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THE EFFECT OF IRRIGATION AND NITROGEN TOP-DRESSING PATTERN ON YIELD AND GROWTH OF SUNFLOWER

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SUMMARY

In order to study the effect of irrigation (I_0: optimum irrigation, I_V and I_R: water stress during vegetative and reproductive stages, respectively) and nitrogen (N_1: 25% at planting, 50% at eight-leaf stage and 25% at head appearance; N_2: 50% at eight leaf stage and 50% at head appearance; N_3: 50% planting and 50% head appearance) on yield and growth of sunflower, a split-plot experiment was conducted in 2011 and 2012. Average cross years, I_V and I_R caused a significant reduction of final dry leaf (20.4 and 34.5%), stem (40.5 and 45.7%) and total weight (25.9 and 28.0%) and also a significant reduction of the grain yield as much as 14.8% and 13.3% in comparison to I_0. N_1 caused a significant 25 and 14% reduction of the leaf area index in comparison to N_3 and N_2; however, the grain yield was not significantly different in N_3 and N_2 in both years. In I_0, N_3 caused a significant 34.8% increase of final dry weight of the leaf and an insignificant increase of dry weight of stem and the total weight as much as 30.9% and 16.3%, respectively and also a significant 16.4% reduction of the grain yield in comparison to N_2. On the whole, N_2 treatment in different irrigation regime caused a higher grain yield in comparison to N_1 and N_3, but N_3 treatment in I_0, and N_1 in I_V and I_R reduced the grain yield.

Key words: **dry matter, irrigation, grain yield, nitrogen top-dressing, sunflower**

INTRODUCTION

Sunflower is relatively tolerant to water stress. Pejić *et al.* (2009) reported that no significant differences in yield of sunflower were observed between irrigated treatment, in which irrigation was used when soil moisture levels dropped to 60-65% of FC (field capacity), and a non-irrigated control treatment when irrigation was not applied from flowering to maturity. However, Hussain *et al.* (2012) reported that growth and yield of sunflower were severely reduced by limited irrigation, when irrigation was withheld at the bud initiation. These examining growth indices in

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analyzing the factors influencing sunflower yield are of great importance (Parmar and Chanda, 2002). By studying the production and partitioning of dry matter and growth indices, it is possible to interpret the reaction of sunflower towards irrigation and nitrogen and their interaction during the growth and also to get to know the plant growth trend better in every region (Mojaddam *et al.*, 2012). Considering the optimum amount of nitrogen and its top-dressing pattern during the growth season in proportion to irrigation regime and the interaction between these two factors, it has a particular importance in minimizing the environment pollution, reducing the costs, and achieving the optimum yield (Jalalian *et al.*, 2012). It seems that true management in using nitrogen in different conditions of soil moisture is one of the most important farming issues which has considerable effects on the growth indices of sunflower, so that by choosing the right amount of nitrogen and appropriate management during its distribution in relation to various moisture conditions, it is possible to achieve a balanced combination of growth indices in plant community (Mojaddam *et al.*, 2012). This research is conducted with regard to the current challenges in the region in terms of using nitrogen and lack of proper management during its consumption and it tries to study the interaction effect of this factor and water stress on physiological indices of growth, as well as intends to offer a way for proper utilization of nitrogen and water.

MATERIALS AND METHODS

This research was conducted in Omidiye-Iran (latitude: 49°41'; longitude: 30°44'; altitude: 27 meters) with hot and dry climate. The average temperature of the coldest and the hottest month of the year and precipitation are -2°C, 52°C and 274 mm per year. The experiment location had a sandy loam soil with Ec of 4.2 dS/m and pH of 7.6. The soil organic matter was 0.7% and the amount of nitrogen, potassium, and phosphorus was 5.2 (poor), 108 (rich), 63 (good) parts per million, respectively. The sunflower hybrid used in the study was Iroflor that is bred by Plant Breed Institute of Iran. The experiment was carried out based on randomized complete block design with split-plot arrangement in 3 replicates. Irrigation treatment was considered as the main factor and the nitrogen top-dressing pattern as the sub-factor. Irrigation treatment was performed at three levels: optimum irrigation (I_0), exercising water stress from eight-leaf stage until head appearance (I_V) and exercising water stress from head appearance to maturity. In moderately irrigated (I_0) and water stressed plots, irrigation was done after 50 and 120 mm evaporation from class A pan, respectively. Soil moisture was 25% and 75% of the available soil water content (FC_WP) in moderate irrigated (I_0) and water stress plots, respectively. In all three levels of nitrogen top-dressing pattern, 120 kg nitrogen per hectare was equally used but in different stages of plant growth: at the first level, 25% nitrogen was applied in the planting stage, 50% in the eight-leaf stage, and 25% in the head appearing stage; at the second level, 50% nitrogen was applied in the eight-leaf stage, and 50% in the head appearing stage, and at the third level, 50% nitrogen was used in the planting stage and 50% in the head appearing stage. Experimental plots had eight planting rows as long as 6 meters and a distance of 75 cm between rows. The distance between the bushes on planting lines was 15 cm after thinning and the depth of planting was 3 cm. The density of 9 plants per square meter was considered. At the end of the growing season, the amount of yield and its components was measured by the surface harvest of 1 meter area on 6 central rows of each plot. In this research 5 samples were totally taken. The first sample was taken 21 days after planting and it was repeated in 14-day intervals that are 35, 49, 63, and 85 days after planting. In each sample, 30 plants were harvested on 6 central rows of each plot. The samples were separated into leaves, stems, and heads. After measuring the leaf area, samples were placed in a 72°C oven for 48 hours and were weighed after they dried. To calculate the components of growth analysis the following formulas were applied respectively:

Net Assimilation Rate: $CGR = NAR \times LAI \Rightarrow NAR = \frac{CGR}{LAI}$

Crop Growth Rate: $CGR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{1}{GA}$

Where:

GA= Ground Area;

T = time;

w_1 and w_2 = dry weight of primary and secondary sample, respectively.

Data analysis was carried out by SAS software and by drawing diagrams with Excel and the means were compared by Duncan's multiple range tests at 5% level.

RESULTS

Irrigation

I_V and I_R caused a significant reduction of grain yield (2011: 13.1 and 8.6%; 2012: 16.7 and 30.5%) and total biomass at maturity (2011: 25.3 and 27.1%; 2012: 26.4 and 28.9%) and increase of harvest index (2011: 14.0 and 20.0%; 2012: 11.9 and 13.4%) in comparison to I_0 (Table 3), the effect of year × irrigation was not significant for these two traits (Table 1).

Table 1: The mean squares of ANOVA for grain yield (GY), total biomass at maturity (TB), grains per head (GPH), 100 grain weight (GW) and harvest index (HI) in combined analysis of 2010 and 2011 data

S.O.V	DF	GY	TB	GPH	GW	HI
Y	1	NS	NS	NS	NS	NS
W	2	**	**	NS	**	**
YW	2	NS	NS	NS	NS	NS
N	2	**	**	**	NS	*
WN	4	*	*	NS	*	NS
YN	2	**	**	**	NS	*
YWN	4	NS	NS	NS	NS	NS

** P<0.01; * P<0.05; ns P>0.05

(Note: Y-year effect; W-water regime effect; N-nitrogen dividing pattern).

Table 2: The simple effect of irrigation and nitrogen on dry weight of leaf (LDW), stem (SDW), head (HDW), total dry weight (TDW), leaf area index (LAI), crop growth rate (CGR) and net assimilation rate (NAR) for pooled data of 2010 and 2011

	Leaf dry weight (g m^{-2})					Stem dry weight (g m^{-2})					Head dry weight (g m^{-2})				
	Days after planting					Days after planting					Days after planting				
	21	35	49	63	85	21	35	49	63	85	21	35	49	63	85
I_0	17.6^{a}	94.2^{a}	156.4^{ab}	229.3^{a}	216.2^{a}	6.4^{a}	76.2^{a}	165.3^{a}	264.8^{a}	282.5^{a}	-	8.8^{a}	110.9^{a}	315.5^{a}	563.6^{a}
I_V	16.9^{a}	69.6^{a}	102.2^{b}	175.1^{b}	172.1^{b}	5.8^{a}	54.8^{a}	88.0^{b}	187.6^{b}	168.2^{b}	-	6.3^{a}	51.7^{b}	233.7^{b}	446.4^{b}
I_R	15.2^{a}	86.9^{a}	160.2^{a}	141.5^{b}	145.5^{b}	5.3^{a}	67.8^{a}	175.1^{a}	218.6^{ab}	153.4^{b}	-	7.7^{a}	124.2^{a}	262.2^{ab}	469.2^{b}
N_1	16.5^{a}	87.8^{a}	172.4^{a}	200.0a	152.4^{b}	5.7^{a}	69.4^{a}	162.6^{a}	232.0^{a}	187.4^{a}	-	7.8^{a}	108.7^{a}	268.4^{a}	458.6^{a}
N_2	16.9^{a}	83.7^{a}	146.6^{a}	176.8a	173.9^{ab}	6.3^{a}	65.0^{a}	126.2^{a}	211.5^{a}	189.7^{a}	-	6.9^{a}	91.8^{a}	261.3^{a}	511.2^{a}
N_3	16.3^{a}	79.2^{a}	145.7^{a}	200.0a	203.5^{a}	5.5^{a}	64.4^{a}	139.5^{a}	227.5^{a}	227.1^{a}	-	8.2^{a}	86.3^{a}	281.7^{a}	509.4^{a}
	Total dry weight (g m^{-2})					Leaf area index					Net assimilation rate (g m^{-2} day^{-1})				
I_0	24.0	179.2^{a}	432.6^{a}	809.7^{a}	1062.6^{a}	0.17^{a}	1.1^{a}	1.7^{ab}	2.3^{a}	1.7^{a}	-	10.1^{a}	10.2^{a}	11.8^{a}	10.4^{a}
I_V	22.7^{a}	130.8^{a}	241.9^{b}	596.4^{b}	786.5^{b}	0.17^{a}	0.8^{a}	1.1^{b}	1.7^{b}	1.4^{b}	-	9.4^{a}	6.9^{b}	8.5^{b}	7.8^{b}
I_R	22.7^{a}	162.5^{a}	505.6^{a}	653.3^{b}	764.2^{b}	0.15^{a}	1.0^{a}	2.3^{a}	1.7^{b}	1.1^{b}	-	10.1^{a}	10.8^{a}	5.5^{c}	6.6^{b}
N_1	20.5^{a}	165.0^{a}	443.8^{a}	700.4^{a}	874.9^{ab}	0.16^{a}	1.0^{a}	1.9^{a}	2.0^{a}	1.2^{b}	-	9.9^{a}	9.6^{a}	9.1^{b}	4.3^{b}
N_2	22.2^{a}	155.6^{a}	364.7^{b}	649.7^{a}	786.5^{b}	0.16^{a}	0.9^{a}	1.6^{a}	1.8^{a}	1.4^{ab}	-	9.6^{a}	8.6^{a}	11.0^{a}	10.9^{a}
N_3	23.2^{a}	151.8^{a}	371.6^{ab}	709.3^{a}	940.3^{a}	0.16^{a}	0.9^{a}	1.6^{a}	2.0^{a}	1.6^{a}	-	10.0^{a}	9.4^{a}	11.4^{a}	9.6^{a}
	Crop growth rate (g m^{-2} day^{-1})														
I_0	-	11.1^{a}	18.1^{a}	26.9^{a}	18.0^{a}										
I_V	-	7.7^{b}	7.9^{b}	25.3^{a}	13.2^{b}										
I_R	-	10.1^{a}	17.5^{a}	10.5^{b}	7.9^{c}										
N_1	-	10.2^{a}	19.9^{a}	18.3^{b}	6.6^{b}										
N_2	-	9.4^{a}	14.9^{b}	20.3^{ab}	16.5^{a}										
N_3	-	9.2^{a}	15.7^{b}	24.1^{a}	16.5^{a}										

I_0: optimum irrigation, I_V and I_R: water stress during vegetative and reproductive stages, respectively. N_1: 25% nitrogen at planting, 50% at eight-leaf stage and 25% at head appearance; N_2: 50% nitrogen at eight leaf stage and 50% at head appearance; N_3: 50% nitrogen at planting and 50% at head appearance

The number of grains per head was not affected by irrigation regimes in both years, while I_V and I_R caused a significant reduction of 100 grain weight from 7.0 to 6.5 g (Table 3).

Table 3: The simple effect of irrigation and nitrogen on grain yield (GY), grains per head (GPH), grain weight (GW), harvest index (HI) and biomass at maturity (BM) for separate data of 2010 and 2011

	Grain yield		Grains per head		100 Grain weight		Harvest index		Biomass at maturity	
	GY (g m^{-2})		GPH		GW (g)		HI (%)		BM (g m^{-2})	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
I_0	267^a	311	536.0^a	521.2^a	7.0^a	7.1^a	25.1^b	24.4^b	1062^a	1061^a
I_V	232^b	259^a	493.5^a	467.5^a	6.6^b	6.6^b	29.2^{ab}	27.7^a	794^b	778^b
I_R	244^b	216^b	526.1^a	468.2^a	6.5^b	6.5^b	31.5^a	28.2^a	774^b	754^b
N_1	240^b	213^b	497.0^a	478.1^a	6.8^a	7.2^a	30.0^a	25.5^a	800^b	942^a
N_2	301^a	241^a	560.2^a	376.5^b	6.5^a	6.9^a	29.5^a	32.9^a	1020^a	552^b
N_3	237^b	182^b	498.4^a	506.1^a	6.8^a	7.0^a	26.4^a	25.0^b	897^b	991^a

I_0: optimum irrigation, I_V and I_R: water stress during vegetative and reproductive stages, respectively.
N_1: 25% nitrogen at planting, 50% at eight-leaf stage and 25% at head appearance;
N_2: 50% nitrogen at eight leaf stage and 50% at head appearance;
N_3: 50% nitrogen at planting and 50% at head appearance

Dry weight of leaf (LDW) and stem (SDW) during the growth period was significantly affected by irrigation (Table 2). LDW and SDW was the same in all three levels of irrigation until about 35 days after planting (Figures 1 and 2), because I_V was exercised 28 days after planting. In 35th day after planting, the difference between irrigation levels gradually increased (Figures 1 and 2), so that there was a significant difference between irrigation treatments in terms of LDW and SDW since one week after exercising the I_V until the maturity (Table 2). Average cross years, exercising I_V and I_R led to significant decrease of final dry weight of leaf (20.4 and 32.7%), stem (40.5 and 45.7%), head (20.8 and 16.7%), total weight (26.0 and 28.1%), leaf area index (17,6 and 35.3%) and grain yield (15.0 and 20.4%) in comparison to I_0 and there was no difference between I_R and I_V in terms of these traits expect for leaf area index (Table 2). I_R was exercised concurrent with the third sampling 49 days after planting. I_V caused a slower trend of weight increase of stem and leaf in comparison to I_0, while I_R caused a rapid decrease of SDW and LDW at 49 and 63 days after planting, respectively (Figures 1, 2). The head appeared 35 days after planting and there was a slow increase of weight in all three levels of irrigation until 49 days after planting (Figure 3). Changes of total dry weight (TDW) in early stages of growth were very few and there was no significant difference between irrigation levels (Figure 4). The highest crop growth rate (CGR) within 63 days of planting belonged to the I_0 (Figure 8). In I_R and I_V the CGR considerably decreased (Table 2). The net absorption rate (NAR) decreased in drought stress and in final stage 85 days after planting (Figure 9); the highest reduction was related to I_R which was not significantly different from I_V (Table 2).

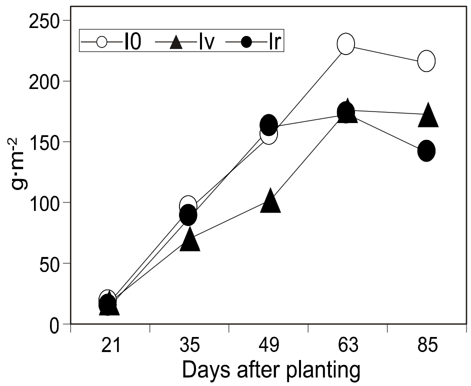

Figure 1: The effect of irrigation (I) on sunflower dry weight of leaf (LDW) (pooled data of 2011 and 2012)

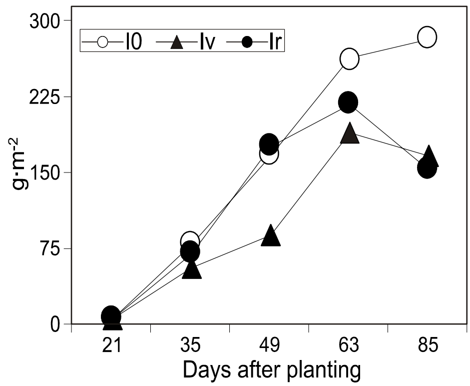

Figure 2: The effect of irrigation (I) on sunflower dry weight of stem (SDW) (pooled data of 2011 and 2012)

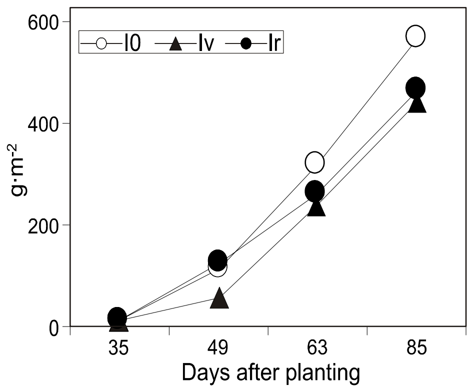

Figure 3: The effect of irrigation (I) on sunflower dry weight of head (HDW) (pooled data of 2011 and 2012)

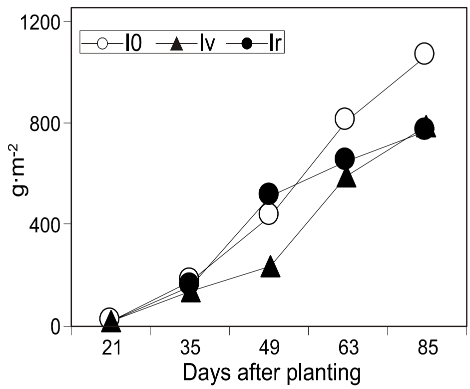

Figure 4: The effect of irrigation (I) on sunflower total dry weight (TDW) (pooled data of 2011 and 2012)

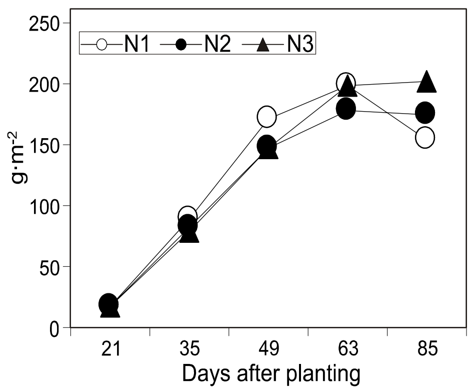

Figure 5: The effect of nitrogen (N) on sunflower dry weight of leaf (LDW) (pooled data of 2011 and 2012)

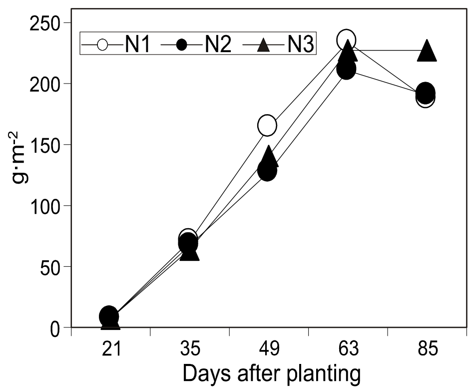

Figure 6: The effect of nitrogen (N) on sunflower dry weight of stem (SDW) (pooled data of 2011 and 2012)

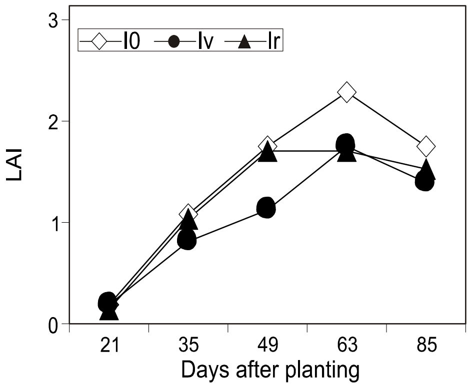

Figure 7: The effect of irrigation (I) on sunflower leaf area index (LAI) (pooled data of 2011 and 2012)

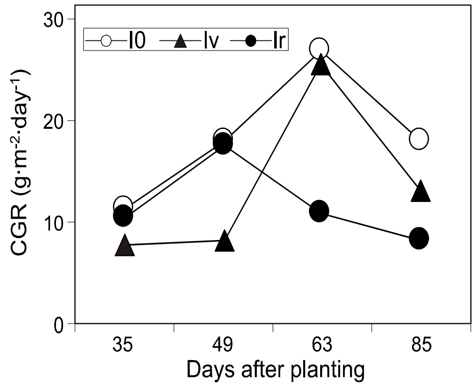

Figure 8: The effect of irrigation (I) on sunflower crop growth rate (CGR) (pooled data of 2011 and 2012)

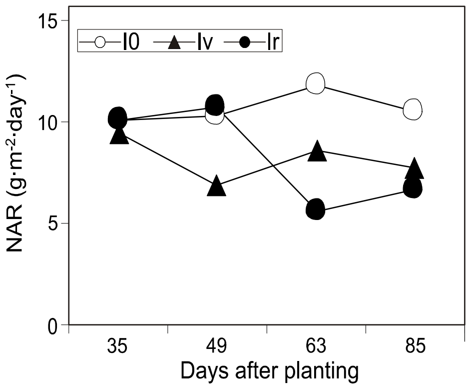

Figure 9: The effect of irrigation (I) on sunflower net assimilation rate (NAR) (pooled data of 2011 and 2012)

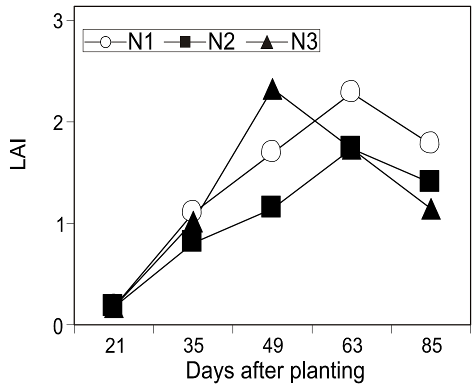

Figure 10: The effect of nitrogen (N) on sunflower leaf area index (LAI) (pooled data of 2011 and 2012)

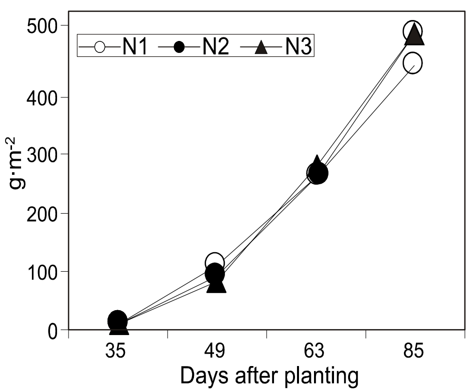

Figure 11: The effect of nitrogen (N) on sunflower dry weight of head (HDW) (pooled data of 2011 and 2012)

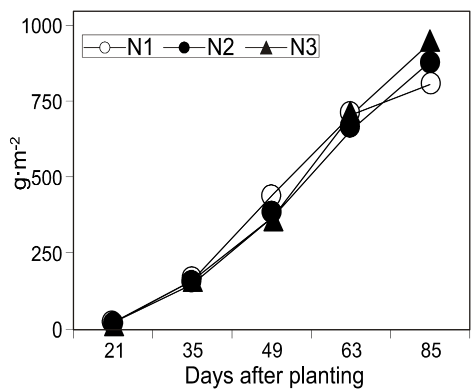

Figure 12: The effect of nitrogen (N) on sunflower total dry weight (TDW) (pooled data of 2011 and 2012)

Nitrogen

The curve of LDW and SDW during the growth season shows that in fertilizer treatments the rate of weight increase is very slow in early stages then goes upward and increases, so that the maximum amount of LDW and SDW is obtained 63 days after planting (Figures 5, 6), but then the photosynthetic matters in leaf and stem move towards the grain and head because of the quick growth of grain and the accumulation of dry matter in head increases (Figure 11), which consequently increases the TDM (Figure 12). The effect of nitrogen top-dressing pattern on LDW and TDW was significant only 85 days after planting (Table 2). Average cross years, N_1 caused a significant reduction of the TDW and the LDW as much as 25.1% and 15.1%, respectively in comparison to N_3 (Table 2). However, the grain yield did not significantly change compared to N_3 in both years (Table 3). The effect of nitrogen division and its interaction with the year was significant (Table 1). In 2010, N_2 resulted to 20.0 and 27.0% higher grain yield (GY) and 21.5 and 12% higher total biomass at maturity (TB) compared to N_1 and N_2 (Table 3). However, in 2011, N_2 had significantly lower GY and TB compared to N_3 and N_1 (Table 3). It could be due to low N content of the soil at the beginning of the second growing season and lack of nitrogen application in this treatment during planting. Nitrogen top-dressing pattern did not have a significant effect on the SDW and HDW even until the end of growing season (Figures 6 and 11). However, N_3 treatment which had not consumed nitrogen in 8 leaf stage had 20% lighter dry weight than N_1 treatment which had consumed 50% nitrogen in this stage (Table 2). In N_2, nitrogen was not used in planting stage and in spite of using nitrogen in 28 (8 leaf) and 49 days after planting (14 days after head appearing), the increase of LDW from 49 days after planting until the end of growing season was less than that of two other nitrogen treatments which had received nitrogen in planting stage (Figure 5). In N_3 treatment, lack of nitrogen in the 8-leaf stage did not reduce the increase of LDW (Figure 5). In N_1 treatment, which had a lighter LDW at the end of growing season, HDW was also lighter than other nitrogen treatments (Figures 5, 11). The leaf area index was the same in all three levels of nitrogen until 21 days after greening, because nitrogen top-dressing pattern was used 10 days after planting and the fertilizers did not have enough time to affect it, gradually the difference among fertilizer levels increased (Figure 10). LAI was significantly affected by fertilizer treatment in the final stage while the grain yield was not affected significantly (Tables 1, 2). N_1 top-dressing pattern caused a significant 25% reduction of final LAI in comparison to N_3 (Table 2). Although there was not a significant difference between N_2 and N_3 treatments in terms of their effect on LAI (Table 2). CGR in N_2 and N_3 in final stage 85 days after planting stage was more than that of N_1 which can be interpreted as the superiority of accumulation of dry matter and greater LAI in N_2 and N_3 treatments (Table 2; Figures 10 and 13). The changes of net absorption rate during the growing season were affected by fertilizer treatments (Figure 14). At maturity, the highest decrease of net absorption rate was related to N_1 and there was not much difference between N_2 and N_3 (Table 2).

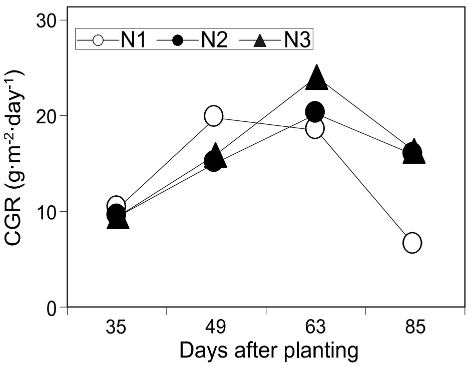

Figure 13:The effect of nitrogen (N) on sunflower crop growth rate (CGR) (pooled data of 2011 and 2012)

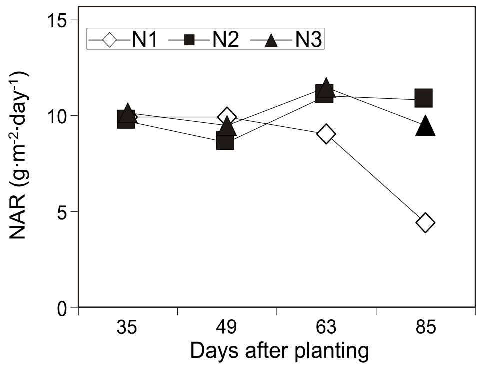

Figure 14:The effect of nitrogen (N) on sunflower net assimilation rate (NAR) (pooled data of 2011 and 2012)

Irrigation × Nitrogen

LDW, SDW and TDW and LAI and GY were affected by irrigation and nitrogen interaction (Table 4). In I_0, N_3 caused a significant 34.8% increase of LDW and an insignificant increase of SDW and TDW as much as 30.9% and 16.3% respectively and also a significant 27.1% reduction of the grain yield in comparison to N_2 (Table 4). In I_V, N_1 significantly decreased the LDW (43.7 and 40.4%), SDW (38.5 and 44.1%), and TDW (28.6 and 29.9%) and insignificantly decreased the grain yield as much as 12 and 13% in comparison to N_2 and N_3, respectively (Table 4). N_2 and N_3 treatments did not have any significant differences statistically (Table 4). In I_R, nitrogen top-dressing pattern had no effect on LDW, SDW, TDW and grain yield (Table 4).

Table 4: The interaction effect of irrigation and nitrogen on dry weight of leaf (LDW), stem (SDW), head (HDW), total dry weight (TDW) at maturity and grain yield (GY) for pooled data of 2011 and 2012

		LDW	SDW	HDW	TDW	GY (Mean)
		($g\ m^{-2}$)	($g\ m^{-2}$)	($g\ m^{-2}$)	($g\ m^{-2}$)	($g\ m^{-2}$)
I_0	N_1	200.6^{ab}	287.7^{a}	553.7^{a}	800.0^{a}	279.4^{a}
	N_2	176.5^{b}	228.6^{a}	572.4^{a}	738.7^{a}	280.7^{a}
	N_3	271.4^{a}	331.3^{a}	564.6^{a}	890.7^{a}	204.6^{b}
I_V	N_1	115.8^{b}	114.3^{b}	387.3^{a}	626.6^{a}	204.1^{a}
	N_2	206.1^{a}	185.8^{a}	471.3^{a}	501.3^{b}	237.8^{a}
	N_3	194.4^{a}	204.5^{a}	480.6^{a}	661.3^{a}	232.2^{a}
I_R	N_1	140.7^{a}	160.2^{a}	434.7^{a}	674.7^{a}	228.3^{a}
	N_2	139.2^{a}	154.7^{a}	489.9^{a}	709.3^{a}	243.2^{a}
	N_3	144.6^{a}	145.4^{a}	482.9^{a}	576.0^{b}	250.3^{a}

I_0: optimum irrigation, I_V and I_R: water stress during vegetative and reproductive stages, respectively.
N_1: 25% nitrogen at planting, 50% at eight-leaf stage and 25% at head appearance;
N_2: 50% nitrogen at eight leaf stage and 50% at head appearance;
N_3: 50% nitrogen at planting and 50% at head appearance

DISCUSSION

The increase of vegetative and reproductive growth increased the dry weight in I_0 (Table 1), while the decrease of LAI and NAR decreased the dry substance in I_R and I_V which consequently resulted in reduction of grain yield (Figures 7, 9). In I_R and I_V, variation of CGR was affected by variation of LAI and NAR, but variation of CGR in nitrogen levels was affected by variation of LAI. This is also reported by Mojaddam *et al.* (2012).

Results from the I_0N_3 treatment sounds that in I_0, the consumption of 50% of nitrogen in planting stage has increased the vegetative growth and production of dry matter which has disrupted the reproductive growth and transmission of photosynthetic materials of the grains. Ozer *et al.* (2004) and Oyinlola *et al.* (2010) reported that high N availability may shift the balance between vegetative and reproductive growth toward excessive vegetative development, thus delaying crop maturity and reducing seed yield.

In N_1 top-dressing pattern when the plant faced drought stress, the lack of water reduced the absorption of nitrogen and its transmission to photosynthetic organs and also decreased the assimilate and thus decreased the production of shoots (Hu *et al.*, 2009; Gholinezhad *et al.*, 2009), which in turn led to the decrease of biomass and the grain yield (Table 4). In I_VN_2 treatment, the use of nitrogen in 8-leaf stage and when the plant faced drought stress disrupted the absorption of nitrogen by the plant and slowed down the increase of LAI rapidly. Considering the direct relation which is reported between the leaf index and the grain yield (Mojaddam *et al.*, 2012), it could be stated that by the reduction of LAI, HDM and the grain yield have decreased in this treatment (Table 4). The limits of nitrogen absorption and the reduction of positive effects of using nitrogen during the decrease of soil moisture have been reported by other researchers (Gholinezhad *et al.*, 2009). On the whole, N_2 treatment in different irrigation regimes caused more increase of grain yield, but N_3 in I_0 and N_1 treatment in I_R and I_V irrigations are not recommended.

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