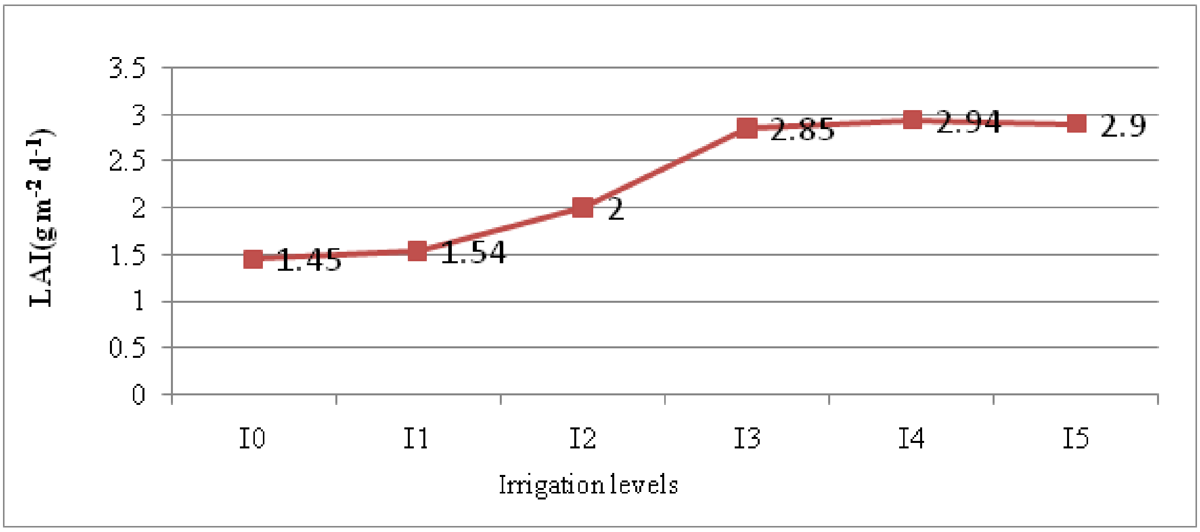

Fig. 1b. Effect of irrigation levels on LAI after 65 days of sowing.

Main factors: years, planting method and irrigation level also had highly significant effect on 100 achene weight (Table 2). 100 achene weights of plants in 2013 was greater than 100 achene weight of plants in year 2012 (Table 3). These results also manifest the effect of environment on 100 achene weight (Table 4).

Plants grown on ridges showed more 100 achene weight than plants grown on flats. The greater 100 achene weight may be attributed to the fact that the plants grown on ridges larger had diameter, hence produced larger achenes with greater 100 achene weight.

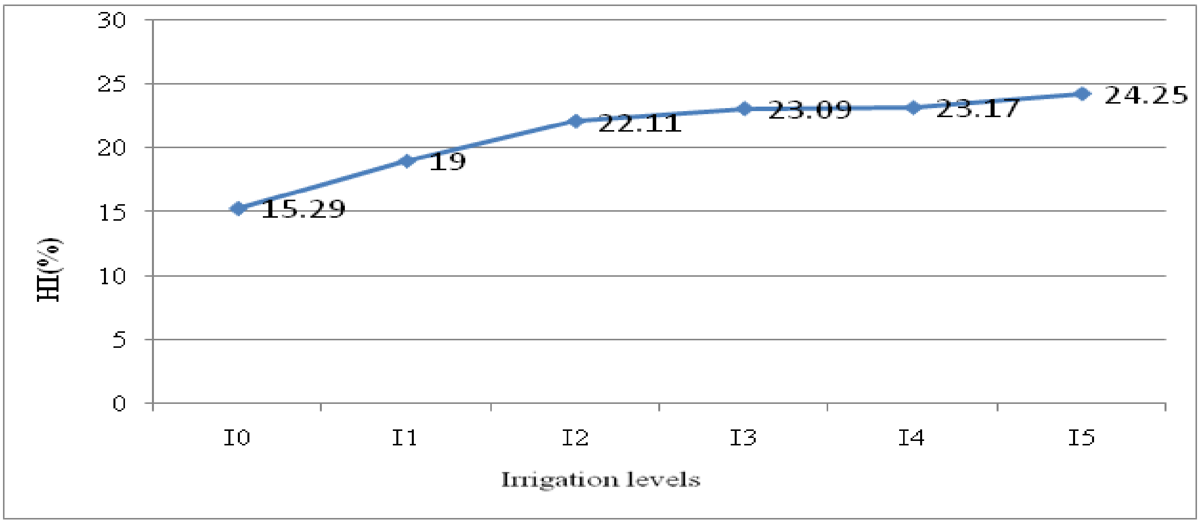

Fig. 2. Mean value of HI of sunflower hybrid as affected by different irrigation levels.

These results are also in agreement with those of Akhtar and Malik (2005) who reported greater 100 achene weight from ridge sown plants than flat sown plants.

Effect of irrigation levels on sunflower hybrids for 100-achene weight was highly significant. Increased number of irrigation at critical developmental stages also highly significantly increased the 100 achene weight (Table 2 and Fig. 3).

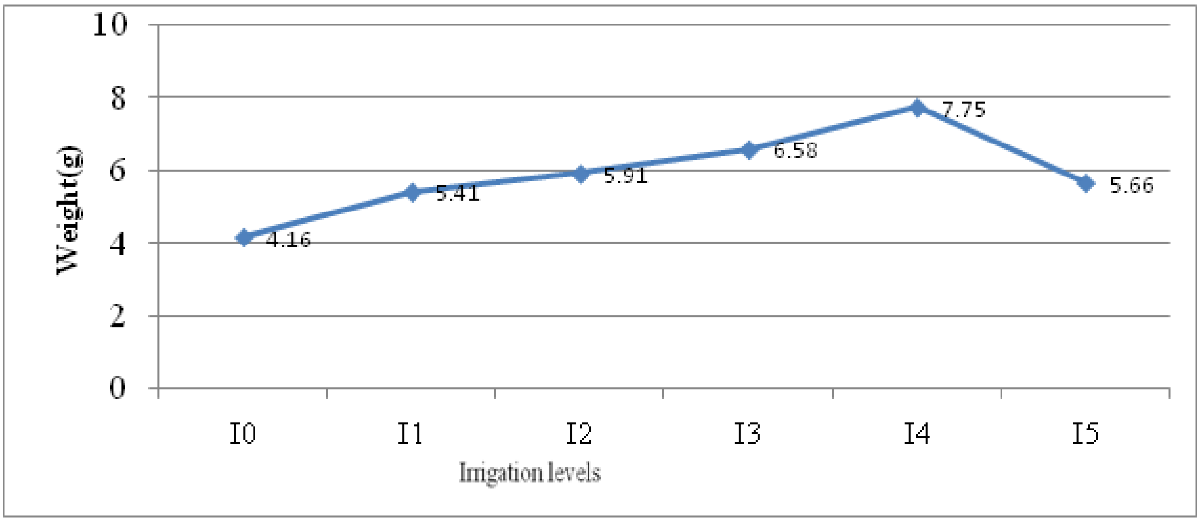

Fig. 3. Mean value of achene weight (g) of sunflower hybrid as affected by different irrigation levels.

The lowest 100 achene weight was recorded in plants grow in control plots (no irrigation) while maximum 100 achene weight was harvested from the plants that were grown in I_4 (four irrigations).

The additional irrigation after the critical stage (I4) reduced 100-achene weight. These findings suggest that the additional irrigation after 4th growth stage has adverse effect on 100-achene weight.

These results are also in agreement with those of Ali *et al.* (2013), Akhtar and Malik (2005), Akhtar *et al.* (1993) and Bakhsh *et al.* (1999) who noticed increase in 100 achene weight with application of water at critical growth stages. These results suggest that the application of water at critical growth stages enhance plant growth, which results in a bigger diameter of head thus may have bigger grains and larger 100 achene weight. Similar results also observed by Akhtar and Malik (2005) who reported that the plants with larger head produced greater 100 achene weight.

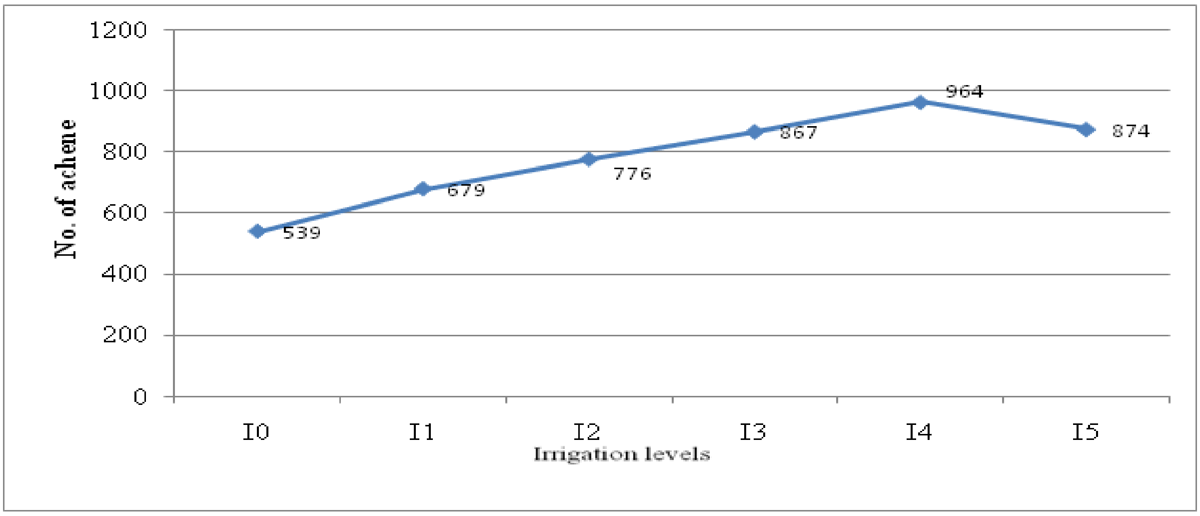

Fig. 4. Effect of irrigation levels on number of achenes/head of sunflower hybrid.

Number of achenes head^{-1}

Effect of irrigation x planting method and years x planting methods interaction was non-significant for number of achene per head whereas interactive effect of irrigation levels x years and irrigations x planting methods x years were highly significant for number of achene per head (Table 2). Shahid *et al.* (2012) also observed non-significant effect of irrigation levels x planting methods for number of achene per head. Akhtar and Malik (2005) also reported non-significant effect of years x sowing methods interaction on number of achene per head. The main factors highly significantly affected the number of achene per head (Table 2). Year 2013 had comparatively better environmental conditions for production of more number of achene per head. This finding indicated that environment had significant effect on number of achene per head of sunflower.

The plants on ridges produced more number of achene per head than those planted on flats (Table 4). These results are in agreement with those of Ahmad *et al.* (2000) and Shahid *et al.* (2012) who reported that sowing methods had significant effect on number of achene per head of sunflower. They also reported greater number of achene per head from the plants sown on ridges than those grown on flats. The greater number of achene per head may be due to bigger heads of sunflower that were harvested from ridge sown plant. A head with larger diameter may produce more number of achenes. Similar results have also been observed by Esechie *et al.* (1996).

The application of irrigation at critical stages of growth also highly significantly increased number of achene per head (Fig 4). The greater number of achene per head was noticed from plots that were irrigated four times (I_4). After 4th irrigation the number achene per head was decreased. The possible explanation in this regard may be that the plants received optimum water had larger head, so that the number of achene in the larger heads were more than that of smaller heads. Similar findings have also been reported by Roshdi *et al.* (2006) who found increased number of achene per head with application of irrigations at critical growth stages. Other explanation of lower number of achene per head in control plots (no irrigation) may be attributed to lower number of fertile florets in flowers. Water deficiency at reproductive face may disturb the proper distribution of photosynthetic products (carbohydrates) to the different sinks existing in plants. This may lead to dry pollen and stigma of florets in head. This explanation also supported by Jabari *et al.* (2007) and Taherabadi *et al.* (2013).

Achene yield (kg ha⁻¹)

Effect of planting methods x irrigation levels and years x irrigation levels interaction was highly significant on achene yield ha^{-1} whereas years x planting methods interaction was only significant. Three-way interaction effect of years x planting methods x irrigation levels was non-significant on achene yield (Table 2). These findings are in line with those of Shahid *et al.* (2012), Taherabadi *et al.* (2013) and Akhtar and Malik (2005). Shahid *et al.* (2012) who reported a significant effect of irrigations x planting methods interaction on achene yield. Similarly, Akhtar and Malik (2005) and Taherabadi (2013) also noted a significant effect of years x irrigation levels on achene yield.

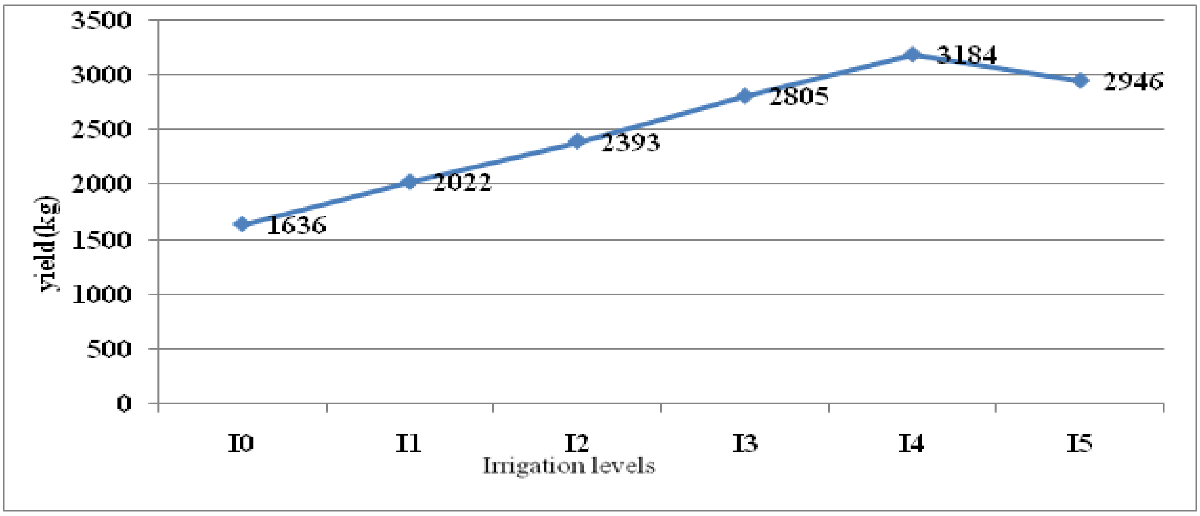

Fig. 5. Effect of irrigation levels on achenes yield (kg/ha) of sunflower hybrid.

The main effect of year, irrigation levels and planting method was also highly significant on achene yield ha^{-1} (Table 2). Achene yield ha^{-1} was higher in 2013 as compared to year 2012 (Table 3). Bakht *et al.* (2010) also reported significant effect of year on achene yield. The environmental condition in year 2013 may be favorable for better plant growth and consequently good yield.

As for as planting methods are concerned a greater achene yield ha^{-1} was harvested from the plants grown on ridges (Table 4). Esechie *et al.* (1996), Ahmad *et al.* (2000) and Shahid *et al.* (2012) also reported similar findings. They reported that the achene yield ha^{-1} was greater on ridges than flats. This could be explained by the fact that the ridges provide a better porous and soften soil. This soil would have comparatively a better aeration and absorption of sufficient nutrient and water, which would help in a better plant growth, higher LAI, better CGR, efficient net assimilation, and better distribution of carbohydrates. This might have ultimately increased yield ha^{-1}. Achene yield ha^{-1} was significantly affected by irrigation levels.

The irrigation in critical growth stage has profound effect on sunflower hybrid yield (Fig. 5). The achene yield was increased from 1635 kg ha^{-1} at control to 3184 kg ha^{-1} at I_4. The achene yield at I_5 (2946 kg ha^{-1}) was lower than the achene yield at I_4 (Fig. 5).

These findings indicated that irrigation more than optimum level had adverse effect on sunflower achene yield. Similar results were reported by Akhtar and Malik (2005), Bakht *et al.* (2010), Kazemeini *et al.* (2009) and Shahid *et al.* (2012). They reported that the irrigation at critical growth stages increased plant growth, NAR, LAI and head diameter.

The larger head may have more number of achene per head and more 100 achene weights resulted in greater achene yield ha^{-1} with application of optimum number of irrigation at critical stages of growth.

Conclusion

From the above discussion it can be deduced that ridges provide better environmental conditions for sunflower hybrid growth and consequently fetchesa good yield as compared to flats. Similarly, the application of water at critical growth stages enhances the achene yield of sunflower hybrid. Increased number of irrigations beyond the optimum level shows adverse effect on sunflower achene yield.

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