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STUDY THE EFFECTS OF PLANTING DATE AND LOW IRRIGATION STRESS ON QUANTITATIVE TRAITS OF SPRING SUNFLOWER (*HELIANTHUS ANNUUS* L.)

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ABSTRACT

Water stress is a major limiting factor for sunflower production in the arid and semi arid regions in the world. In order to study the effects of sowing date and limited irrigation stress on plant height, head diameter, seed number per head, thousand seed weight, seed yield, biologic yield and harvest index of spring sunflower cultivar (Mehr), an experiment was conducted using a split plot arrangement based on randomised complete block design with three replications in Karaj, Iran, during 2008 and 2009.The present study showed that optimal environmental conditions around reproductive stages, provided by early sowing not only enhanced plant growth but also produced higher yield compared with those of late sowing dates. The April 20th and May 9th sowing produced larger seed yield, biologic yield and harvest index with no water stress treatment compared to late May sowing date with limited irrigation stress at stem elongation, flowering and grain filling stages respectively. The results showed that the limited irrigation stress resulted in reduction of seed yield due to limited vegetative and reproductive development. It is of prior concern to consider optimum sowing date so that high temperature of late sowing would not coincide with the reproductive stages of sunflower.

Key words: sunflower, sowing date, limited irrigation stress, yield.

INTRODUCTION

Sunflower originating in North America is a short season plant that is potentially useful for seeds, oil and forage crops and can be fitted well in the present cropping system of Iran without implying any major change in agriculture setup. Sunflower oil has an ideal combination of saturated and poly-unsaturated fatty acids, which are important for the reduction of high serum cholesterol levels, and its oil cake contains higher amount of protein (40-44%) and balanced amino acids (Balasubramaniyan and Palaniappan, 2001). Environmental factors greatly affect sunflower plant growth and yield. The period of seed development for spring oilseed sunflower in central Iran regions can coincide with high daily temperatures. Therefore, sowing date is an important determinant of yield and yield components in sunflower. Sowing date depends on the onset of significant rainfall, temperature and humidity of a region. In delayed sowing date, high temperature inhibited pollen germination and pollen tube growth, which resulted in lower seed yield (Kakani et al., 2002). Decreasing crop yield in delayed sowing date has been reported by many workers (Kohn and Storrier, 1970). Among various factors responsible for yield level, water requirement of crop is the most important, because water has direct relationship with the growth, development and yield of crop. Sunflower is a deep rooted crop intermediate in water use and can extract soil water from below root zones of normal small grain crops (Unger, 1984). The drought tolerance of sunflower, combined with its tolerance to low and high temperature and day length insensitivity, makes it suitable for production in central part of Iran. Osman and Talha (1975) reported that seed yield in sunflower increased as the amount of water and irrigation number increased in a study in

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Egypt. In Iran, sunflower has the potential to be grown in both irrigated and rain fed areas of the country. The sunflower uses only 20-25% of its total water needed during the first 30days and the peak demand is during its reproduction stage (Ghani et al., 2000) The most critical period of sunflower yield determinants are anthesis and grain filling (Chimenti and Hall, 1992). Judicious and timely application of irrigation at critical growth stages of sunflower increases yield considerably. The aim of this study was to evaluate the influence of irrigation and three sowing dates on quantitative characteristics of sunflower seed in a semi-arid environment.

MATERIAL AND METHODS

The research was carried out in Karaj city - Iran, located at Lat. 35º, 59', Long. 50º, 75', with 1312 m. elevation, as split plot arrangement on randomised complete block design, with three replicates, during two growing seasons (2008 and 2009). Two agronomic factors were studied, i.e. the sowing dates (20 April, 9 May and 30 May) as main plots and four irrigation levels including: normal irrigation (I0) during the growing period (I0: irrigation after 100 mm evaporation from class “A” pan) as control, limited irrigation after 210 mm evaporation from stem elongation (I1), flowering (I2) and grain filling (I3) up to the end of the growing period as subplots. Soil moisture was determined gravimetrically using augers. All treatments were irrigated with equal amount for each time, which was measured with the help of a 15 cm throat Parshall flume fixed in the irrigation channel. The data for day length (h), temperature (ºC), relative humidity (%) and precipitation (mm) were obtained from Karaj meteorological substation (Figure 1).

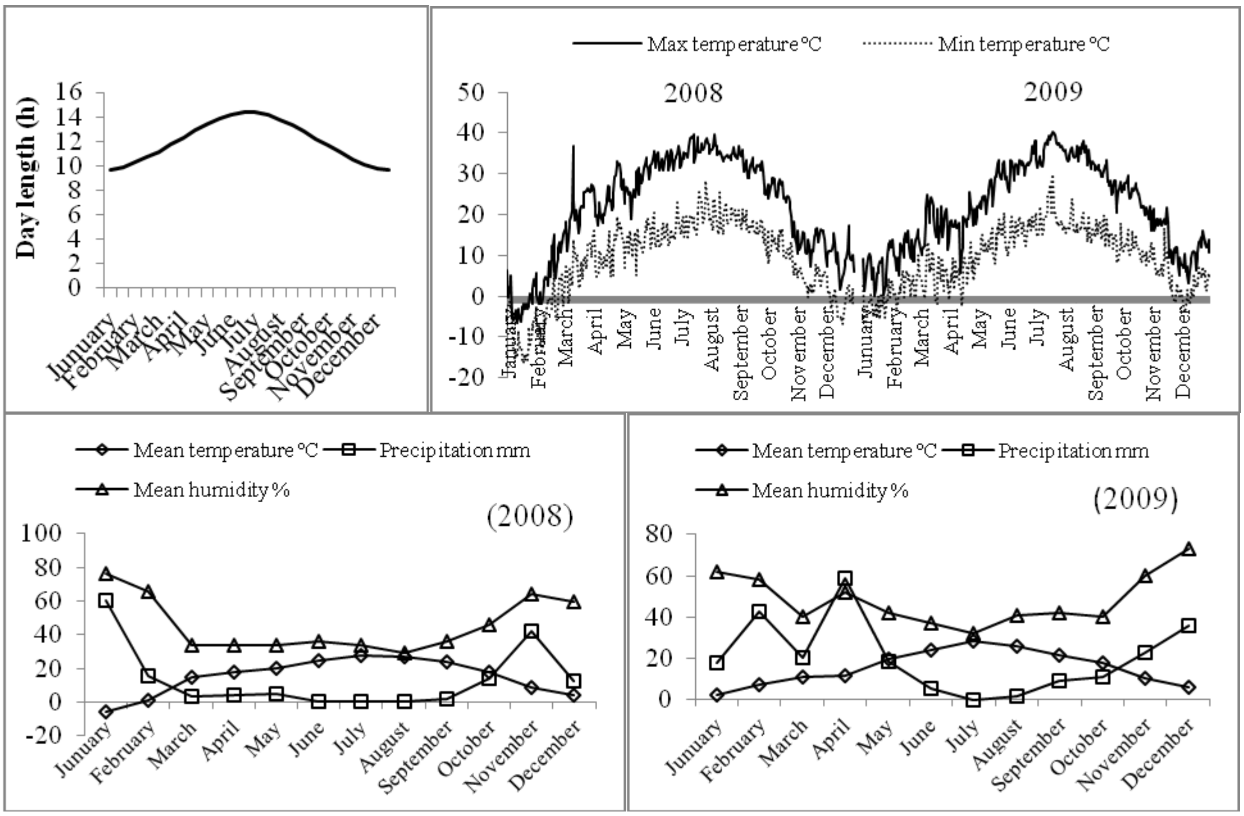

Figure 1. Air temperature, rainfall and relative humidity during sunflower growing season of 2008 and 2009 in Karaj

Karaj is located in the central regions of Iran and has a mean annual temperature of 14.1ºC and average rainfall of 251 mm. Soil samples were taken (0-30 cm) before sowing and soil analysis results showed that it was silty loam in texture with pH of 7.4, contained 0.53% organic matter; total nitrogen of 0.11 ppm, available phosphorus of 6.3 ppm, exchangeable potassium of 275 ppm with no salinity problems (E.C. = 2.36 $ds.m^{-1}$). On the basis of soil analysis, 200 kg ha^{-1} urea and 100 kg ha^{-1} ammonium phosphate fertilizer were applied to the site and harrowed before seedbed preparation. Nitrogen was applied in two applications as split; half before sowing and the remaining half was applied top dressed at flower-bud-visibility stage. The area of each plot was 10 m^2 consisting of four rows, 5 m long and 50 cm apart. Seeds were sown 20 cm apart at about 4-5 cm depth. A 1.0-m alley was left around each plot. Plots were over seeded and subsequently thinned to final plant density of about 10 plants m^{-2} at seedling stage. Weeds were controlled by both Trifluralin (2.5 L ha^{-1}) as pre-plant and by hand as needed. Seed yields were measured at maturity by harvesting the central two rows of each plot for seed yield determination. Sub-samples were dried at 105ºC for moisture determination. Seed yield was adjusted to 9% moisture content, and all other measurements were reported on a dry weight basis. Ten plants were randomly collected from the central two rows with edging shears (0.1 m cutting width) and the following characteristics were recorded for each plot; Plant height (cm), head diameter (cm), seed number per head, thousand seed weight (g), seed yield (kg ha^{-1}), biological yield (kg ha^{-1}) and harvest index (%). Seeds were threshed by hand and weight of seed (g m^{-2}) was recorded. Plots were harvested at maturity and seeds were dried to uniform moisture content for 24-48 h at 75-80ºC. Analysis of variances of data for each attribute and combined analysis of the split plot designs in two years were computed using the SAS computer program (SAS Institute 2001). F test in combined analysis of the experiments was carried out using expected values of the mean squares which year and replication were assigned as random variables and sowing date and limited irrigation were considered as fixed variables. The Duncan's multiple range tests at 5% level of probability was used to test significant main effects. The MSTAT-C software package was used to test significant interaction effects between treatments (MSTAT-C, 1993). Accumulated growing degree days (GDD) were calculated by summing the daily degree day values (ºC) obtained by adding the maximum and minimum temperatures for the day, dividing by two and subtracting the base temperature, which for sunflower is 6ºC (Table 3). The coefficient of linear regression equation between the traits mean as the dependent variables and growth degree day of all the growth season of sunflower as the independent variable are calculated by SAS.

RESULTS

Effect of year, sowing date and irrigation levels

The effect of years on all the characters of sunflower was significant (Table 1). In 2009 sunflower produced significantly higher plant height, head diameter, seed number per head, thousand seed weight, seed yield, biological yield and harvest index as compared to 2008 (Table 2).

Sowing date showed a significant effect for all sunflower characters (Table 1). The highest value for plant height, head diameter, thousand seed weight and harvest index was recorded in the first and second sowing date, while the lowest value were recorded for the last sowing date (Table 2).

Maximum seed number per head, seed yield and biological yield were obtained on April 20th sowing. The drought stress at different growth stages had significant effect on all studied traits in the analysis of combined data (Table 1).

The highest value for plant height, head diameter, seed number per head, thousand seed weight, seed yield, biological yield and harvest index were recorded from no stress treatment, whereas lower values were recorded from limited irrigation stress at stem elongation, flowering and grain filling stages respectively (Table 2).

Interaction effect of year and sowing dates

The combined ANOVA revealed that values of plant height, thousand seed weight, biological yield and harvest index were significantly influenced by year*irrigation interaction (Table 1). Interaction of sowing dates and years produced statistically non-significant difference for head diameter, seed number per head, and seed yield. Data presented in Table 4 revealed that sowing dates showed different influences on plant height, thousand seed weight, biological yield and harvest index in 2008 and 2009 (Figure 2).

Table 1. F values of combined analysis of variance for the effects of year, sowing dates and limited irrigation water stress on quantitative characters of spring sunflower (r = 3)

Sources of variation	D.F.	Plant height	Head diameter	Seed number per head	Thousand seed weight	Seed yield	Biological yield	Harvest index
Y	1	779.5**	13.12**	22543**	120.5**	1142568**	2062819**	94.53**
T	2	12923**	40.68**	202841**	572.2*	9232894**	19305034*	715.9*
Y×T	2	61.03**	0.32^{ns}	201.9^{ns}	17.16**	2850^{ns}	322452.4**	23.45**
R×T(Y)	12	6.06	0.168	305.5	1.18	2245	5569	0.57
I	3	1357**	48.96*	168380**	893.8**	99981089**	50547171**	217.9**
T×I	6	13.03*	0.168^{ns}	955.1^{ns}	3.06^{ns}	65184*	706783.4**	15.94**
Y×I	3	17.05^{ns}	2.03**	3210.6**	14.51**	118074**	1603047**	0.532^{ns}
Y×T×I	6	2.32^{ns}	0.089^{ns}	444.3^{ns}	1.41^{ns}	12165**	65803**	0.544^{ns}
Pooled error	36	6.4	0.347	591.6	2.08	3525	14057.7	0.29

$p \leq 0.05$; $^{**}p \leq 0.01$; ^{ns}: non-significant; R: Block; D..F.: degrees of freedom; Y: Year of sowing; T: sowing date; I: Irrigation treatments

Table 2. Duncan's mean comparison test for the effects of year, sowing dates and limited irrigation water stress (±SE) on quantitative characters of sunflower

Factors	Plant height (cm)	Head diameter	Seed number per head	Thousand seed weight (g)	Seed yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
Year (Y)							
Y_1	165.5±3.38^b	10.79±0.34^b	488±20.3^b	40.44±1.37^b	2096±146^b	6892±301^b	29.28±1.06^b
Y_2	172.1±3.57^a	11.64±0.29^a	523±18.7^a	43.02±1.14^a	2348±133^a	7230±263^a	31.57±0.82^a
Sowing dates (T)							
T_1	185.2±1.51^a	12.17±0.32^a	583±17.34^a	46.42±1.22^a	2785±145^a	7986±328^a	34.47±0.45^a
T_2	179±1.95^a	11.75±0.35^a	529±19.47^b	42.11±1.32^a	2323±149^b	7001±348^b	32.6±0.53^a
T_3	142.2±1.92^b	9.73±0.33^b	404±18.82^c	36.67±1.48^b	1557±121^c	6196±263^c	24.22±1.08^b
Irrigation levels (I)							
I_0	177.1±4.45^a	12.75±0.27^a	602±18.7^a	50.49±0.94^a	3087±143^a	8980±236^a	34.09±0.82^a
I_1	157.6±5.11^c	9.09±0.27^c	382±21.6^c	33.76±1.23^d	1355±115^d	5065±175^c	26.04±1.53^d
I_2	166.5±4.74^b	10.77±0.35^b	478±18.5^b	39.29±1.11^c	1937±120^c	6484±174^b	29.5±1.25^c
I_3	174±4.52^a	12.25±0.33^{ab}	559±19.5^a	43.39±1.07^b	2507±139^b	7715±226^{ab}	32.1±0.95^b

Mean of each group in columns of each treatment with similar letters are not significantly different (Duncan 5%). Y_1: 2008; Y_2: 2009; T_1: 20 April; T_2: 9 May; T_3: 30 May; I_0: Normal irrigation at all growth stages; I_1: Limited irrigation stress at stem elongation stage; I_2: Limited irrigation stress at flowering stage; I_3: Limited irrigation stress at grain filling stage.

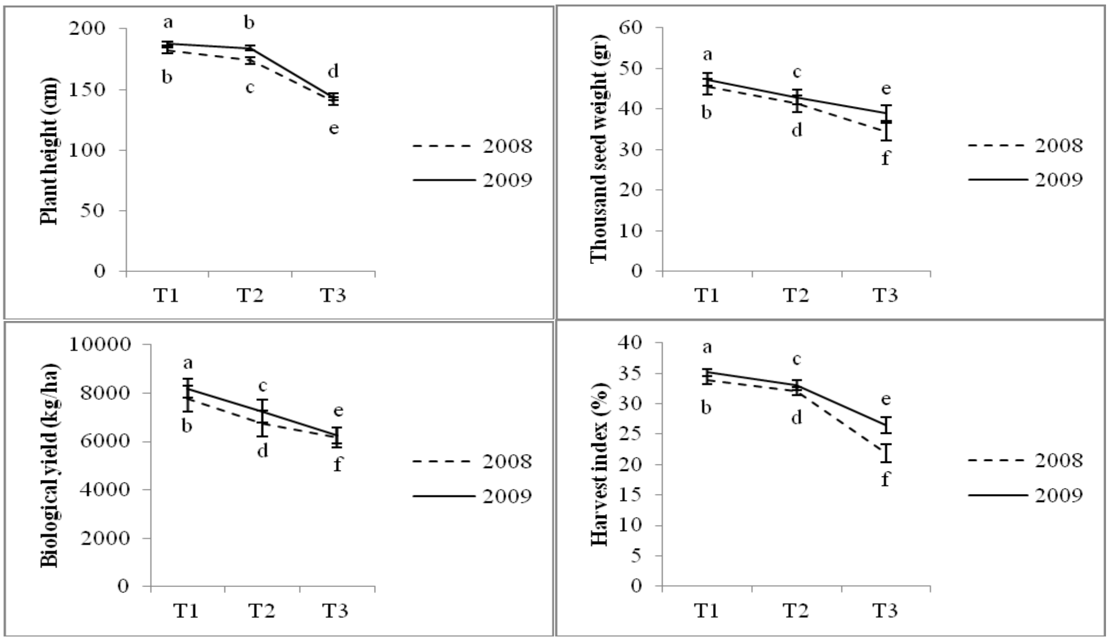

Figure 2. Duncan's mean comparison test for the interaction effects of year and sowing date (±SE) on plant height, thousand seed weight, biological yield and harvest index of sunflower
(Mean of each treatment with same letters are not significantly different (Duncan p≤ 5%). T_1: 20 April; T_2: 9 May; T_3: 30 May)

Interaction effect of sowing dates and irrigation levels

Interaction effect of sowing dates and irrigation for the values of head diameter, seed number per head and thousand seed weight of sunflower were not significant, whereas for plant height, seed yield, biological yield and harvest index were the effects significant (Table 2). This parameters decreased by increasing the drought stress and delaying sowing date. The April 20th and May 9th sowing produced the best seed yield, biological yield and harvest index with no stress treatment, compared to May 30th sowing with limited irrigation stress at stem elongation, flowering and grain filling stages respectively.

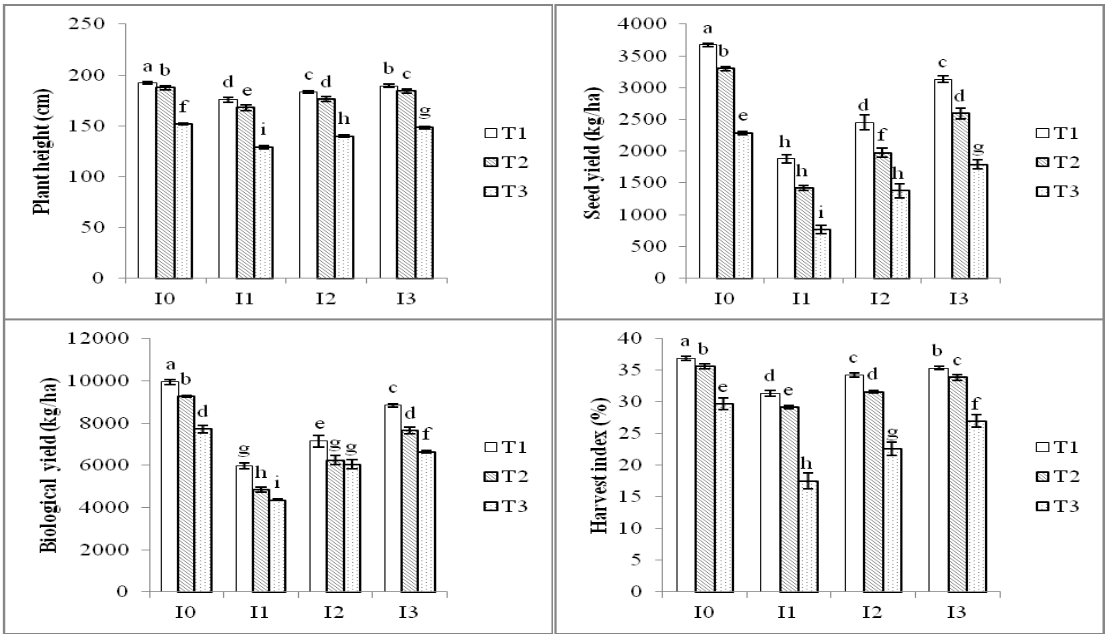

Figure 3. Duncan's mean comparison test for the interaction effects of sowing dates and limited irrigation stress (±SE) on plant height, seed yield, biological yield and harvest index of sunflower
(Mean of each treatment with same letters are not significantly different (Duncan 5%). T_1: 20 April; T_2: 9 May; T_3: 30 May; I_0: normal irrigation at all growth stages; I_1: limited irrigation stress at stem elongation; I_2: limited irrigation stress at flowering stage; I_3: limited irrigation stress at grain filling stage)

The lowest seed yield, biological yield and harvest index were recorded from limited irrigation stress at stem elongation on May 30th sowing (Figure 3).

Interaction effect of year and irrigation levels

Irrigation*year interaction was significant ($p \leq 0.01$) for all sunflower measured traits except plant height and harvest index (Table 1). Irrigation significantly increased all the characters of sunflower in both years.

The mean comparison of interaction between year and irrigation levels revealed that in 2009, limited irrigation stress treatments led to different influences on head diameter, seed number per head, thousand seed weight, seed yield and biological yield compared to 2008 (Figure 4).

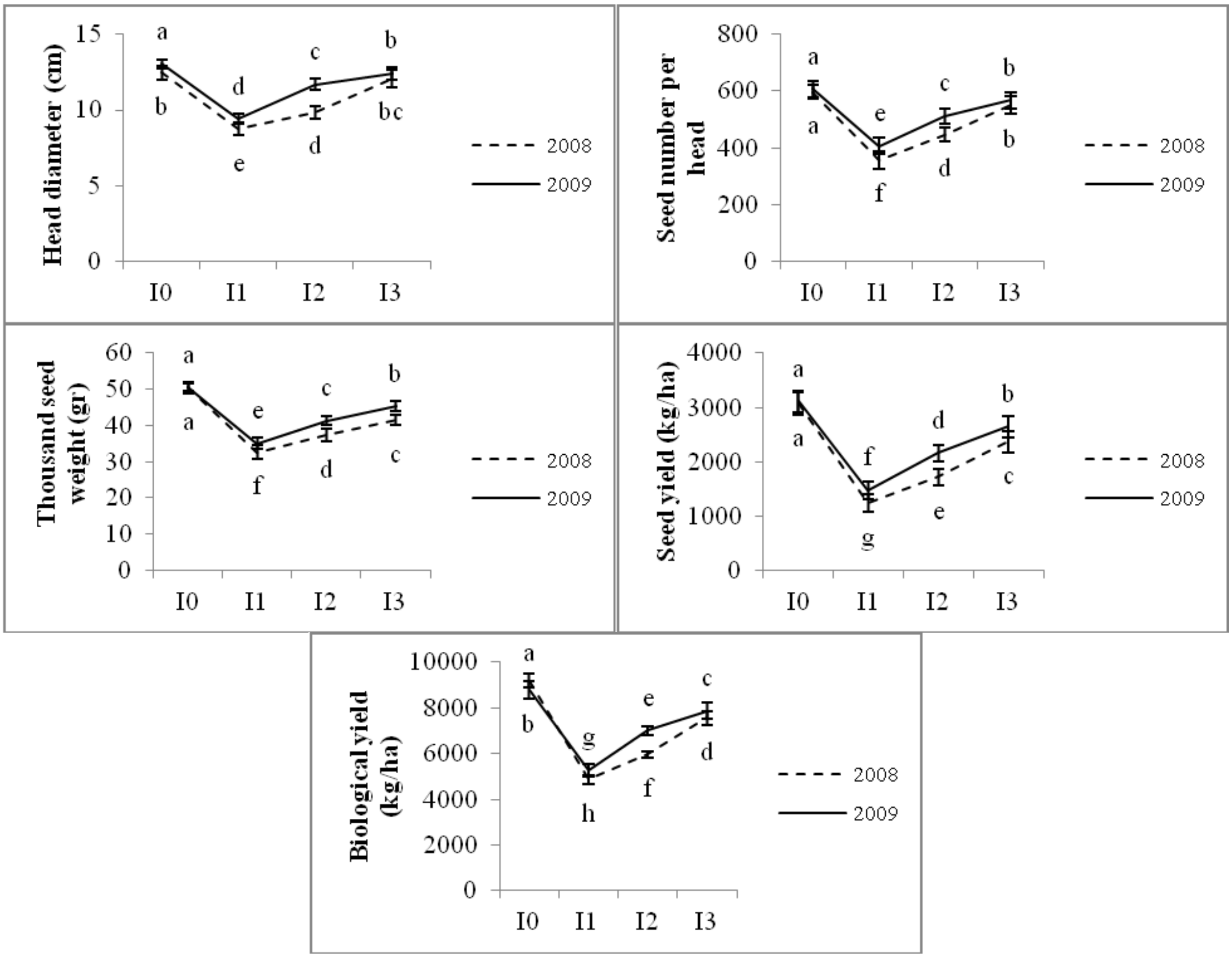

Figure 4. Duncan's mean comparison test for the interaction effects of year and limited irrigation stress (±SE) on head diameter, seed number per head, thousand seed weight, seed yield and biological yield of sunflower
(Mean of each treatment with same letters are not significantly different (Duncan 5%).
I_0: normal irrigation at all growth stages; I_1: limited irrigation stress at stem elongation stage; I_2: limited irrigation stress at flowering stage; I_3: limited irrigation stress at grain filling stage)

Regression model

The relationship between growth degree day (x) and sunflower factors (Y) was significant at 0.001 level in all cases, in pooled values for 2008 and 2009 (Table 4, Figure 5). The highest value of GDD recorded in the first sowing date compared to second and third sowing date of sunflower in both years. The results revealed that duration (days) for the maturity of sunflower by normal irrigation was highest and reduced with limited irrigation stress at elongation stage and flowering stages (Table 3).

Table 3. Sunflower growing period (Duration) under different treatments of sowing dates and limited irrigation stress in 2008 and 2009

Year		T_1				T_2				T_3			
2008		I_0	I_1	I_2	I_3	I_0	I_1	I_2	I_3	I_0	I_1	I_2	I_3
	Duration (Days)	101	57	63	86	92	48	57	69	60	36	42	49
	GDD (ºC days)	1770	879	983	1410	1614	763	928	1152	1064	615	729	858
2009	Duration (Days)	108	68	84	98	95	52	60	80	62	40	49	53
	GDD(ºC days)	1755	972	1276	1571	1663	823	973	1384	1136	691	862	937

Table 4. Regression relationship between growth degree days and some quantitative traits of sunflower during growing season (pooled values for 2008 and 2009)

	Plant height	Head diameter	Seed number per diameter	Thousand seed weight	Biologic yield
a	117**	5.8**	157**	18.9**	1884**
b	0.05**	0.005**	0.31**	0.02**	4.6**
R^2	0.60	0.83	0.88	0.90	0.92

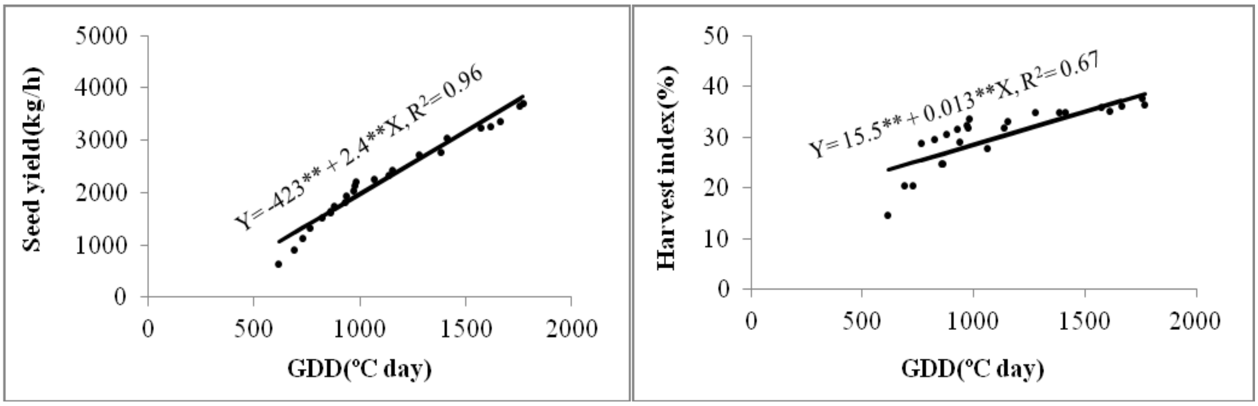

Figure 5. Regression relationship between growth degree days with seed yield and harvest index of sunflower during growing season (pooled values for 2008 and 2009)

DISCUSSION

Plant height

The higher plant height in second year can probably be explained by the better climate factors during this season (Table 2, Figure 1). Early sowing had a dominant positive effect on plant height, as sowing date and limited irrigation interaction indicated that the response to water stress depended on sowing date (Table 2, Figure 3). During the vegetative stage, high day temperatures can cause damage to components of leaf photosynthesis, reducing carbon dioxide assimilation rates and plant height compared to environments having closer to optimal temperatures.

In other reports, water and temperature stress have been shown to reduce plant height by increasing respiratory losses (Marshall, 1989). In both years, irrigation treatments showed a highly significant effect on plant height (Table 2). This result is consistent with finding of Teama and Mohammed (1994), who reported reduction in plant height by water stress from seedling stage to before flowering, whereas stress after flowering had no effect on plant height.

Head diameter

With a delay in sowing date, head diameter was obviously reduced due to shorter growth season (Tables 2, 3). The lower value of head diameter at T_2 and especially T_3 sowing dates could be due to higher temperatures, which occurred during flowering stage, resulting in increased flower and seed abortion and decline in sunflower head diameter (Teama and Mohamoud, 1994). In our research, drought stress at different growth stages had significant effect on head diameter (Table 2, Figure 4). This was in accordance with the finding of Nezami et al. (2008). Human et al. (1990) found that the head size was significantly reduced as water stress increased. Moreover, the reduction in head diameter may explain the reduction in number of seeds per head.

Seed number per head

The lower seed number per head associated with late sowing (Table 2) have been previously reported by Flagella et al. (2002), who revealed decreasing seed number per head in sunflower due to warmer temperatures during the growth period at late sowing date, which promote excessive early system growth and reduce time to flowering. Warmer temperatures and declined incident radiation photosynthesis after anthesis affects the dynamics of grain filling. Hocking and Stapper (2001) reported that the late sowing resulted in a shortening of the pre-flowering period and decline of duration between flowering and maturity in sunflower. Number of seed per head diminished with increasing limited irrigation stress.

The maximum seed number per head was recorded under control (Normal irrigation) and minimum at stem elongation stress (Table 2, Figure 4). Similar result was reported by (Lahlou et al., 2003).

On the other hand, the same researcher reported that in case of limited irrigation, water stress should be scheduled according to critical growth stages such as flowering, heading and milking stages (Tolga and Lokman, 2003).

Thousand seed weight

Based on comparing the sowing date treatments in both years, the maximum seed weight per plant was obtained in April 20th sowing (Table 2, Figure 2). This was apparently associated with the cooler weather conditions occurring during the early growth stage and flowering, particularly at the first sowing date. This is considered a factor of practical importance in terms of seed growth and development of sunflower (Figure 1). Low thousand seed weight in sunflower under delayed sowing was positively correlated with the results of other workers (Taylor et al., 1991). Limited irrigation stress led of decline 1000-seed weight (Table 2, Figure 4). The reduction of 1000-seed weight may due to lower photosynthetic production, because of excessive loss of leaves at the flowering stage (Rauf, 2008). High 1000-seed weight, resulting from more irrigation, was probably due to the availability of adequate soil moisture and translocation of assimilates from source to sink during seed formation and seed ripening stages. Razi and Asad (1998) indicated that irrigation resulted in an increase in both head size and 1000-seed weight.

Seed yield

Sunflower seed yield depends on the number of seed per head, head diameter and seed weight. The best yield was obtained from the sowing on April 20th followed by May 9th and the poorest yield was obtained when sowing was delayed to May 30th (Table 2). The seed yield of sunflower was closely related to temperature during flowering and early seed development, and increased by minimizing the crop exposure to high temperature and water stress. The late sowing usually causes a decline in growth, leaf area, and a faster maturation (Mckay and Schneiter, 1990), thus decreasing seed yield The highest seed yield was obtained from I_0 irrigation treatment due to an increase of both 1000 seed weight and seed number per head (Table 2, Figure 4). Yield and yield components were positively affected by irrigation (Asbagh et al., 2009). Lower seed yield under water stress conditions was due to decreased pollen viability that decreased seed number (Khalilvand and Yarnia, 2007). Early sowing had a dominant positive effect on yield and yield components, as the irrigation by sowing date interaction indicated that the response to irrigation depended on the sowing date (Figure3). In this study, sowing date was a very important management tool in minimizing the negative impact of high temperature and moisture stress during the critical flowering and seed filling periods.

Biological yield

The climate conditions of sunflower growth season in 2009 were more favorable than in 2008, as the prolonged vegetative growth period (Figure 1, Table 3), led to higher biological yield in 2009 (Table 2, Figures 2, 4). Delaying sowing date reduced biological yield (Table 2, Figures 2, 3). This result could be due to higher temperatures, which occurred during growth and reproductive phases in sunflower. Naab et al. (2005) reported that planting dates and plant life duration affected biomass and yield in peanut. Planting date should be selected such a way that reproductive development does not coincide with stress conditions.

Although sunflower is known as a drought tolerant crop and is grown under dry land conditions, substantial yield increases were achieved by irrigation. Biological yield significantly declined with limited irrigation stress at different growth phases of sunflower (Table 2, Figures 3, 4).

These results support findings by Jasso et al. (2002) in similar experiments. The reason for increase in biological yield under optimum irrigation was the extension of leaf area and its higher duration that allowed plants to take advantage of received light and therefore produce higher biological yield. Karaata (1991) found that full irrigations applied at heading, flowering and milk ripening stages and limited irrigation at milk ripening stage gave the highest biological yield, whereas non-irrigated treatments and irrigation only at milk ripening stage produced the lowest biological yield.

Harvest index

Sowing date is one of the many factors that can compensate high temperature and drought stress effects on plants and decreases environment effects Late-sowing date caused a significant decrease in harvest index (Table 2, Figure 2). Rad et al. (2005) reported that there were positive correlations between plant height and seed weight, seed yield, biological yield and harvest index. Degenhardt and Kondra (1981) also suggested that delayed seeding resulted in a significant decrease in seed yield and harvest index. In this study, drought stress decreased seed yield with a higher degree than biological yield and this resulted in a lower harvest index (Table 2). Chimenti et al. (2002) found a significant decrease of seed yield, seed size and harvest index, caused by drought stress in sunflower. Irrigation by sowing date interaction indicated that the response to irrigation depended on the sowing date (Figure 3) Ardakani et al. (2005) reported that water stress treatments, at any stage reduced harvest index.

Regression model

In both years, for all irrigation and sowing date treatments, there was a highly significant linear relationship between growing degree days (GDD) for the total growing season and all of sunflower studied traits (Table 4, Figure 5). Different sowing dates and limited irrigation stress levels caused flowering and seed development to occur during periods of different temperatures and day length (Figure 1, Table 3), as could be seen in the findings of Barros et al. (2004). They indicated that with delayed sowing date, development is hastened because the crops encounter higher temperatures during the vegetative growth, shortening of the growing cycle, decline the amount of radiation intercepted during the growing season and thus a reduction of quantitative traits of sunflower.

Balakrishnan and Natarajaratanam (1981) stated that early sown crop produced more dry matter and also resulted in higher seed yield than the late sown crop, as the early sown crop could benefited from more growing degree days.

CONCLUSIONS

Under arid and semiarid Mediterranean conditions, like Iran, the occurrence of terminal temperature and drought stress can reduce seed formation, yield and yield components. Under these conditions, optimal sowing dates and supplemental irrigation at reproductive stages, i.e. flowering and seed filling periods could be an important management option to reduce the negative effects of temperature and drought stress, making these critical sunflower stages coincide with more favourable environmental conditions.

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