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Effects of drought stress and defoliation on sunflower (*Helianthus annuus*) in controlled conditions

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Abstract

In order to evaluate the effects of drought stress and defoliation on sunflower, a study was conducted under controlled conditions. Treatments were a combination of three levels of drought ((100, 60 and 30 percent of Field Capacity (FC)) and three levels of defoliation (control, removal of either 4 or 6 leaves from lower part of the plant) laid out, in a Completely Randomized Design with four replications. Drought stress was applied from 4-leaf- stage up to the end of plant growth period while leaf removal was conducted at the heading stage. Results indicated that drought stress affected most of the measured parameters. Plant height, plant dry matter, stem diameter, head size, seed number/head, 100-seed weight and seed weight/ head declined upon drought stress as compared to control. SPAD readings increased as drought stress increased. Defoliation caused an increase in SPAD and a decrease in seed number/head. Leaf number was not affected by either drought or defoliation.

Keywords: Defoliation; Drought stress; Plant height; Seed weight; Sunflower

1. Introduction

Sunflower is one of the most important oil crops and due to its high content of unsaturated fatty acids and a lack of cholesterol, the oil benefits from a desirable quality (Razi, H. and M.T. Asad, 1998). 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 tolerance of short periods of water deficit, are useful traits of sunflower for producing acceptable yields in dryland farming. On the other hand, some evidences have indicated that stress during vegetative phase, flowering or seed filling period causes considerable decrease in yield and oil content of sunflower (Razi, H. and M.T. Asad, 1998). Vivek and Chakor (1994) found that plant height, leaf area index and number of green leaves were reduced with no irrigation compared to irrigation as treatments of IW:CPE, IW:CPE 0.6 and IW:CPE 0.3[1]. In an experiment on 14 cultivars of sunflower, Razi and Asad (1994) indicated that irrigation led to an increase in days to physiological maturity, head size, stem diameter, number of leaves per plant, plant height, 1000-seed weight, seed yield and harvest index. Also drought stress at flowering stage was observed to be a limiting factor for seed filling, so significant reduction of unfilled seeds was observed as a result of irrigation. D'Andria *et al.* (1995) concluded that yield components of sunflower were affected by irrigation treatments. In their experiment, treatments with two or three times of irrigation during growing season produced higher seed weight as compared to control (no irrigation).

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1 - Irrigation Water: Cumulative Pan Evaporation ratio

Abolhasani and Saeedi (2004) evaluated 15 genotypes of sunflower in two irrigation regimes based on 50 and 85% depletion of soil moisture content and observed that the highest positive correlation between measured variables and yield was related to seed number per head, plant height and days to maturity, and while among these, seed number was the most important criterion for yield improvement in either stressed or unstressed condition.

There is contrasting information on the effects of drought stress on leaf chlorophyll content. De souza *et al*. (1997) found that there was no significant difference in leaf chlorophyll content of soybean between irrigations of field capacity and 60% of field capacity, but irrigation at 30% of field capacity caused a significant reduction in leaf chlorophyll and nitrogen content. In contrast, Ommen *et al.* (1994) found a significant increase in wheat leaf chlorophyll content during anthesis under drought stress.

Leaf area loss (as a result of either hail or pests and diseases) is one of the factors loading to crop yield reduction. Yield loss is affected by intensity and stage of defoliation (Schneite *et al.*). Ball *et al*. (2000) reported that limitation of assimilates in seed filling period as a result of shading or pest damages (reduction of leaf area) will lead into yield reduction. Schneiter *et al.* (1987) found that most part of the sunflower yield reduction was due to the leaf losses. Also Schneiter and Johnson (1994) reported that removal of leaf bud or leaves on the ⅓ of upper part of sunflower in the flowering stage caused considerable yield reduction.

The objective of this experiment was to investigate sunflower responses to drought stress and defoliation in controlled conditions.

2. Materials and Methods

This experiment was carried out in the experimental glasshouses of the Faculty of Agriculture, Ferdowsi University of Mashhad in 2004. Drought stress was induced at three levels of 100 (control), 60 and 30% field capacity Defoliation covered three levels of control, removal of 4 and 6 leaves from the lower part of the plant. Five seeds of sunflower (Chernianka cultivar) were planted in 6 liter plastic pots containing soil/sand/leaf mould mixture (1:1:1 in volume). They were thinned to two plants per pot at 2-3 leaf stage.

For determination of soil moisture content in FC, pots were saturated and kept for 48 hours to let the gravimetric water be drained and then pots were weighed. The difference between pot weight after 48 hours with initial pot weight (before saturation) was considered as soil water content in FC. Drought stress was imposed from 4-leaf stage of seedling to the end of the growth period. In 100% FC treatment, individual pots were weighed, water added to bring the soil to the FC. For 60 and 30% FC treatments, pots received 60% and 30% of water added to the 100% FC treatment, respectively. Defoliation was imposed five weeks after emergence coincided with the head-visible stage. Confidor pesticide was used to control white fly and aphid as necessary.

Chlorophyll concentration was assessed using a chlorophyll meter (SPAD-502, Minolta), measurements being taken at three points of each leaf (upper, middle and lower part). Average of these three readings was considered as SPAD reading of the leaf. Recording of SPAD readings was carried out weekly from 10 days after defoliation, in the 7th leaf to the top of the plant. Plant height, number of leaves per plant, base stem diameter and head size were recorded at the end of the growth period and before harvest. Dry matter, 100-seed weight, number and weight of filled seeds per head were evaluated after harvesting.

The experiment was laid out in a factorial arrangement based on a Completely Randomized Design with 4 replications. Statistical analysis was carried out through MSTAT-C and SigmaStat while drawing graphs was done by using SigmaPlot. Means of variables were compared by Duncan's test at a significance level of 0.05.

3. Results and discussion

Plant height was significantly affected by stress treatments (Table 1). Increasing drought stress resulted in decrease in plant height, so the highest (58.2 cm) and the lowest (35.0 cm) values were obtained in 100 and 30% FC, respectively (Table 2). Riahi nia (2003) in his experiment on sunflower, cotton, bean and maize also came to similar results. D´Andria *et al*. (1995) in a two-year experiment on sunflower observed that plant height was increased in the first year by increasing the irrigation frequency, whereas no significant difference was observed during the second year among irrigation treatments. Likely, drought stress has led to reduction in stem cells' water potential to a lower level needed for cell elongation and consequently shorter internodes and stem height. Defoliation had no effect on plant height (Table 1). In a study by Moriondo *et al.* (2003) on defoliation of sunflower also no significant difference was observed in terms of plant height. Similarly, Johnson (1972) in his investigation on yield and other traits of sunflower found that defoliation treatments influenced neither plant height nor lodging.

Plant dry matter was significantly affected by irrigation treatments (P<0.01). Dry matter increased as amount of irrigation increased, the highest dry matter (11.7 g) belonging to 100% FC (Table 2). Low water availability caused plant growth inhibitors such as abscisic acid (ABA) to increase and growth regulator hormones to decrease. Reduction of plant regulator hormones is one of the most important factors in plant growth suppression (Molz and Klepper, 1973).

Table 1. Analysis of variance of data on some morphological and yield components of sunflower

	df	Plant height	Stem diameter	Head size	Leaf no.	Dry weight	Seed Number /head	100-seed weight	Seed weigh/ head
Drought stress	2	1604.7^{**a}	24.00**	3037.8**	7.75^{ns}	256.9**	16385.2**	5.39*	28.8**
Defoliation	2	15.7^{ns}	0.52^{ns}	48.0^{ns}	3.08^{ns}	2.5^{ns}	2094.2*	0.03^{ns}	2.5^{ns}
Drought stress * Defoliation	4	24.8^{ns}	0.89^{ns}	13.2^{ns}	2.71^{ns}	5.0^{ns}	829.2^{ns}	1.82^{ns}	1.2^{ns}
Error	27	37.8	0.87	70.8	11.36	4.4	798.3	1.30	1.0

[a] ** = significant at 1% level, * = significant at 5% level, ^{ns} = not significant.

Table 2. Plant height, dry matter, stem and head diameter as well as leaf number of sunflower in drought stress conditions

Irrigation treatment	Plant height (cm)	Dry matter (g)	Stem diameter (mm)	Head size (mm)	Leaf number
FC	58.2 ^{a*}	11.7^{a}	6.0^{a}	53.8^{a}	15.5^{a}
60% of FC	46.3^{b}	5.9^{b}	4.8^{b}	37.7^{b}	15.3^{a}
30% of FC	35.0^{c}	2.8^{c}	3.2^{c}	22.0^{c}	14.0^{a}

* In a column, means followed by a common letter are not significantly different at 5% level of significance.

Stem diameter was affected by drought stress. Reduction of soil water content to 60 and 30% FC caused a 20 and 46% reduction in this parameter as compared to control, respectively (Table 2). Molze and Klepper (1973) reported that in field conditions, one of the effects of low water availability is the reduction of stem diameter due to lower radius growth of stem. In this condition, the main stem and lateral branch growth are suppressed and thus a lower stem dry matter will be obtained. Defoliation did not have any effects on stem diameter (Table 1), these are in agreement with the results of Moriondo et al (2005). These authors measured the stem diameter in the first, 13th and 19th node of sunflower and found that the stem diameter was not affected by defoliation treatments.

SPAD readings showed a declining trend with approaching the end of the plant growth period showing normal pattern of leaf senescence (Figure 1). Sawhney and Singh (2002) found that chlorophyll content of flag leaf in several wheat genotypes was reduced towards the end of growing season.

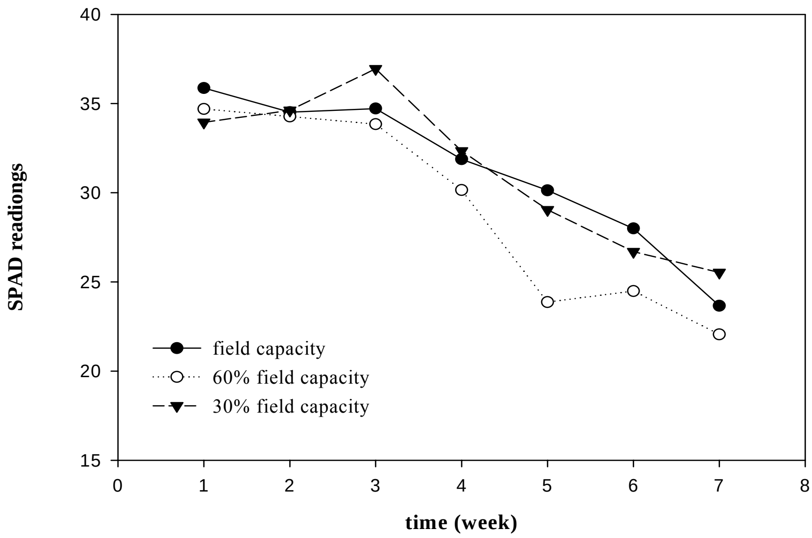

Fig. 1. Trend of SPAD readings from the 7th leaf to the top of the sunflower after defoliation in drought stress treatments

SPAD readings were significantly affected by irrigation treatments (Table 3). Reducing water content to 60% FC caused 7% reduction in SPAD reading as compared to control, but more reduction in water content from 60 to 30% FC caused an increase in the SPAD readings. The difference between control and 30% FC was not significant (Table 4). Ahmadi and Baker (2000) indicated that moderate water stress (15% of FC) significantly reduced wheat leaf chlorophyll content. In contrast, Ommen *et al*. (1999) in their investigation on effects of drought stress on wheat verified that increasing stress led to significant increase in chlorophyll content.

Effect of defoliation on SPAD reading was significant (Table 3) and greater values of this parameter were observed in defoliation treatments as compared to control (Table 4).

Table 3. Analysis of variance of data on SPAD reading from sunflower leaves under rought stress and defoliation

Treatment	df	SPAD
Drought stress	2	156.58* [a]
Defoliation	2	167.26*
Drought stress*Defoliation	4	101.15*
Time	6	720.40**
Drought stress* Time	12	49.90[ns]
Defoliation*Time	12	17.78[ns]
Drought stress* Defoliation*Time	24	25.26[ns]
Error	189	51.23

[a] ** = significant at 1% level, * = significant at 5% level, [ns] = not significant.

Table 4. Interaction of drought stress and defoliation on SPAD reading from sunflower leaves

Defoliation \ Drought stress	FC	60% of FC	30% of FC	Average
Control	27.8[a*]	27.5[c]	31.8[ab]	29.0[b]
Removal of 4 leaves	34.1[a]	30.6[abc]	30.6[abc]	31.8[a]
Removal of 6 leaves	31.9[ab]	29.9[bc]	32.3[ab]	31.1[a]
Average	31.3[a]	29.1[b]	31.6[a]	

* Mean separation by DMRT at 5% level.

It seems that an increase in leaf greenness after defoliation may be due to a compensation of leaf area losses.

There was a significant difference between irrigation treatments in terms of head size (Table 1), head size decreasing by increase in drought stress (Table 2). In an experiment on influence of water stress on net photosynthesis and yield of sunflower Human *et al.* (1990), observed that head size was, significantly reduced as water stress increased. Also, Razi and Asad (1998) showed that irrigation resulted in greater head and stem diameter, plant height and yield in sunflower. Stomatal closure, reduction of leaf area and depression of photosynthesis due to drought stress, caused the lower assimilation and plant growth (Kafi et al., 2000).

Seed number per head significantly decreased as a result of drought stress (Table 1), percentage of reduction in 30% FC (48.2%) being higher than 60% FC (13.8%). It seems that most reduction in seed number per head, due to stress, is related to reduction of head size, according to the high correlation (r=0.89**) between head size and seed number per head (Figure 2).

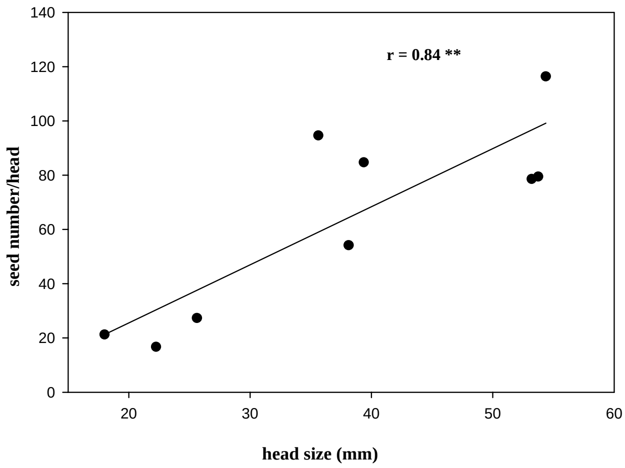

Fig. 2. Correlation between seed number per head and head size of sunflower under drought stress and defoliation

Table 5. Seed number per head, 100-seed weight and seed weight per head of sunflower in different levels of drought stress and defoliation

Treatment		Seed number/ head	100-seed weight	Seed weight/ head
Drought stress	FC	91.5 [a *]	4.1 [a]	3.6 [a]
	60% of FC	78.9 [a]	3.5 [ab]	2.7 [b]
	30% of FC	47.4 [b]	2.8 [b]	0.6 [c]
Defoliation	Control	76.2 [a]	3.5 [a]	2.8 [a]
	Removal of 4 leaves	65.1 [ab]	3.5 [a]	2.3 [a]
	Removal of 6 leaves	49.9 [b]	3.6 [a]	1.9 [a]

* In a column, means followed by a common letter are not significantly different at 5% level.

Defoliation affected seed number per head, so that 34.5% reduction in seed number occurred by removal of 6 leaves from lower part of the plant (Table 5). Muro *et al.* (2001) also came up with the same results. Removal of the plant leaves is an index for lowering photosynthesis capacity. Since at the present study defoliation was performed in the head-visible stage, prior to seed number determination, the plant came up with a decrease in seed number rather than producing weak seeds.

Hundred seed weight was significantly affected by drought stress (Table 1). Average of 100-seed weight was decreased by 32.7% as soil water content decreased from 100 to 30% FC (Table 5). Bieloria and Hopmans (1975) reported that drought stress *via* stomatal closure, reduction in leaf area and photosynthesis and also a shortening of the seed filling period limited the carbohydrate supply for seeds.

Effect of drought stress on seed weight per head was significant (Table 1), and there was a decreasing trend in response to increasing stress intensity (Table 5). Reduction in seed weight per head followed by water stress treatments is also reported by others (D' Andria et al., 1995, Razi and Asad, 1998, Vivek and Chakor, 1992). Since seed weight per head is determined by number and weight of seed, and in this experiment these parameters were reduced under drought stress (Table 5), thus, seed weight per head was reduced in response to drought stress.

4. Conclusion

Results indicated that drought stress had a considerable effect on plant height, dry matter, stem diameter, head size, seed number as well as seed weight per head and 100-seed weight. Water stress also caused a reduction in these parameters.

Reduction of soil water availability to 60% of FC decreased SPAD readings as compared to control, whereas further water reduction (30% of FC) increased it. Defoliation decreased seed number per head but increased the SPAD-reading.

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