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Full Length Research Paper

Effect of water stress on yield and yield components of sunflower hybrids

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A field experiment during year 2009 was conducted in the research station of the University of Tehran, College of Abouraihan in Pakdasht region, Iran. The study was aimed to investigate the effect of water stress on seed yield, yield component and some quantitative traits of four sunflower hybrids namely Azargol, Alstar, Hysun 33 and Hysun 25 under three different irrigation regimes; irrigation after 50 (normal irrigation), 100 (mild stress) and 150 (intense stress) mm cumulative evaporation from evaporation Pan class A. The experiment was laid out as a split plot design based on randomized complete block design (RCBD). The results showed that, water stress significantly (P > 0.05) decreased seed yield, yield components and seed oil content but increased the seed protein content in all the sunflower hybrids. The highest seed yield of 2591 kg ha^{-1} was obtained from normal irrigation. An increase of the seed protein content and a decrease of the seed oil content occurred when water input decreased. Although at different level of water stress, each hybrid behaved differently according to their genetic makeup. Alstar hybrid exhibited the highest value for all the mentioned characteristics, except for seed oil and protein contents. The results also indicated that, under normal irrigation, mild and intense water deficit stress, maximum seed yield was obtained by Azargol (3448 kg ha^{-1}), alstar (2121 kg ha^{-1}) and alstar (829 kg ha^{-1}), respectively. Therefore, alstar hybrid under both levels of water deficit stress conditions in respect of seed yield and related traits such as seed number per head, 1000 seed weight and head diameter had the highest tolerance to these conditions. However, with normal irrigation, Azargol hybrid produced the highest seed yield.

Key words: Seed oil content, seed yield, sunflower, water deficit stress, yield component.

INTRODUCTION

Sunflower, with a world production of grain and oil of over 28.5×10^6 and 10.5×10^6 Mg, respectively, and grown around 22.6×10^6 ha with a seed yield of 1.3 Mg/ha (2003 to 2007 means), is one of the most common grown oilseed species (FAO-STAT Agriculture, 2009). Sunflower seeds contain a high amount of oil (40 to 50%) which is an important source of polyunsaturated fatty acid (linoleic acid) of potential health benefits (Lopez et al., 2000; Leon et al., 2003; Monotti, 2004). Water shortage and the increasing competition for water resources between agriculture and other sectors compel the adoption of irrigation strategies in semi arid Mediterranean regions, which may allow saving irrigation water and still maintain satisfactory levels of production (Costa et al., 2007). The growth, development and spatial distribution of plants are severely restricted by a variety of environmental stresses. Among different problems faced by crop plants, water stress is considered to be the most critical one (Boyer, 1982; Soriano et al., 2004; Sinclair, 2005). Shortage of water, the most important component of life, limits plant growth and crop productivity, particularly in arid regions more than any other abiotic environmental factor (Boyer, 1982). Water deficit effects have been extensively studied on several crops such as maize (Achakzai, 2008), sorghum (Achakzai, 2007; 2009a, b), sugar beet (Sepaskhah and Kamgar-Haghighi, 1997) and hot pepper (Dorji et al., 2005) etc. Reduced precipitation together with the higher evapotranspiration is expected to subject natural and agricultural vegetation to a greater risk of drought in those areas (Samarakoon and Gifford, 1995). Even a short term drought can cause

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substantial losses in crop yield (Ashraf and Mehmood, 1990). Decreasing water supply either temporarily or permanently affects morphological and physiological and even biochemical processes in plants adversely (Achakzai, 2007; 2008; 2009ab). D'Andria et al. (1995) reported that, the ability of sunflower to extract water from deeper soil layers “when water stressed during the early vegetative phase causes stimulation of deeper root system” and a tolerance of short periods of water deficit, are useful traits of sunflower for producing acceptable yields in dry land farming. On the other hand, some evidences have indicated that water stress deficit causes considerable decrease in yield and oil content of sunflower (Stone et al., 2001). Although a lot of literature is available about water stress effects on sunflower (Wise et al., 1990; Tahir and Mehdi, 2001; Angadi and Entz, 2002), information regarding the effect of normally irrigated and water deficit environment on seed yield, yield component, seed oil and protein content is scanty. Therefore, this study was mainly conducted to determine whether and how water deficit environment influence the seed yield and related traits such as seed number per head, 1000 seed weight, head diameter, harvest index and some quantitative characteristics (seed oil content and protein content) of sunflower hybrids.

MATERIALS AND METHODS

The experimental factors were irrigation regimes consisting of tree levels of irrigation after 50 (normal irrigation), 100 (mild stress) and 150 (intense stress) mm cumulative evaporation from evaporation pan class A, respectively and genotypes represented by four sunflower hybrids (Azargol, Alstar, Hysun 33 and Hysun 25). Sunflower seeds were obtained from the Plant Improvement Institute in Karaj, Iran. All combinations of the stated treatments were laid out in 2009 in the field according to a split-plot randomized complete block design (RCBD) with three replicates assigning water supply treatments to the whole units and genotypes to the subunits. The soil used was loam. The soil texture was determined with the hygrometer method (Dewis and Freitas, 1970).

The physiochemical characteristics are presented in Table 1. Electrical conductivity, pH and ions of saturation extract were determined according to Jackson (1962). The available phosphorous was determined from saturated paste extract (Olsen and Sommers, 1982). The ammonium was estimated by acid digested material (Bremner and Mulvaney, 1982) and organic matter through sulphuric acid using the Walkley-Black method (Sahrawat, 1982). The pre-planting irrigation was applied 15 days before sowing. When the soil came into condition of field capacity, then it was well ploughed for sowing. Seeds were hand drilled on May 14, 2009 with row to row distance of 65 cm. Thinning of the plants was done 15 days after germination to keep plants at a distance of 20 cm. Water deficit treatments were applied at the vegetative stages of plant growth (Chimenti and Hall, 1993). All the dry weights were expressed on a unit area basis after drying samples in a forced air oven at 70°C for at least 72 h. At maturity, yield plant^{-1} was recorded. The plants of a 5.2 m^2 area in the middle of each subplot were harvested and their seed were separated manually from heads to determine their yield, yield component, oil and protein content. Representative undehulled fruit samples per replicate plot were ground and utilized to determine the oil content (% of d.m.) by a Soxhlet apparatus using petroleum ether 40 to 60°C as a solvent. The protein content of each cultivar was determined by Lowary et al. (1951).

Harvest index was calculated as the ratio of seed yield to aboveground biomass (carbohydrate equivalent) at maturity. Analysis of variance (ANOVA) of the data from each attribute was computed using the SAS package (SAS Institute, 1988) and MSTAT computer program (MSTAT Development Team, 1989). The Duncan's new multiple range test at 5% level of probability was used to test the differences among mean values (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

The analysis of variance (ANOVA) for the studied traits showed that, water stress had significant effect (P > 0.01) on the seed yield, yield component, seed oil content and seed protein content of all the sunflower hybrids (Table 2). Differences among hybrids were also found significant for the studied traits (Table 2). The water treatment-hybrid interaction were significant for seed number per head, 1000 seed weight, head diameter, harvest index, seed protein content and seed yield. The results also revealed non-significant role of water treatment-hybrid interaction in seed oil content (Table 2). The seed yield of all the sunflower hybrids progressively decreased as water stress increased (Table 3). The decrease in seed yield and related traits (seed number per head, 1000 seed weight and head diameter) was more pronounced in intense water stress deficit (150 mm cumulative evaporation from evaporation pan class A) than that in the mild water deficit stress (100 mm cumulative evaporation from evaporation pan class A), which may be due to decrease in some morphologic and physiologic traits (Boyer, 1982). Application of mild water deficit (WD2) and intense water deficit stress (WD3) caused 51 and 79% decrease in seed yield of water stressed plants, respectively when compared with the normally irrigated ones (Table 3). The highest and least seed yield in normal irrigation was found on Azargol (3448 kg ha^{-1}) and Hysun 25 (1688 kg ha^{-1}), respectively (Table 4).

However, in the mild and intense water stress conditions, the Alstar had the highest value for seed yield (2121 and 829 kg/ha, respectively) and Azargol and Hysun 33 had the lowest values (893 and 263 kg ha^{-1}, respectively) (Table 4). The means comparison between the three irrigation treatments for the studied traits showed that, water deficit stress (WD) had significant adverse effect on all the yield components (Table 3). The mean values of the seed number per head, 1000 seed weight, head diameter and the harvest index were lower in water deficit conditions (WD2 and WD3) compared with the normal irrigation (WD1) (Table 3). Table 3 also shows that, water stress treatments decreased yield components in all the sunflower hybrids. Therefore, cultivars exhibited different response toward water stress conditions. Thus, within hybrid, Alstar had the highest seed number per head, 1000 seed weight, head diameter and harvest index (771, 44.62 g, 13.30 cm and 32%,

Table 1. Physicochemical characteristics of field soil.

Soil characteristic	Result
Soil texture	Loam
Sand (%)	36
Silt (%)	39
Clay (%)	25
Saturation percentage	33
Organic matter (%)	1.1
NH_4–N (mg kg^{-1} dry soil)	0.11
Available phosphorus (mg kg^{-1} dry soil)	3.1
Potassium (mg kg^{-1}dry soil)	245
Calcium (mg kg^{-1} dry soil)	62.81
Soil pH	7.62
Electrical conductivity (dSm^{-1})	1.8

Table 2. Mean square values from analysis of variance (ANOVA) of seed number per head, 1000 seed weight, head diameter, harvest index, seed oil content, seed protein content and seed yield of sunflower hybrids (H) subjected to water deficit (WD).

S.O.V	df	Seed number per head	1000 seed weight (g)	Head diameter (cm)	Harvest index (%)	Seed oil content (%)	Seed protein content (%)	Seed yield (kg ha^{-1})
Rep	2	2416 NS	1.42 NS	0.75 *	79.22 **	24.33 *	19.36 *	147177.33 **
Water deficit (WD)	2	747032 **	2237.68**	117.547**	1238.43**	325.46**	54.06 **	12825106.54 **
Error a	4	716	0.81	0.10	15.88	1.71	1.79	16140.67
Hybrid (H)	3	99235 *	147.58 **	28.896 **	188.06 **	8.76 *	73.21 **	1130703.75 **
WD × H	6	56457 **	3.14 *	2.10 **	90.78 **	2.91 NS	76.65 **	840906.04 **
Error b	18	752	1.10	0.21	14.32	1.89	2.32	48939.56
CV		4.23	2.67	4.22	14.98	3.15	4.38	15.01

* = $p < 0.05$; ** = $p < 0.01$; NS = non-significant.

Table 3. Effect of irrigation treatments and hybrids on studied attributes of sunflower hybrids.

Treatment*		Seed number per head	1000 seed weight (g)	Head diameter (cm)	Harves t index (%)	Seed oil content (%)	Seed protein content (%)	Seed yield (kg ha^{-1})
Water stress (WD)[1]	WD1	919 [a]	54.61 [a]	14.30 [a]	37 [a]	47.92 [a]	32.54 [c]	2591 [a]
	WD2	593 [b]	34.75 [b]	10.30 [b]	22 [b]	45.23 [b]	36.77 [b]	1274 [b]
	WD3	429 [c]	28.45 [c]	8.20 [c]	17 [c]	37.86 [c]	34.96 [a]	552 [c]
Hybrid (H)[2]	H1	568 [c]	37.05 [c]	9.60 [c]	25 [b]	44.99 [a]	34.13 [b]	1585 [b]
	H2	771 [a]	44.62 [a]	13.30 [a]	32 [a]	43.78 [ab]	34.64 [b]	1914 [a]
	H3	553 [c]	35.38 [d]	9.50 [c]	21 [c]	42.68 [b]	31.68 [c]	1284 [c]
	H4	697 [b]	40.03 [b]	11.40 [b]	24 [bc]	43.24 [b]	38.57 [a]	1107 [c]

* WD1 = Normal irrigation; WD2 = mild water deficit stress; WD3 = intense water deficit stress; H1 = Azargol; H2 = Alstar; H3 = Hysun 33; H4 = Hysun 25. [a, b, c, d] Within columns, means followed by the same letters were not significantly different ($P < 0.05$).

respectively), while hybrids Hysun 33 had the least values of seed number per head, 1000 seed weight, head diameter and harvest index (553, 35.38 g, 9.50 cm and 21%), respectively (Table 3). Ashraf and Mehmood (1990) reported that, even a short term water deficit stress can cause substantial losses in crop yield, which isin agreement with our results. The means comparison for the water treatment-hybrid interaction is summarized in Table 4. In the normal irrigation treatments, Hysun 33 had the highest seed number per head and Hysun 25

Table 4. Effect of irrigation treatment-hybrid interaction on seed number per head, 1000 seed weight, head diameter, harvest index and seed yield sunflower hybrids.

Treatment*		Seed number per head	1000 seed weight (g)	Head diameter (cm)	Harvest index (%)	Seed yield (kg ha^{-1})
WD1[1]	H1	956 [ab]	53.03 [bc]	13.90 [b]	43 [a]	3448 [a]
	H2	887 [abc]	60.03 [a]	15.63 [a]	39 [a]	2793 [ab]
	H3	979 [a]	49.66 [c]	13.53 [b]	34 [ab]	2437 [b]
	H4	855 [bc]	55.73 [b]	14.40 [ab]	30 [abc]	1688 [cd]
WD2[1]	H1	460 [fg]	32.80 [ef]	8.43 [d]	18 [cd]	893 [ef]
	H2	805 [c]	39.93 [d]	13.50 [b]	34 [ab]	2121 [bc]
	H3	425 [g]	30.33 [fg]	8.70 [d]	18 [cd]	1154 [de]
	H4	682 [d]	35.96 [e]	10.73 [c]	20 [bcd]	929 [ef]
WD3[1]	H1	288 [h]	25.33 [h]	6.53 [e]	14 [d]	413 [ef]
	H2	621 [de]	33.90 [ef]	10.76 [c]	21 [bcd]	829 [ef]
	H3	255 [h]	26.16 [h]	6.27 [e]	11 [d]	263 [f]
	H4	554 [ef]	28.40 [gh]	9.23 [cd]	21 [bcd]	704 [ef]

* WD1 = Normal irrigation; WD2= mild water deficit stress; WD3 = intense water deficit stress; H1 = Azargol; H2 = Alstar; H3 = Hysun 33; H4 = Hysun 25. [a, b, c, d] Within columns, means followed by the same letters were not significantly different ($P < 0.05$).

had the least value of seed number per head. The results of this study indicated that, in the normal irrigation conditions, Alstar had the highest and Hysun 33 had the least amount of 1000 seed weight, head diameter and harvest index (Table 4). In moderate and intense water stress, Alstar had much higher seed number per head (805 and 621, respectively), 1000 seed weight (39.93 and 33.90 g, respectively), head diameter (13.50 and 10.76 cm, respectively) and harvest index (34 and 21%, respectively) (Table 4). Our result is also in agreement with the results obtained in sunflower by Stone et al. (2001) and Angadi and Entz (2002).

Generally, the seed oil contents were higher than the seed protein contents in all the cultivars studied (Table 3). Highly significant ($p \leq 0.01$) differences with respect to seed oil content were observed in the all irrigation treatments (Table 2). The result of this study indicated that, water stress treatments decreased the oil content in all the sunflower hybrids (Table 3). The decrease in seed oil content was more pronounced for the water supply after 150 mm evaporation (20%) than that at the mild water stress deficit (6%). The seeds oil content for all the irrigation treatments ranged from 38 to 48% with Azargol having the highest value (44.99%), while Hysun 33 had the least value (42.68%) as shown in Table 3. The seed oil content of the different cultivars in the normal irrigation treatments ranged from 47 to 48% with Azargol having the highest (48.48%) and Hysun 25 having the least (47.12%) value (Figure 1). However, in the irrigation after 100 and 150 mm evaporation (mild and intense water deficit stress, respectively), the seed oil contents ranged from 44 to 46% and 36 to 40%, respectively with Azargol having the highest value (46.17 and 40.33%, respectively) and Hysun 33 with the lowest value (43.59 and 36.47%, respectively) (Figure 1). The findings of this work are consistent with the previous studies that showed that, sunflower seed could serve as rich sources of oiland protein to both temperate regions and the tropics. Monoti (2004) reported that, sunflower seed oil was rich in unsaturated fatty acids such as linoleic acid which is an essential fatty acid in human nutrition.

The normal irrigation treatments generally had the least protein contents (32.54%), while the mild water stress (irrigation after 100 mm evaporation) had the highest protein contents (36.77%) for all the sunflower hybrids studied (Table 3). This suggested that, water stress treatments significantly increased the protein content in all the sunflower hybrids, although the result of this study indicated that, intense water deficit stress (irrigation after 150 mm evaporation) decreased protein content (Table 3). However, there were significant differences ($p \leq 0.05$) in the seed protein contents among the various genotypes with Hysun 25 having the highest seed protein content (38.57%), while Hysun 33 had the least values of protein (31.68%) in the seed (Table 3). The seed protein content of the different genotypes in the normal irrigation treatments ranged from 28.42 to 39.45% with Hysun 25 having the highest and Azargol with the least value (Figure 2). However, in the irrigation after 100 mm evaporation (mild water deficit stress) the seed protein contents ranged from 30.34 to 42.38% with Hysun 25 having the highest value and Hysun 33 with the lowest value. In the intense water deficit stress (irrigation after 150 mm evaporation) the protein content ranged from 32 to 40%, with Alstar having the highest value and Azargol having the lowest value (Figure 2). Therefore, in the

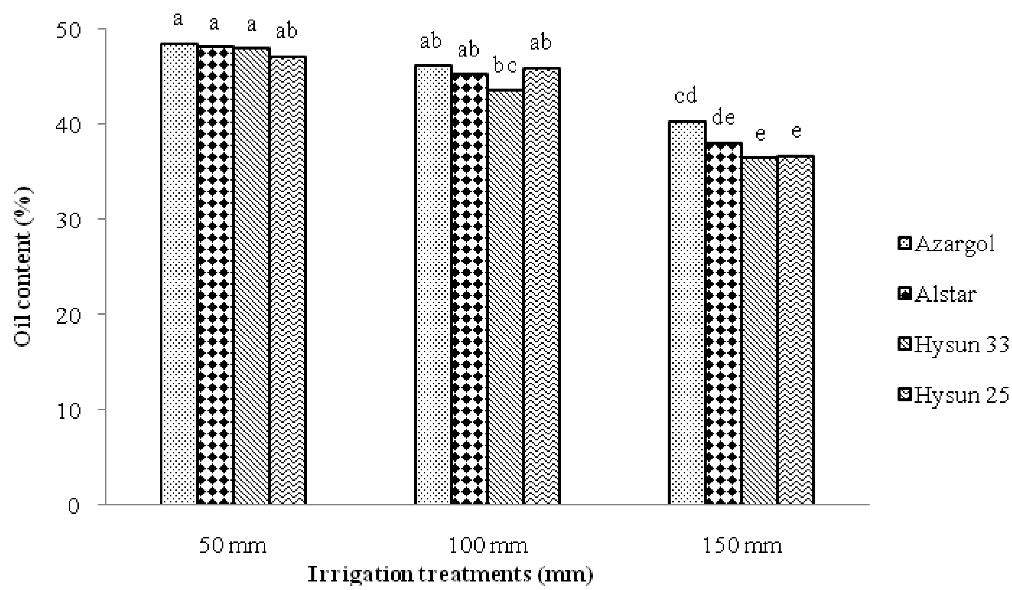

Figure 1. Effect of irrigation treatments on the oil contents of sunflower seeds.

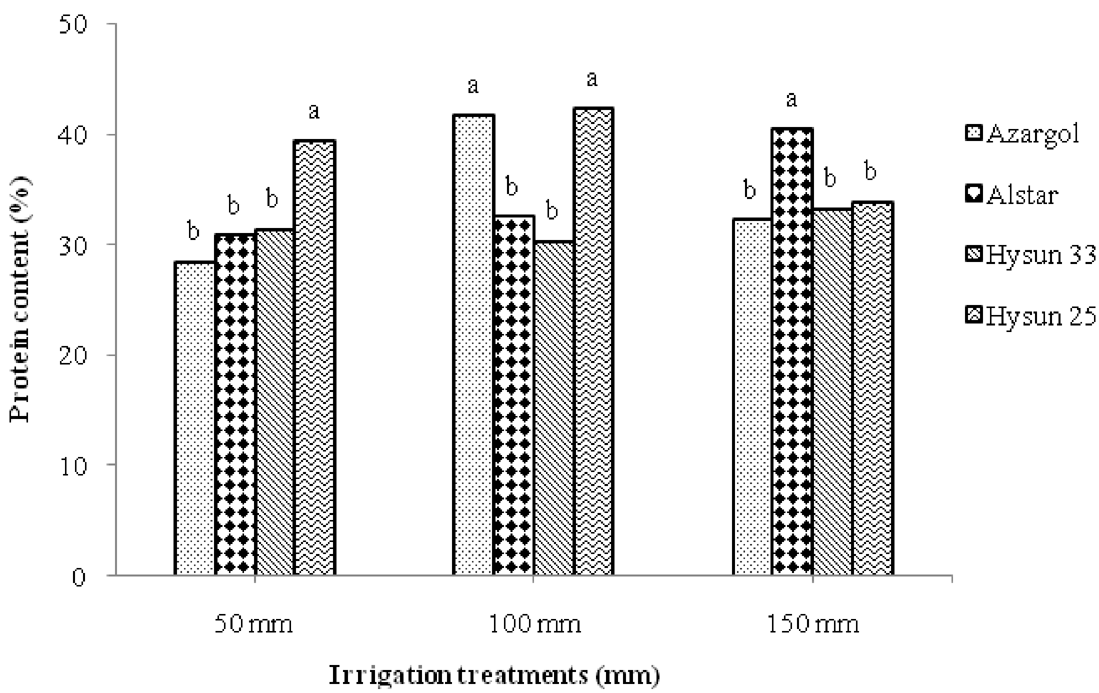

Figure 2. Effect of irrigation treatments on the protein contents of sunflower seeds.

water deficit conditions the sunflower hybrid Alstar showed the highest protein content (40%) than those of the other hybrids (Figure 2). It is evident that water deficit stress enhanced the protein content in all the cultivars studied specially in the sunflower dwarf cultivars such as Alstar and Hysun 25. The result of this study suggests that, variety and irrigation treatments significantly influenced the protein content of the sunflower seed. Therefore, it will find useful applications in food fortify-cation or supplementation to make foods rich in protein content and thus, provide a cheap source of protein to low income earners.

It appears from this and the previous studies that, water stress had adverse effect on all the studied traits in this research. A large genetic variation was observed for seed yield, yield contents, seed oil and protein content under well watered and water deficit conditions. In our study, the dwarf cultivars such as Alstar and Hysun 25 under water stress conditions had the highest amount of seed yield and related traits.

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