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Full Length Research Paper

Assessment of Water Scarcity Impacts on Sunflower Hybrid Performance

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In order to study the effect of water deficit stress on seed yield, yield component and some quantitative characteristics of sunflower hybrids, under three irrigation regimes (irrigation after 50 [normal irrigation], 100 [mild stress] and 150 [intense stress] mm cumulative evaporation from evaporation pan class A) and four sunflower hybrids (Azargol, Alstar, Hysun 33 and Hysun 25), an experimental split plot design based on a RCB was conducted in 2009 in the research station of university of Tehran, college of Abouraihan in Pakdasht region, Iran. Water stress significantly decreased seed yield, yield components and seed oil content but increased seed protein content in all sunflower hybrids. The highest seed yield of 2591 kg/ha 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 for each hybrid according to their genetic constitution. Allstar hybrid had highest amount of all characteristics, except of seed oil and protein content. Results indicated that under normal irrigation, mild and intense water deficit stress, maximum seed yield was obtained by Azargol (3448 kg/ha), Alstar (2121 kg/ha) and Alstar (829 kg/ha) respectively. Therefore, Alstar hybrid under both levels of water deficit stress conditions in aspect of seed yield and related traits such as seed number per head, 1000 seed weight and head diameter had the most tolerance to these conditions. However, with normal irrigation, Azargol hybrid had 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, respectively over 28.5×10^6 and 10.5×10^6 Mg achieved on around 22.6×10^6 ha with a seed yield of 1.3 Mg/ha (2003–2007 means), is one of the most common grown oilseed species (FAO-STAT Agriculture, 2009). Sunflower seeds contain a high amount of oil (40–50%) which is an important source of polyunsaturated fatty acid (linoleic acid) of potential health benefits (Lopez et al., 2000; Leon et al., 2003; Monoti, 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, 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 single environmental factor (Boyer, 1982). Water deficit effects have been extensively studied on several crops (Sepaskhah and Kamgar-Haghighi, 1997; Dorji et al., 2005). 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 substantial losses in crop yield (Ashraf and Mehmood, 1990). Decreasing water supply either temporarily or permanently affects morphological and physiological processes in plants adversely. D'Andria et al. (1995) reported that the ability of sunflower to extract water from deeper soil layers “when water stress during the early vegetative phase causes stimulation of deeper root system” and a

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Table 1. Soil characteristics of experimental site.

Physiochemical properties results	Results
Soil texture	Loam
Sand (%)	36
Silt (%)	39
Clay (%)	25
Saturation percentage	33
Organic matter (%)	1.1
NH4–N (mg/kg dry soil)	0.11
Available phosphorus (mg/kg of dry soil)	3.1
Potassium (mg/kg of dry soil)	245
Calcium (mg/kg of dry soil)	62.81
Soil pH	7.62
Electrical conductivity (dSm^{-1})	1.8

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 and seed oil and protein content is scare. The present study was conducted to determine whether and how water deficit environment influence on 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 seed 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 genotype represented by four sunflower hybrids (Azargol, Alstar, Hysun33 and Hysun 25). Sunflower seeds were obtained from the Plant Improvement Institute in Karaj, Iran. All combinations of the above treatments were laid out in 2009 in the field according to a split-plot randomized complete block design 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, the field was well ploughed for sowing. Seeds were hand drilled on May 14, 2009 with row to row distance of 65 cm. Thinning 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 et al., 1993). All 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 per plant 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 utilised to determine oil content (% of d.m.) by a Soxhlet apparatus using petroleum ether 40-60°C. 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 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 for the studied traits shows that water deficit stress has significant effect (P>0.01) on seed yield, yield component, seed oil content and seed protein content of all sunflower hybrids (Table 2). Differences among hybrids were 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; also the results of this work revealed non-significant role of water treatment-hybrid interactionin seed oil content (Table 2). Seed yield of all sunflower hybrids progressively decreased as water deficit 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

Table 2. Mean square values from analysis of variance 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 stress (WD).

S.O.V	df	Seed number per head	1000 seed weight	Head diameter	Harvest index	Seed oil content	Seed protein content	Seed yield
Rep	2	2416 NS	1.42 NS	0.75 *	79.22 **	24.33 *	19.36 *	147177.33 **
Water deficit treatments (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 traits.

Treatments[†]		Seed number per head	1000 seed weight	Head diameter	Harvest index	Seed oil content	Seed protein content	Seed yield
Water deficit 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 are not significantly different ($P < 0.05$).

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 stress (WD2) and intense water deficit stress (WD2) caused a 51 and 79% decrease in seed yield of water deficit stressed plants, respectively as compared with normally irrigated ones (Table 3). The highest and least seed yield in normal irrigation were found on Azargol (3448 kg/ha) and Hysun 25 (1688 kg/ha) respectively (Table 4). However, in the mild and intense water deficit stress the seed yield with cultivar Alstar having the highest value (2121 and 829 kg/ha respectively) and Azargol and Hysun 33 had the lowest value (893 and 263 kg/ha respectively) (Table 4). The means comparison between the three irrigation treatments for the studied traits shows that water deficit stress (WD) has significant adverse effect on all yield components traits (Table 3). The mean values of the seed number per head, 1000 seed weight, head diameter and the harvest index are lower in water deficit stress conditions (WD2 and WD3) compared with the normal irrigation (WD1) (Table 3). Table 3 shows that water deficit stress treatments decreased yield components traits in all sunflower hybrids, thus with hybrid Alstar having the highest seed number per head, 1000 seed weight, head diameter and the harvest index (771, 44.62 g, 13.30 cm and 32% respectively),

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

Treatments†		Seed number per head	1000 seed weight	Head diameter	Harvest index	Seed yield
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, e, f, g Within columns, means followed by the same letters are not significantly different (P < 0.05).

while hybrids Hysun 33 had the least values of seed number per head, 1000 seed weight, head diameter and the harvest index (553, 35.38 g, 9.50 cm and 21%) (Table 3). Ashraf and Mehmood (1990) reported even a short term water deficit stress can cause substantial losses in crop yield that is in 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 having the highest seed number per head and Hysun 25 having the least value of seed number per head. The results of this study indicated that in normal irrigation conditions, Alstar have the highest, and Hysun 33 the least amount of 1000 seed weight, head diameter and harvest index (Table 4). In moderate and intense water deficit 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 the harvest index (34 and 21% respectively) (Table 4). Our result is also in agreement with the result observed in sunflower by Stone et al. (2001) and Angadi and Entz (2002).

Generally, the seed oil contents are higher than the seed protein contents in all the cultivars studied (Table 3). Highly significant ($P > 0.01$) differences with respect to seed oil content were observed in the all irrigation treatments (Table 2). The result of this study indicated water deficit stress treatments decreased oil content in all sunflower hybrids (Table 3). The decrease in seed oil content was more pronounced when water was supplied after 150 mm evaporation (20%) than that at the mild water stress deficit (6%). The seeds oil content for all irrigation treatments ranged from 38 to 48% with Azargol having the highest value (44.99%), while Hysun 33 had the least value (42.68%) (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 had the lowest value (43.59 and 36.47% respectively) (Figure 1). The findings of this work is consistent with other previous studies that sunflower seed could serve as rich sources of oil and 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 deficit stress (irrigation after 100 mm evaporation) had the highest protein contents (36.77%) for all the sunflower hybrids studied (Table 3). This suggests that water stress treatments significantly increased protein content in all the sunflower hybrids, although results of this study indicated that intense water deficit stress (irrigation after 150 mm evaporation) decreased protein content (Table 3). However, there are 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 having the least value

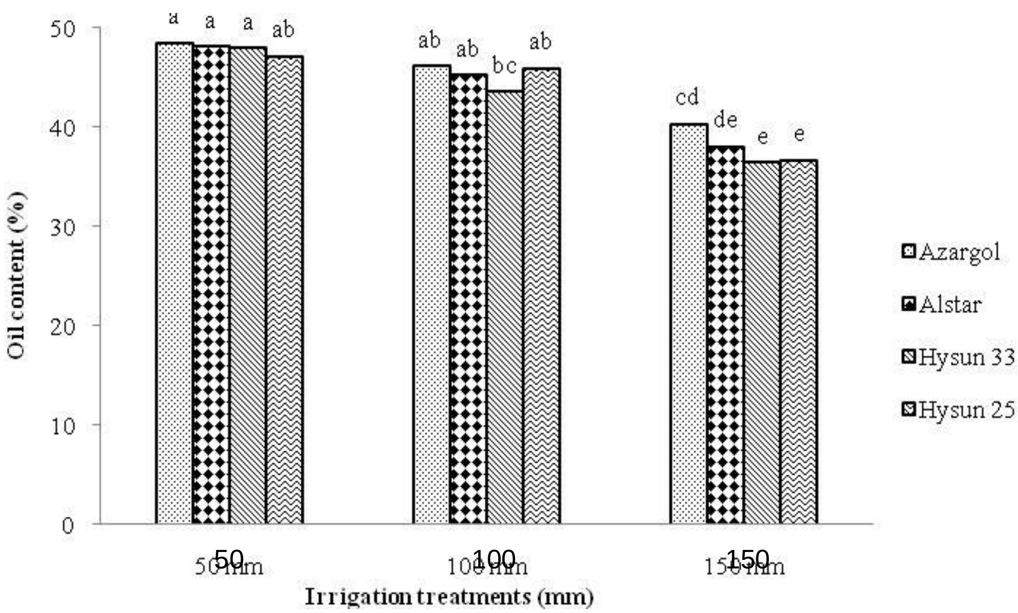

Figure 1. Effect of irrigation treatments on the oil contents of sunflower seeds.

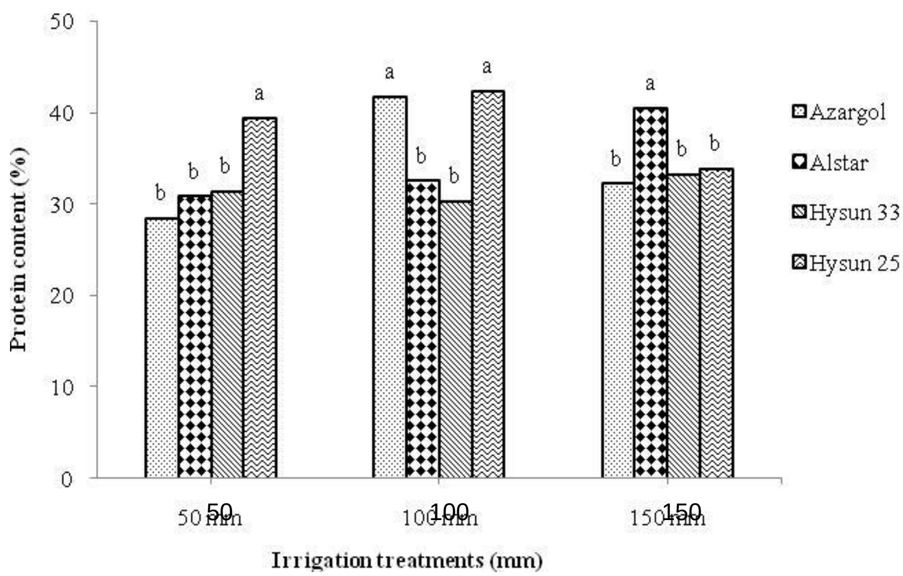

Figure 2. Effect of irrigation treatments on the protein contents of sunflower seeds.

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

It appears from the present and previous studies that water deficit stress has adverse effect on all 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 stressed conditions. In our study, dwarf cultivars such as Alstar and Hysun 25 under water deficit stress conditions had the highest amount of seed yield and related traits.

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