AcademicPres

Available online at www.notulaebotanicae.ro

Print ISSN 0255-965X; Electronic ISSN 1842-4309

Not. Bot. Hort. Agrobot. Cluj 37 (2) 2009, 85-94

Notulae Botanicae Horti Agrobotanici Cluj-Napoca

Study of the Effect of Drought Stress on Yield, Yield Components and Harvest Index of Sunflower Hybrid Iroflor at Different Levels of Nitrogen and Plant Population

Esmaeel GHOLINEZHAD[1), Amir AYNABAND[2), Abdollah HASSANZADE GHORTHAPEH[3), Gorban NOORMOHAMADI[4), Iraj BERNOUSI[5)

[1) *Islamic Azad University, Science and Research Branch of Khozestan, Iran; gholinezhad_1354@yahoo.com*

[2) *University of Chamran Ahwaz, Iran; isco-scu@scu.ac.ir*

[3) *Agriculture and Natural Resource Institute Research, West Azerbaijan, Iran; Gorthapeh-h@yahoo.com*

[4) *Islamic Azad University, Iran; gnoorm@yahoo.com*

[5) *Urmia University, Iran; Ibernosi@yahoo.com*

Abstract

This work was carried out to study the effects of water deficiency stress, different levels of nitrogen application, and plant population on Water Uptake Efficiency and Nitrogen consumption of oily sunflower. It was conducted at West-Azarbaijan's Research Center for Agriculture during 2008 and 2009. The study consisted of split-split-plot experiments using Randomized Complete Block Design with three replications. The main factor was considered to be irrigation treatments including optimum irrigation, moderate stress and severe stress in which irrigation was done after depletion of 50%, 70% and 90% of field capacity, respectively. Three nitrogen levels of 100, 160 and 220 Kg N ha^{-1} were considered as sub plots with sub – sub plots consisting of three plant population of 5.55, 6.66 and 8.33 plant m^{-2}. The combined variance analyses indicated that water deficiency stress, nitrogen and plant population have a considerable impact on grain and biological yields, seeds per head, head diameter, kernel percentage to seed, 1000-grain weight, plant grain yield and harvest index. The maximum grain yield (4200 kg/ha) was attributed to optimum irrigation treatment. Severe drought stress reduced the grain yield by 44% compared to the optimum irrigation condition. Grain yield increased at higher nitrogen application rates. The response of grain yield to increase in plant population was positive. All yield components were affected by the changes in plant population. The harvest index decreased with increasing severe drought stress and plant population. According to the results obtained in this research, application of 220 kg N ha^{-1} and larger plant population in optimum conditions and moderate drought stress is recommended for suitable yield, although an increase in nitrogen consumption and plant population has a little impact on grain yield in severe drought stress conditions.

Keywords: sunflower, drought stress, nitrogen, plant population, yield

Introduction

The main objective in agriculture production, so far, focused mostly on the increasing of yield and production (Ulusoy, 2001). Since Iran is located on a dry and semi-dry region and has different climates, the recognition of traits related to growth, yield as well as adaptation of sunflower, especially in relation to drought stress, can remarkably affect the development of planting area and its yield increase. Nezami *et al.* (2008) indicated that plant height, plant dry matter, stem diameter, head size, seed number head^{-1}, weight of 1000 grains and grain weight head^{-1} under dry and semi-dried conditions declined. Ahmad *et al.* (2009) reported that plant height and plant dry matter decreased with increasing water stress under controlled conditions. Chimenti *et al.* (2002); Erdem *et al.* (2006) indicated that grain yield and weight of 1000 grains decreased with increasing drought stress. Karam *et al.* (2007) showed that with increasing drought stress leaf area index, grain yield and its component decreased. Blum (1988) believes that environmental stresses in farm appear mainly in the form of such factors as water, nutrition and heat deficiency. Dekow *et al.* (2000) showed that net photosynthetic rate decreased more in sunflower under PEG-induced water stress and high-temperature stress. Relative water content (RWC) of the leaves decreased under drought stress (Unyayar *et al.*, 2004). Ali Meo (2000) conducted that plant height and number of grains head^{-1} decreased significantly by lowering the nitrogen level or increasing drought stress. Kalamian *et al.* (2006) showed that drought stress decreased biologic yield. The results of Roshdi *et al.* (2006) showed that with increasing irrigation intervals and applying water stress the head diameter and grain yield of sunflower decreased. Jabari *et al.* (2007) showed that with drought stress grain yield decreased about 83 percent because of decreasing in weight of 1000 grains and number of grains head^{-1}. Furthermore, the results from Anwar *et al*. (1995), Anderia and Chiaranda (1995) showed a decrease in head diameter with increasing drought stress. Flenet *et al*. (1996) demonstrated that decreasing the level of irrigation resulted in decreasing the number of grains head^{-1}. According to Daneshian *et al.* (2005) weight of 1000 grain decreased due to water stress. Human *et al.* (1998) concluded that drought stress in stages of flowering, fertilization and grain filling in Sunflower caused the most reduction of grain yield.Yegappan *et al.* (1982) found that drought stress reduced number of leaf, head diameter, leaf area, weight of 1000 grains and grain yield significantly. Zubriski and Zimmerman (1974), Singh *et al.* (1996), Mathers and Stewart (1982) showed that increase in use of nitrogen caused an increase in grain yield. Fereres *et al*. (1986) observed that drought stress reduced grain yield by lowering number of grains head^{-1}, photosynthesis reduction, and increasing hollow percentage. Fathi *et al.* (1997), Zaman and Das (1991) concluded that with increasing nitrogen, grain yield, number of grains head^{-1}, plant height and weight of 1000 grains increased. Robinson *et al.* (1980) reported that with increasing plant density, length of growth period, weight of 1000 grains, number of grains head^{-1}, stem diameter and head diameter decreased but plant height increased because of a higher interplant competition. Abbadi and Gerendas (2009) showed that optimal and high supply nitrogen in sunflower produced grain yield more efficient than low supply of nitrogen. Robinson *et al*. (1985), Dixon and Luteman (1992) showed that increasing plant density led to a significant reduction in the number of grains head^{-1}. Taghdiri *et al.* (2006) showed that with increasing plant density biologic and grain yield increased but number of grains head^{-1} and 1000-grain weight decreased. Killi (2004) determined that the lowest plant density resulted in the highest head diameter, total number of grains head^{-1}, grain yield head^{-1} and weight of 1000 grains also N treatments significantly increased head diameter, total number of grains head^{-1}, weight of 1000 grains and grain yield. According to Zaffaroni and Schneiter (1991) at higher plant density, number of grains head^{-1} and dry weight of hanging parts decreased whereas grain yield and plant height increased. Therefore the aim of this study was to evaluate the effect of different levels of nitrogen application and plant density in different moisture conditions on yield and yield components of sunflower in order to achieve the optimum use of resources.

Materials and methods

This experiment was conducted in order to investigate the effects of water deficit stress, different levels of nitrogen and plant density on grain yield and yield components and harvest index in oily sunflower (Var: Iroflor). It was performed during 2008 and 2009 at the research farm of the Centre of Agriculture and Natural Resources in Orumieh, West-Azerbijan, Iran. The experiment was implemented in a split-split-plot using Randomized Complete Block design with three replications. The main factor was irrigation treatments including optimum irrigation, moderate stress and severe stress. Irrigation was done after depletion of 50, 70 and 90 percent of field capacity, respectively. Three nitrogen levels consisting of 100, 160 and 220 kg N ha^{-1} were considered as sub plots with sub- sub- plots consisted of three plant densities of 5.55, 6.66 and 8.33 plant m^{-2}. The plant distance on each row was 20, 25 and 30 cm and distance between rows was 60 cm. These spacing were randomly located in the main plots, sub plots and sub- sub plots. Each sub-plot consisted of 7 plant line. Each plant line was 4 meter long. The distance between two sub-plots and two main plots were 1m and 2m, respectively. Thus main plot area was 51.6 m^2 with total area of 2500 m^2. The operations of plough and preparation of farm included a deep plough, two vertical disks, leveling, furrow, mound and plot making. The soil texture was loamy silt clay. The amount of fertilizer added to farm was determined by soil analysis. The planting was done manually after irrigation in 27 may 2008 and 2009. The grains used in this study were Hybrid Iroflor. This hybrid comes from the variety of single-cross and the group of middle ripping and has registered in 1988 in France.

The first irrigation was done in 5 June. The thinning conducted in 4-5 leaf stage. The weeding conducted in 2 stages of 20 and 40 days after planting. Nitrogen fertilizer applied in the form of surplus in 2 stages of 7-8 leafage and flowering time. When downside of head turned to brownish yellow the final harvest was performed. In this stage seeds had 20 percent of moisture. In order to remove the edge effect, the sampling was not conducted from lateral rows. For determining soil moisture samples were taken from 2 depths of soil 0-30 and 30-60 cm in each (Tab. 1.). Then weight moisture percentage was determined by pressure plate (armfield CAT.REF: FEL13B-1 Serial Number: 6353 A 24S98). In this experiment field capacity of soil was determined to be 26 with permanent wilting point of 14. In order to obtain the exact irrigation time, soil was sampled by auger from root development depth in each treatment 48 hours after irrigation to measure soil weight moisture. Based on the measurement, the irrigation time was determined to be at soil weight moisture of 20, 17.6 and 15.2. To implement the irrigation operation the water usage volume was calculated by the following equation 1:

$$V = \frac{(fc - \theta m) \times \rho \times Droot \times A}{Ei}$$

V= Irrigation water volume (m^{-3})
Θm = soil weight moisture percentage irrigation
A= Irrigated area (m^{-2})
FC= field capacity
ρm = soil external specific density (gcm^{-3})
Droot= root development depth (m^{-1})

Therefore the required water volume in each stage of irrigation in each treatment was calculated and was distributed equally based on the water distribution efficiency of 90 percent by flume and chronometer. The final harvesting area was equal to 4.8 m^{-2} that was done from two middle lines of planting. Final measurements were conducted from these samples. For moisture measurement grains were located in the oven in the temperature of 72 degrees centigrade for 48 hours. Leaf area index was determined by leaf area meter (LP-80 Accupar PAR/LAI Ceptometer). Relative water content was calculated to examine plant reaction to water deficit stress. For this purpose, leaves of three plants from second and fifth rows were separated before irrigation at 12pm and were taken to the laboratory. In the laboratory disks of the leaves were prepared and weighed immediately to measure the fresh leaf weight. Then the disks were placed in distilled water for about 24 hours at 4°C until they were saturated completely. At the end of this stage, the leaf disks were dried by towels of dry paper and were then weighed again. The samples were placed in the oven for about 48 hours at 72°C until they were dried. The weight of dried leaves was recorded. Relative water content was calculated using equation 2:

$$RWC = \frac{Wf - Wd}{Ws - Wd} \times 100$$

RWC=Relative Water Content
Wf= Fresh Leaf Weight
Wd= Dry Leaf Weight
Ws= Saturated Leaf Weight

The yield components including the number of grains $head^{-1}$ and weight of 1000 grains were calculated. Harvest index was calculated by equation 3:

$$HI = \frac{Ye}{Yb} \times 100$$

HI= Harvest index
Ye= Economical yield
Yb= Biological yield

For calculating weight of 1000 grains, 5 replications of 1000-fold from each treatment were selected and averaged. Analysis of variance was performed using PROC ANOVA of SAS. The comparison of the means was done by Tokey's test at a probability level of 5 percent.

in the final stage ranged from 1.25 at optimum irrigation to 0.62 and 0.4 at moderate and severe stress, respectively (Tab. 2. and 3.). The decreasing leaf area index in drought stress conditions can be related to the decrease in relative water content of leaf. Cosculleola and Fact (1992) observed that with increasing drought stress leaf water potential strongly becomes negative. The similar reports have been presented by Tayzer and Zinger (1999). Ariy (1987) reported that water drought stress in growth stage led to minimize the leaf size and to accelerate leaf aging and paleness as well as to reduce the leaf area index and light absorption by plant. Tayzer and Zinger (1999) showed that growth and development of cell was a process related to pressure potential and is strongly sensitive to water deficit and prevention of cell growth causes a decrease in leaf area index.

With decreasing plant water content, Wrinkle cells, cell wall becomes weak and decreasing cell volume leads to reduce pressure potential (Ariy, 1987).

The nitrogen consumption had strong effect on production and development of leaf area. Plants which received more nitrogen had larger leaf area index compared with plants with low nitrogen consumption (Muchow and Davis, 1988; Connor, 1993).

The effects of different nitrogen levels (100, 160 and 220 kg ha^{-1}) on leaf area index were significant (Tab. 2). With increasing nitrogen consumption, leaf area index in treatment 220 kg Nitrogen ha^{-1} reached to 0.94.

The average leaf area index in treatment 100 kg Nitrogen ha^{-1} was 0.53. This study is in agreement with reports of Muchow and Davis (1988), Connor *et al.* (1993) who stated that leaf area index and its durability as well as plant photosynthesis rate increased with nitrogen consumption. In this study it was observed that increasing nitrogen consumption in optimum irrigation conditions had a considerable positive effect on leaf area index whereas in severe drought stress positive effect of nitrogen consumption was not great (Tab. 2). This situation probably was the result of a disorder in nitrogen absorption process by plant under severe drought stress. Bock (1984) stated that severe water

Tab. 1. Chemical and physical properties of farm soil at depth of 0-30 cm

Electrical conductivity DS m^{-1}	pH	Percentage of saturation (%)	lime (%)	clay (%)	silt (%)	sand (%)	Carbon Organic (%)	Nitrogen (%)	Phosphor (ppm)	Potassium (ppm)
0.8	8	57	16	33	55	12	1.2	0.12	12	800

Results and discussions

Leaf area index

The results of combined analysis of variance showed that with increasing stress intensity, leaf area index decreased significantly, so that the increase in leaf area index

deficit in soil caused a limitation in plant ability to absorb nitrate from soil. More nitrogen consumption resulted in increasing leaf area index and its preservation until the end of growth period. The results of this study about the effect of applying different amounts of nitrogen on leaf area agree well with Allison and Haslam (1993).

With increasing plant density leaf area index showed increasing trends so that the maximum leaf area indices of 0.58, 0.75 and 0.94 were obtained from densities 55500, 66600 and 83300 plants ha^{-1}, respectively (Tab. 3.). Duncan (1985) showed that increasing plant density was accompanied with decreasing leaf area per plant and increasing leaf area index, light absorption and crop growth rate; which is in complete agreement with this study.

Leaf Relative Water Content

The results of combined ANOVA showed that leaf relative water content strongly affected by water deficit stress and with intensifying stress decreased significantly (Tab. 2 and 3). Decreasing leaf relative water content is an indication of decrease of swelling pressure in plant cells and causes growth to decrease. With depletion of water from soil and lack of a substitute for it, water potential in root region decreases and if resistances remain consistent water potential in plant similarly decreases in order to maintain transpiration rate (Tiyar and Pit, 1994). Difference among leaf relative water contents was significant at nitrogen levels so that the plants which received larger amount of nitrogen had more leaf relative moisture (Tab. 2. and 3.). There are several reports that increasing nitrogen application and carbohydrates consumption via the increase of making proteins and increasing cell wall thickness cause absorption of extra water by protoplasm and improvement leaf relative water content (Saneoka *et al.*, 2004). In this study the effect of plant density on leaf relative moisture was considered to be significant in 1 percent level and in fact, the higher the plant density, the higher the leaf relative moisture (Tab. 2. and 3.). Lower leaf relative moisture in compacted plants indicates the more vigorous effect of water deficit stress on these plants and the main reason for this situation is the existence of more competition between aerial and underground parts of condensed plants for using maximum level of recourses and less development of root system. This phenomenon causes these plants to suffer excess damage in drought stress condition (Nautiyal *et al.*, 2002).

Biological yield

Water deficit, nitrogen consumption and plant density had significant effect on biological yield which is repre-

Tab. 2. Combined analysis of variance for traits of sunflower in different drought stress, nitrogen and plant population (2008 – 2009)

S.O.V.	df	Grain weight/plant	Grain 1000 weight	Grains head	Biological yield	RWC	LAI	HI	Grain yield
Year	1	101.37**	5803.9**	7667.3**	45171878.8**	0.134ns	5.99**	582.42**	458764.9**
Irrigation	2	16686.65**	1997.49**	2802922.9**	427451336.9**	1453.7**	10.34**	271.48**	78009743.7**
Year × irrigation	2	0.09 ns	5.36ns	1413.5**	6719.1ns	0.94ns	2.33**	10.28**	329.7ns
Error 1	8	10.72	40.65	1360.7	951389.1	19.31	0.068	0.96	44513.5
Nitrogen	2	1614.11**	260.25**	456271.3**	37131536.4**	108.49**	2.33**	44.61**	7444267.1**
Nitrogen ×Year	2	0.016 ns	5.84ns	1337.1*	2073ns	2.52ns	0.0075ns	1.73ns	86.9ns
Irrigation ×nitrogen	4	13.02*	2.95ns	27777.5**	300961.5ns	8.56**	0.291**	0.44ns	71212.2**
Irrigation × nitrogen × Year	4	0.106ns	4.9ns	1243.9**	7195.2ns	0.29ns	0.039ns	0.089ns	422.7ns
Error 2	24	7.65	1.89	474.09	136596.8	1.48	0.018	0.38	32529.3
Density	2	1906.26**	951.5**	135752.8**	42521672.2**	574.71**	1.71**	172.38**	1976288.1**
Density × Year	2	1.36ns	16.09**	210.08ns	23256.1ns	0.13ns	0.21**	6.96**	47.4ns
Irrigation ×Density	4	13.75*	3.59ns	1102.2**	8754650.1**	3.75ns	0.16**	0.53ns	1000115.9**
Density × irrigation × Year	4	0.038ns	0.78ns	135.1ns	24349.3ns	0.48ns	0.035ns	0.31ns	181.2ns
Density × nitrogen	4	3.32ns	17.58**	4368.3**	526548.4**	1.17ns	0.036ns	0.113ns	54061ns
Density × nitrogen × Year	4	0.0015ns	5.28*	76.9ns	5487.1ns	0.19ns	0.024ns	0.177ns	16.1ns
Density × nitrogen × irrigation	8	4.59ns	2.12ns	1147.4**	207313.6ns	2.73ns	0.013ns	0.79ns	28846ns
Density × nitrogen × irrigation × Year	72	0.041ns	3.27ns	74.11ns	13934.4ns	0.029ns	0.015ns	0.04ns	151.9ns
Error 3		4.65	326.2	326.2	168384	2.17	0.025	1.62	20080.9
CV	-	4.95	2.12	2.38	5.11	2.62	20.88	3.5	4.83

** , * and Ns significant at the 1%, 5% probability levels and non significant respectively

Tab. 3. Combined mean comparison for traits of sunflower in different drought stress, nitrogen and plant population (2008 – 2009)

Treatments	HI (%)	Grain yield Kg ha^{-1}	Grain weight/ plant (gr)	Grain 1000 weight (gr)	Grains head	Biological yield Kg ha^{-1}	RWC	LAI
Irrigation								
Optimum irrigation	38.57 a	4251.84 a	62.91 a	55.36 a	1005.40 a	11134.00 a	60.61 a	1.25 a
Moderate drought stress	36.39 b	2627.47 b	39.00 b	48.08 b	713.60 b	7292.10 b	57.23 b	0.62 b
Severe drought stress	34.09 c	1905.08 c	28.63 c	43.29 c	556.44 c	5652.70 c	50.42 c	0.40 c
Nitrogen Kg ha^{-1}								
100	35.66 c	2565.95 c	38.16 c	46.69 c	666.37 c	7207.69 c	54.49 b	0.53 c
160	36.33 b	2910.53 b	43.29 b	48.95 b	758.88 b	8005.44 b	56.57 b	0.81 b
220	37.27 a	3307.91	49.09	51.08	850.21	8865.76	57.20	0.94
Density plant per m^{-2}								
8.33	34.81 c	3124.63 a	37.46 c	44.27 c	709.46 c	8886.7 a	53.07 c	0.94 a
6.66	35.94 b	2917.28 b	43.74 b	50.03 b	756.34 b	8077.8 b	55.65 b	0.75 b
5.55	38.31 a	2742.48 c	49.34 a	52.43 a	809.67 a	7114.2 c	59.55 a	0.58 c

Means followed by similar letters in each column are not significantly different at the 5% level of probability according to Tokay's Test.

sented by dry material assemblage in aerial body at harvest time (Tab. 2.). The results showed that with increasing intensity of drought stress there was a significant decrease in biological yield. These results confirmed results of Radford (1986), Kalamian *et al.* (2006), Jasso *et al.* (2002) who also showed decreasing biological yield because of drought stress. The reason for increase in TDM (total dry matter) production in plants under optimum irrigation was the extension of leaf area and its higher durability that provided enough physiological resource to take advantage of received light and therefore produce more dry matter (Jasso *et al.*, 2002).

The reduction of nitrogen consumption level from 220 to 100 kg nitrogen ha^{-1} reduced biological yield by the average of 1657 kg ha^{-1} (Tab. 3.). This reduction was considerable (Tab. 2.). The reduction of biological yield at little quantities of nitrogen consumption was reported by other researchers (Singh *et al.*, 1995; Hasanzade *et al.*, 2002). In this study, at greater quantities of nitrogen, accumulation of photosynthates increased at stem and leaf parts which resulted in increased gathering of nutrients in grain. The

Tab. 4. Matrix of simple correlation coefficient among different traits

Harvest index	Grain yield	Grain Yield of single plant	Grain 1000 weight	Grains $head^{-1}$	Biological yield	Leaf relative water content	Final Leaf area index	Plant density	Plant density	Drought stress	
							1	0.26**	0.26**	-0.64**	Final Leaf area index
						1	0.39**	-0.46**	-0.46**	-0.75**	Leaf relative water content
					1	0.48**	0.67**	0.26**	0.26**	-0.82**	Biological yield
				1	0.81**	0.80**	0.65**	-0.19**	-0.19**	-0.88**	Grains head-1
			1	0.60**	0.30**	0.63**	0.57**	-0.38**	-0.38**	-0.54**	Grain 1000 weight
		1	0.63**	0.97**	0.77**	0.84**	0.59**	-0.29**	-0.29**	-0.87**	Grain Yield of single plant
	1	0.88**	0.49**	0.90**	0.94**	0.64**	0.75**	-0.14ns	-0.14ns	-0.90**	Grain yield
1	0.38**	0.52**	0.73**	0.50**	0.08ns	0.66**	0.37**	-0.32**	-0.32**	-0.44**	Harvest index

**** , * and Ns significant at the 1%, 5% probability levels and non significant respectively.**

nitrogen deficit causes leaf size reduction which in turn is the cause of reduction in the amount of light absorption and light usage for plant photosynthesis which finally leads to reduced biological yield (Tab. 3.). The difference of average biological yields at different densities was significant (Tab. 2.) and with increasing plant density the biological yield increased (Tab. 3.). Although competitions such as competition for light absorption, food, water and carbon dioxide is more intense at high plant densities but it seems that in Orumieh climate condition interplant competition corresponds with the optimum plant density range even at the biggest plant density investigated in this study. Reports about positive effect of increasing plant density on biological yield have been presented (Taghdiri *et al.,* 2006; Gubbels *et al.,* 1999). The combined effect of irrigation-density on biological yield was significant at 1 percent level (Tab. 2.). Comparison of mean values for combined effect of irrigation-density showed that the case of highest density with optimum irrigation condition is considerably better than other cases with respect to the dry matter production whereas in severe drought stress condition change of biological yield due to increasing density was not outstanding. The reduction of biological yield in all densities in the case of severe drought stress condition was the result of decreasing the grain yield and dry weight of growing parts due to increasing competition (Gubbels, 1999). In optimum irrigation condition and moderate drought stress the more the number of plant per area unit was, the more dry matter obtained because the reduction of single plant dry matter weight was compensated increasingly. However, at severe drought condition, intensive reduction of single plant dry matter weight was not compensated and as a result the difference of biological yields was not significant among densities. Therefore, it is recommended that in sunflower planting high densities can just be useful at optimum conditions. Comparison of the mean values showed that the changes of dry matter yield due to increasing the plant density had not the same trend at all levels of nitrogen application. At higher levels of nitrogen consumption with increasing density the reduction of single plant weight was compensated and therefore the biological yield increased. These results agree with Gubbels *et al.* (1999).

Number of Grains head^{-1}

In this study increasing the intensity of drought stress reduced the number of grains head^{-1} dramatically so that the treatment of severe drought stress had the minimum number of grains head^{-1}with the average of 556.4 grains (Tab. 2. and 3.). Uhart and Andrade (1995) reported that the number of grains head^{-1}increased with nitrogen consumption due to the improvement of crop growth rate and stated that increasing nitrogen consumption caused increasing in light use efficiency at flowering stage and increasing in crop growth rate. Since there is a close relationship between crop growth rate and providing elaborate sap during flowering and nitrogen application has a positive effect on these processes, increasing the number of grains head^{-1}due to increasing nitrogen consumption was expected. Mishra *et al.* (1995) stated that with increasing nitrogen consumption the number of grains head^{-1} increased. The effect of density and combined effects of irrigation-density, density-nitrogen and irrigation-nitrogen-density on the number of grains head^{-1} were significant. A decrease in the number of grains head^{-1} was because of negative effect of increase in density on head diameter (Tab. 3.). Decreasing the number of grains head^{-1} at high plant densities was due to direct competition between original unripe seeds or unfilled grains to receive the nutrients as well as infertility and failure of some grains during filling. This phenomenon has been reported by other researchers (Hashemi-Dezfouli and Herbert, 1992). Comparison of the mean values for combined effect of density-nitrogen consumption showed that with increasing plant density at all irrigation levels the number of grains head^{-1}decreased. Zaffaroni and Schneiter (1991) stated that with increasing plant density the number of grains head^{-1} decreased. They reported that the main reason for decreasing the number of grains head^{-1} arises from the competition effects at higher density which is also the cause of decreasing head diameter and grain size. They reported that there is a negative correlation between density and number of grains head^{-1}.

It was found in this study that there is a negative and significant correlation between density and number of grains head^{-1} that agree with the aforementioned results (Tab. 4.). Khalifa (1984) reported that the number of seeds per head increased with decreasing density; so the most grains head^{-1}were obtained at the lowest plant density.

1000-Grain Weight

Results of combined ANOVA showed that drought stress caused significant decrease in grain weight so that the maximum and minimum 1000-grain weight were obtained in optimum irrigation and severe drought stress, respectively (Tab. 2. and 3.). Average value of Grain weight is firstly determined by the quantity of elaborated matter available to be transported to head from flowering stages to grain maturity stage. This is, in turn, a function of the durability of leaf area after flowering stage as well as the sink-source relationship (Gardner *et al.* 1994). Decreasing 1000-grain weight at severe drought stress can be related to the lack of stored carbohydrates before pollination stage at productive parts and to decreasing durability of leaf area at plants of under treatment that resulted in a short period of grain filling. Westgate (1994) reported that the main reason of grain weight reduction is decrease in grain filling period due to stress. Banziger *et al.* (2002) demonstrated that delay in leaf aging and availability of foodstuff at grain filling period increase grain weight. On the other hand, it has been specified that stem is counted as a little storage source of mobile non building carbohydrates, which also transports them to grain after flowering. Occurrence of drought stress especially at growth period decreases the quantity of storage of non-building carbohydrates at stem via decreasing leaf area and photosynthesis; as a result for the reason of lack of storage nutrients at secondary source grain weight decreases (Andria *et al.,* 1995; Angadi and Entz, 2002). In this study, increasing the use of nitrogen increased 1000-grain weight (Tab. 2. and 3.). This is because of ability of the plant to access to more nitrogen and increasing reproductive and productive parts. Fathi *et al.* (1997) reported that with increasing nitrogen consumption head diameter and 1000-grain weight increased due to more access to absorbing nutrients. The effect of plant density on 1000-grain weight was very significant and with increasing density 1000-grain weight decreased so that the highest 1000-grain weight with the average of 52.4 gr belonged to the lowest density (Tab. 2. and 3.). The less storage of carbohydrates at stems before pollination and decreasing current photosynthesis arising from decreasing durability of leaf area after flowering and high respiration requirements at high densities caused noticeable decrease in 1000-grain weight. These results agree with the experiments of Zaffaroni and Schneiter (1991) and Aless *et al.* (1997) on decreasing 1000-grain weight due to density increase. Combined effects of irrigation*nitrogen levels, density*irrigation and density*nitrogen and density*nitrogen*irrigation were not significant on 1000-grain weight (Tab. 2.). 1000-grain weight had positive and significant correlation with grain yield and biological yield (Tab. 4.). This was observed as the increase of grain and biological yield in treatments with more grain.

Grain yield of single plant

Grain yield of single plant was influenced by drought stress, nitrogen, plant density and combined effect of nitrogen*plant density (Tab. 2.). Grain yield of single plant decreased significantly with increasing severe drought stress and density (Tab. 3.). This situation was due to negative and significant correlation between severe drought stress and grain yield of single plant. Negative effect of drought stress on yield component and grain in sunflower has been reported by other researchers (Daulay *et al.,* 1983; Human *et al.,* 1998; Robinson *et al.,* 1985). Aless *et al.* (1997), Zubriski and Zimmerman (1991), Singh *et al.* (1991) reported that with increasing plant density single plant yield decreased and area yield increased. Additionally, with increasing plant density single plant yield decreased due to decreasing feeding space of every plant (Marinkovic, 1999). In this study with increasing nitrogen consumption single plant yield increased significantly (Tab. 1.). Treatment of applying 220 kg nitrogen ha^{-1} with production average of 49.09 gram grain was noticeable compared with other treatments (Tab. 3.). The positive effect of increase in nitrogen consumption on grain yield was due to the improvement of grain yield component because of applying nitrogen (Tab. 3.). These results confirm the findings of Uhart and Andrade (1995) who reported that decreasing nitrogen use decreased the number of grains and grain weight which, in turn, caused grain yield to fall. Comparison of mean values for the combined effects of irrigation*nitrogen interaction and also irrigation*plant density interaction on grain yield of a single plant showed that treatment of applying 220 kg nitrogen ha^{-1} with plant density 5.55 plants per m^{-2} had a noticeable significance in comparison with other treatments. These results showed that use of high densities will just be useful when enough quantity of fertilizer is used.

Grain yield

Results of combined ANOVA showed that the effect of drought stress, nitrogen and plant density was significant on grain yield (Tab. 2.). With increasing severe drought stress, grain yield decreased. Increasing nitrogen application caused grain yield to increase. The consumption of more quantities of fertilizer at optimum irrigation condition caused considerable increase in grain yield whereas at severe drought stress condition using more quantities of nitrogen did not increased grain yield. It seems that this situation results from absorption reduction and increasing nitrogen waste due to water deficit in soil. The results of Martin *et al.* (1992) confirm obtained results in this survey on nitrogen use efficiency at drought stress condition. Increasing number of plants per area was accompanied with considerable increase in grain yield (Tab. 3.). Many researchers have pointed to grain yield increase due to increasing plant density (Sadras *et al.,* 1998; Schneiter *et al.,* 1992). The most grain yield of about 4628.7 kg ha^{-1} obtained from the highest density at optimum irrigation treatment but in moderate and severe drought stress conditions yield increase due to the increase of density was not significant. These results are showing that the use of high densities can be useful at optimum condition. Liang *et al.* (1992) reported that maximum grain yield in maize need high plant density, more irrigation, use of plenty of fertilizer and meeting temperature requirements. In low densities grain yield was low due to decreasing the number of plants per area and increasing nitrogen was effective to some extent due to the limitation in capacity of each plant to use nitrogen and therefore extra nitrogen was not used and remained out of plant access. By plant density increase, grain yield per area unit became more due to the increase in the number of plants per area.

Harvest index

Drought stress affected harvest index considerably and caused harvest index to decrease. The highest harvest index rate of 38.57 belonged to the optimum irrigation (Tab. 3.). In this study drought stress decreased grain yield with a higher degree than dry matter yield as a result of which harvest index decreased. Harvest index implies the relative distribution of photosynthesis products between economical sinks and other existing sinks in the plant. Setter (1990) stated that water deficit is one of the limiting factors of plant growth and development that not only reduces production of dry matter but also causes a disorder to the partitioning of carbohydrates to grain thus reducing the harvest index. Results of this study agree with findings of Cox and Julliff (1988) who reported that with reducing water consumption dry matter production decreased but the reduction of grain yield in response to water deficit was more than the reduction of biological yield. Pandey et al. (2000) suggested that the reason of harvest index reduction at severe drought stress is the higher sensitivity of reproductive growth to undesirable conditions in comparison with generative growth.

The difference between maximum and minimum of harvest index obtained at different nitrogen levels was statistically significant (Tab. 3.). The results obtained in this study showed that nitrogen application did not change the way at which photosynthesis matter are distributed and increased the grain yield with the same level as dry matter. There have been similar reports that application of different quantities of nitrogen does not have any influence on harvest index (singh *et al.,* 1996). The effect of plant density levels on harvest index was significant (Tab. 2.). With increasing plant density harvest index decreased due to severe reduction of assimilates distribution to grain; density of 5.55 plants per m^{-2} with the average of 38.31 and density of 8.33 plants per m^{-2} with the average of 34.81 had the maximum and minimum harvest index, respectively (Tab. 3.).

Since there is competition between vegetative and generative parts of the plant for receiving photosynthesis matter, with increasing density and inter plant competition this intra competition would be more intense. As generative sinks are created later than vegetative parts the resulting competition will firstly affect generative parts and it may cause infertility of some of generative parts at severe competitive conditions. Duncan (1985) reported that at high plant densities, although leaf area index and dry matter yield increased, but due to creating competition between plants, harvest index decreased. Other researchers have also reported the reduction of harvest index resulting from higher plant densities that confirm the results obtained in this study (Zaffaroni and Schneiter, 1991).

Conclutions

Different levels of Water deficit stress had different effects on plant. Among the most important results obtained about application of water deficit stress, significant reduction of leaf area index, leaf relative water content, grain yield, biological yield, grains $head^{-1}$, 1000-grain weight and harvest index at severe and moderate stress in comparison with optimum irrigation can be pointed out. By increasing nitrogen fertilizer from 100 to 220 kg nitrogen ha^{-1} all the aforementioned traits increased significantly. With plant density increase traits of leaf area index, grain and biological yield increased too but with plant density increase from 5.55 to 8.33 plants per hectare, leaf relative water content, grains $head^{-1}$, 1000-grain weight and harvest index found out significant reduction. Combined effects of irrigation*nitrogen showed that with increasing nitrogen, leaf relative water content, grain yield of single plant and grain yield increased. Interaction between of irrigation*plant density showed that at optimum irrigation with the increase in plant density, final leaf area index, grain and biological yield increased but at severe drought stress the highest grain yield obtained from lowest density. Thus at each drought stress level with plant density reduction the number of grains $head^{-1}$ increased. Interaction between of nitrogen*plant density showed that the highest biological yield obtained from the highest level of fertilizer application and the highest plant density. However the highest value of 1000-grain weight obtained from nitrogen treatment of 220 kg nitrogen ha^{-1} and the plant density of 5.55 plants per m^{-2}.

The most grains $head^{-1}$ obtained from the highest fertilizer level and the lowest fertilizer level. In the Interaction between of plant density*irrigation*nitrogen the most grains $head^{-1}$ obtained from optimum irrigation and the highest fertilizer level and the lowest plant density level.

Therefore, at optimum irrigation condition for planting sunflower var. Iroflor fertilizer treatment of 220 kg nitrogen ha^{-1} and plant density of 8.33 plants per m^{-2} and at drought stress condition fertilizer treatment of 160 kg nitrogen ha^{-1} and density of 5.55 plants per m^{-2} is recommended.

Refrences

Abbadi, J. and J. Gerendas (2009). Nitrogen use efficiency of Safflower as compared to sunflower. J. Pant Nutrition. Vol. 32(6): 929-945.

Ahmad, S. H., R. Ahmad, M. Y. Ashraf, M. Ashraf and E. A. Waraich (2009). Sunflower (Helianthus annuus L.) response to drought stress at germination and seedling growth stages. Pak. J. Bot. 41(2): 647-654.

Aless, G., G. F. Power and D. C. Zimmerman (1997). Sunflower yield and water use as influenced by planting date, populateion and row spacing. Agron. J. 69: 465-469.

Ali Meo, A. (2000). Impact of variable drought stress and nitrogen levels on plant height, root length and grain numbers per plant in a sunflower (Helianthus annuus L.) Var. Shams. Pah. J. Agri. Sci. Vol. 37(1-2): 89-92.

Allison, J. C. S., and R. J. Haslam(1993). Theoritical assessment of potential for increasing productivity of sugarcane throught increased nitrogen fertilization. Proc. South African Sugar Technol. Assoc. 57-59.

Andria, D., and F. Q. Chiaranda (1995). Yeild and soil water uptake sunflower sown in spring and summer. Agron. J. 87:1122-1128.

Andria, R., F. Q. Chiaranda, V. Magliulo and M. Mori (1995). Yield and soil water uptake of sunflower sown in spring and summer. Agron. J. 87: 1122-1128.

Angadi, S.V., and M. H. Entz (2002). Water relation of standard height and dwarf sunflower cultivars Crop Science. 42:125-159.

Anwar, M., M. Schentier and M. Jones. (1995). Response of sunflower varieties to different irrigation regimes during kharif season in Peshawar valley. Indian Journal of Agriculture. 11(3): 273-278.

Ariy, J. M. (1987). Corn and corn improvement. Academic Press Inc. New York.

Banziger, M., Edmeades, G. O., and H. R. Lafitte (2002). Physiological mechanisms contributing to the increased N stress tolerance of tropical maize selected for drought tolerance. Field Crops Res. 75(2/3):223-233.

Blum. A. (1988). Plant breeding for stress environments. CRC Press. Boca Raton. USA.

Bock, B. R. (1984). Efficient use of nitrogen in cropping system. In Nitrogen in Crop Production. ASA. CSSA, AND SSSA Inc, Madison. USA. 273-294.

Chimenti, C. A., J. Pearson and A. J. Hall (2002). Osmotic adjustment and yield maintenance under drought in sunflower. Field Crop Res. 75: 235-246.

Connor, D. J., Hall, A. J., and V. O. Sadras (1993). Effect of nitrogen content on the photosynthesis characteristics of sunflower leaves. Aust. J. Plant Physiol. 20: 251-263.

Cosculleola, F., and J. M. Fact (1992). Determination of the (*Zea mays L.*) yield function in respect to water using a line source sprink. Field Crop. Abst. 93:5611.

Cox, E., and G. D. Julliff (1988). Growth and yield of sunflower and soybean under soil deficits. Agron. J. 78:226-230.

Daneshian, J., M. R. Ardakani., and D. Habibi (2005). Drought stress effects on yield, quantitative characteristics of new sunflower hybrids. The 2nd international conference on integrated approaches to sustain and improve plant population under drought stress. Roma. Italy.

Daulay, H. S. and K. C. Sing.(1983). A note on the effect of soil moisture of different growth stages of sunflower. Annuals of Arid Zone. 22(2): 169-172.

Dekov, I., T. Tsonev and I. Yordanov (2000). Effects of water stress and high-temperature stress on the structure and activity of photosynthetic apparatus of Zea mays and Helianthus annuus. Photosynthetica. 38(3): 361-366.

Dixon, F. L. and L. Lutema (1992). Effects of drilling date on growth and yield of sunflower in the UK. J. Agri. Sci. 19(2): 197-204.

Duncan, W. G. (1985). A theory to explain the relationship between corn population and grain yield. Agron. J. 24:1141-1145.

Erdem, T., Y. Erdem, A. H. Orta and H. Okursoy (2006). Use of a crop water stress index for scheduling the irrigation of sunflower (Helianthus annuus L.). Turk. J. Agric. For. 30: 11-20.

Fathi, G., G. K. Mc. Donald, and R. C. M. Lance (1997). Effects of post – anthesis water stress on the yield and grain protein concentration of barley grown at two levels of nitrogen Australian journal of Agricultural Reserch., 48:67-80.

Fereres, W., C. Gimenez, and J. M. Fernandez (1986). Genetic variability in sunflower cultivars under drought. Yield relation ships. Aust.J. Agric.Res. 37:573-582.

Flenet, F., A. Boundiols, and C. Suriava (1996). Sunflower response to a range of soil water contents. European Journal of Agronomy. 15: 161-167.

Gardner, F. P., R. B. Piers and R. L. Michel (1994). Agronomy plant physiology Mashhad. JDM press. P: 467 (Translation in Persian).

Gubbels, G. H. and W. Dedio (1999). Effect of plant density and soil fertility on oil seed sunflower genotypes. Can, J, Pl, Sci. 66 (3):521-527.

Hasanzade, A. (2002). The effect of different amounts of Nitrogen fertilizer on yield and yield component and grain oil of sunflower. Uremia. Agri .SCI . Research 2:1:25-33.

Hashemi-Dezfouli, A. and S. J. Herbert (1992).Effect of leaf orientationand density on yield of corn. Iran Agric. Res. 11: 89 - 104.

Human, J. J., D. Dutoit., H. D. Benzuid Enhout, and L. P. Bruyn (1998). The influence of plant water stress on net photosynthesis and yield of Sunflower.Agriculttural University of south Africa. Crop Science. 164(4):231-241.

Jabari, H., Akbari, G., A. Daneshian, J. Alah dadi, I. Shahbazian (2007). effect of water deficit stress on agronomic characteristics of sunflower hybrids. Agri. Res. Spring. 9(1): 13-22.

Jasso de Rodriguez. D., B. S. Phillips, R. Rodrigues-Garcia and J. L. Angulo Sanchez (2002). Grain Yield and fatty acid composition of sunflower seed for cultivars developed under dry land conditions. Agron, 25: 132-142.

Kalamian, S., S. A. M. Modares sanavi and A. Sepehri (2006). Effect on of water deficit at vegetative and reproductive growth stages in leafy and commercial hybrids of maize. Agri. Res. Winter. 5(3): 38-53.

Karam, F., R. Masaad, T. Sfeir, O. Mounzer and Y. Rouphael (2007). Evaptranspiration and seed yield of field grown soybean under deficit irrigation conditions. Agr. Water Manag. 75: 226-244.

Khalifa, F. M. (1984). Effects of spacing on growth and yield of sunflower under two systems of dry-farming in sudan. J. of Agri. Sci. Vol. 103.pp: 213-222.

Killi, F. (2004). Influence of different nitrogen levels on productivity of oilseed and confection sunflowers (Helianthus annuus L.) under varying plant populations. International Journal of Agriculture and Biology. 4: 594-598.

Liang, B. C., M. R. Millard and A. F. Mackenzie (1992). Effects ofhybrid, population densities, fertilization and irrigation on grain corn (*Zea mays U*) in Quebec. Can. J. Plant Sci. 72: 1163 - 1170.

Marinkovic, R. (1999). Path coefficient analysis of some yield components of sunflower. Euphytical. 60:201-205.

Martin, D. L., D. G. Watts, L. N. Mielke, K. D. Frank and D. E. Eisen –Hauer (1992). Evolution of nitrogen and irrigation management for corn production using water high in nitrate. Soil Sci. Soc. Amer. J. 49: 1056 - 1062.

Mathers C. and B. A. Stewart (1982). Sunflower nutrient uptake, growth, and yield as affected by nitrogen or manure, and plant population. Published in Agron J. 74: 911-915.

Mishra, A., P., Dash, and R. K. Paikaray.(1995). Yield and nutrient uptake by winter sunflower (*Helianthus annuus*) as influenced by nitrogen and phosphorus. Indian Journal of Agronomy, 40: 137-138.

Muchow, R. C, and R. Davis (1988). Effect of nitrogen supply on the comparative productivity of maize and sorghum in a semi-arid tropical environment II. adiation interception and hiomass accumulation. Field Crops Res. 18: 17-30.

Nautiyal, P. C., N. R. Rachapuyi and Y. C. Joshi (2002). Moisture-deficit-induced changes in leaf water content, leaf carbon exchange rate and biomass production in groundnut cultivars differing in specific leaf area. Field Crop Research. 74: 67-79.

Nezami, A., H. R. Khazaei, Z. Boroumand Rezazadeh and A. Hosseini (2008). Effects of drought stress and defoliation on sunflower (Helianthus annuus L.) in controlled conditions. Desert online at http://jdesert.ut.ac.ir. Desert. 12: 99-104.

Pandey, R. K., J. W. Marienville and A. Adum. (2000). Deficit irrigation and nitrogen effect on maize in a sahelian environment. I. Grain yield components. Agric. Water Management. 46: 1-13.

Radford. P. J. (1986). Genetic variability in sunflower cultivars under drought. II. Growth and water relations. Aust. J. Res. 37:583-598.

Robinson, R. G., j. H. Ford , W. E. Lueschen, D. L. Rabas, L. J. Smith, D. D. Warnes,and J. V. Wiersma (1980). Response of sunflower to plant population. Agron. J. 72:869-871.

Robinson,R. G., J. H. Ford., W. E. Lueschen, D. L. Rabas, D. D. Warnes, and J. V. Wiersma (1985). Response of sunflower to uniformity of plant spacing. Agron. J. 74:363-365.

Roshdi, M., H. Heydari Sharifabad, M. Karimi, GH. Nourmohammadi and F. Darvish (2006). A Syrvey on the impact of water deficiency over the yield of sunflower seed cultivar and its components. J. Agri. Sci. 12(1): 109-121.

Sadras, V. O., D. J. Cannor and D. M. Whitfield(1998). Yield, yield components and source-sink relationships in water-stressed sunflower. Field Crop Res. 31:27-39.

Saneoka, H., R. E. A. Moghaieb, G. S. Premachandra and K. Fujita (2004). Nitrogen nutrition and water stress effects on cell membrance stability and leaf water relations in Agrostis palustris Huds. Environment and Experimental Botany. 52: 131-138.

Schneiter, A. A., B. L. L. Janson and T. L. H. Enerson (1992). Rooting depth and water use of different sunflower pheotypes. Pro. 13. Lnt. Sunf. Pisa. Italy.

Setter, T. L. (1990). Transport / harvest index: Photosynthetic partitioning in stressed plants. P. 17-36. Stress responses in plant: Adaptation and accumulation mechanism. Wiley-Liss, Inc. New York. 14853.

Singh, A. and A. H. Khan (1991). Defoliation and yield efficiency in sunflower. National Academy Sci. Letters. 4(8):311-312.

Singh, G. R., K. K. Choudhary, N. K. Chaure and K. S. Pandya (1996). Effect of seed bacterization and nitrogen level on soil properties, yield parameters, yield and economice of sunflower *(Helianthus annuus*). Indian Journal of Agricultural Science. 66: 250-252.

Singh, V., S. K., Sharma, B.I . Verma and V. Singh, (1995). Response of rainy season sunflower *(Helianthus annuus*) to irrigation and nitrogen under north western Rajasthan. Indian Journal of Agronomy. 40: 239-242.

Taghdiri, B., G. Ahmadvan and H. A. Mazaheri Laghab (2006). The effect of plant spacing on yield and yield components of four sunflower cultivars. Agri. Res. 6(1): 26-35.

Tayzer, L. and E. Zinger. (1999). Plant Physiology. Mashhad. JDM press. P: 456. (Translated in Persian).

Tiyar, I. D., and M. M. Pit (1994). Related of water and soil in Agronomy plant. Mashhad. JDM press. p:560.

Uhart, S. A., and F. H. Andrade (1995). Nitrogen deficiency in maize: II. Carbon-nitrogen interaction effects on kernel number and grain yield. Crop Sci. 35: 1384-1389.

Ulusoy, E. (2001). Objectives of agricultural techniques in changing conditions and conceptions in 2000 years. In 20 National Agricultural Mechanization Congress. Sanliurfa, Turkey.

Unyayar, S., Y. Keles and E. Unal (2004). Proline and ABA levels in two sunflower genotypes subjected to water stress. Bulg. J. Plant Physiol. 30(3-4): 34-47.

Westgate, M. E. (1994). Water status and development of the maize endosperm and embryo during drought. Crop Sci. 34: 76-83.

Yegappan, T. M., D. Paton, C. T. Gates, and W. Muller (1982). Water stress in sunflower (response of cyptla size). Annuals of Botany. London. 49: 63-68.

Zaffaroni, E. and A. A. Schneiter (1991). Sunflower production as influenced by plant type, plant population, and row arrangement. Agron. J. 63:113-118.

Zaman, A. and P. K. Das (1991). Effect of irrigation and nitrogen on yield and quality of sunflower. Indian Journal of Agronomy, 36:177-179.

Zubriski, J. C. and O. C. Zimmerman. (1991). Effects of nitrogen, phosphorus and plant density on sunflower. Agron, J. 66:798-801.