RESPONSE OF SESAME TO FOLIAR SPRAY WITH ASCORBIC ACID UNDER WATER STRESS CONDITION.

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ABSTRACT

A trail was conducted in wiry greenhouse of Crop Physiology Department at Giza Experimental Research Station, ARC, during the two summer seasons of 2014 and 2015 study the alleviation of water deficit stress effects on sesame plant (cv. Shandaweel. 3) by foliar application of ascorbic acid (A.A.) *i.e.* control, 200 and 400 ppm. Different levels of water were applied *i.e*. 2600 m^3/fad (wet), 2300 m^3/fad (moist), 2000 m^3/fad (medium) and 1700 m^3/fad (dry). Results could be summarized as follows:

- The highest values of plant height, fruiting zone length, leaf area/plant, capsules number and weight/plant, 1000 seed weight were scored from irrigation by 2600 m^3/fad followed by 2300 m^3/fad with insignificant difference between such two treatments. Whereas, the highest values of shoot dry weight/plant as well as straw and seed yields were obtained when plants irrigated by 2300 m^3/fad followed by 2600 m^3/fad. While, the lowest values of all growth traits, yield and yield components were obtained when plants irrigated by 1700 m^3/fad. Protein content of seed increased and oil content decreased when plants irrigated by 1700 m^3/fad (dry). Relative water content (RWC%) decreased gradually with decreasing water applied up to irrigation by 1700 m^3/fad. Water consumptive use (WCU) increased with increasing water applied from 1700 to 2600 m^3/fad. The heights value of water use efficiency (WUE) was recorded when plants irrigated by 2300 m^3/fad.
- The foliar application of 400 ppm ascorbic acid significantly increased plant height, fruiting zone length, leaf area/plant, shoot dry weight, capsules number and weight/plant, 1000-seed weight as well as straw and seed yields, protein and oil contents of seeds, RWC, WCU and WUE compared to control and 200 ppm ascorbic acid.
- The interaction effect recorded the maximum values of leaf area / plant, capsules number and weight / plant, oil content of seeds, RWC and WUE when plants irrigated by 2600 m^3/fad and sprayed with 400 ppm ascorbic acid. Whereas, the highest values of shoot dry weight/plant, straw and seed yields as well as WUE were recorded when plants irrigated by 2300 m^3/fad. and sprayed with 400 ppm ascorbic acid. The maximum value of seeds protein content was obtained when plants irrigated by 1700 m^3/fad and sprayed by 400 ppm ascorbic acid.

INTRODUCTION

Sesame (*Sesamum indicum* L.) is one of the most important oil crops due to its high seed oil content. It is proper crop for growing in old and newly soils in summer season. The local consumption of sesame is increasing rapidly every year. Sesame is one of the oldest annual oil seed plants. It is easily grown in hot and semi-hot regions, yet, the plant is sensitive to sever water shortage at the time of flourishing and grading (Moghni Bashi and Razmjou, 2012). The recent researches showed the importance of water shortage tension in agricultural product.

Therefore, it is necessary to increase its productivity and water use efficiency (WUE) by improving the agronomic practices such as irrigation and foliar spray of ascorbic acid. Anton and El-Raies (2000) reported that irrigated sesame at 25-30% available soil moisture depletion (ASMD) increased water consumptive use (WCU). Saeed and Abdel-Hameed (2001 a&b) reported that exposing sesame plants to water stress (45% of water holding capacity) gave the lowest values of plant height, number of leaves, leaf area, number of capsules, and number of seeds/plant as well as fresh and dry weight/plant. They started that drought conditions decreased oil yield, total carbohydrates and crude protein of seeds. Abdo and Anton (2009) on sesame plants, concluded that increasing soil moisture stress up to 65-70% ASMD (dry) significantly decreased plant height, fruiting zone length, leaf area index (LAI), 1000-seed weight, number of capsules, in addition capsules, straw and seed weights/plant as well as total carbohydrates and oil contents in seeds. Also, exposing plants to severe water deficit decreased relative water content (RWC), seasonal water consumptive use (WCU) and water use efficiency (WUE).

Ascorbic acid is a small, water-soluble anti-oxidant molecule which acts as a primary substrate in the cyclic pathway of enzymatic detoxification and neutralization of superoxide radicals and singlet oxygen, as presented by (Dolatabadian *et al.*, 2009). Application of ascorbic acid alleviates reactive oxygen species (ROS) and this will be beneficial for plants tolerance to oxidative stresses (Smirnoff, 1995). Rosales *et al*., (2006) reported that, treated cherry tomato by ascorbic acid increased the cell division and causes increasing leaf fresh and dry weights/plant. Such antioxidant treatment properly decreases the damage from oxygen radicals, which are product by drought stress. Ameerkhan and Ammadmr (2006) showed that spraying wheat plants by 100 ppm ascorbic acid reduced adverse effects of drought stress. Dolatabadian *et al.* (2009) indicated that foliar application of ascorbic acid on zea mays reduced the harmful effects of reactive oxygen species and improved plant resistance to water stress. In other word, ascorbic acid treatment reduced the damaging action of drought and decreased enzyme activity due to scavenging of reactive oxygen species (ROS), thereupon it may be effective for the improvement of stressed plants in arid and semi-arid regions.

The objective of this work was to investigate alleviation of water deficit stress effects by foliar application of ascorbic acid (A.A) on growth, productivity, protein and oil contents of seeds as well as relative water content of leaves % (RWC), water consumptive use (WCU) and water use efficiency (WUE) of sesame plants.

MATERIALS AND METHODS

The present work was carried out in wiry greenhouse of crop physiology Department at Giza Experimental Research Station, ARC, during the two summer seasons of 2014 and 2015 to study the alleviation of water deficit stress effects by foliar application of ascorbic acid on sesame plant (*Sesamum indicum* L.). The experiment was carried out in basins 10m long, 2m width and 70cm depth of cementing frame to control water quantities. The soil was clay loam in structure with pH value 7.7, organic matter 1.6% and containing 34.8 ppm nitrogen. The experiment was laid out in a split plot design with three replicates. The main plots were occupied by water applied levels, while sub-plots contained foliar application of ascorbic acid. Each sub-plot was 2 m^2 (1×2m) and included 2 ridge, 2m long and 50 cm apart.

The treatments are as follows:

I- Main plots (water applied levels):

a- Irrigation by 2600 m^3/fad (wet)

b- Irrigation by 2300 m^3/fad (moist)

c- Irrigation by 2000 m^3/fad (medium)

d- Irrigation by1700 m^3/fad (dry)

II- Sub-plots (Ascorbic acid)

1- Spray water (control)

2- Spray 200 ppm Ascorbic acid (A.A)

3- Spray 400 ppm Ascorbic acid (A.A)

Sesame seeds (cv. Shandaweel-3) were planted on 4 June and 31 May, in the first and second seasons, respectively, in hills spaced 10 cm. plants were thinned to one plant per hill 21 days after sowing (DAS). 15 kg P_2O_5/fad as calcium superphosphate (15% P_2O_5) was incorporated into soil before sowing. 50 kg N/fad as ammonium nitrate (33.5% N) and 24 kg K_2O/fad in the form of potassium sulphate (48% K_2O) were added at 21days after sowing. Irrigation treatments were applied at 21 days after sowing (DAS). While, Ascorbic acid was sprayed two times, at 30 and 45 days after sowing, 0.5% wetting agent of Tween 20 was used. Other, cultural practices were applied according to the methods being adopted for growing sesame crop in the locality.

Growth traits:

For determine some growth traits five plants were randomly taken from each sub-plot at 80 days after sowing (DAS). In each sample, plants were

separated into their components *i.e.* leaves, stems and capsules, then dried at 70^{o}C in a ventilated oven into a constant weight to determine shoot dry weight, whereas leaf area/plant (LA) was determined according to Hunt (1990) by taken 10 disks (r=0.5 cm) from leaves for each treatment and dried, the disks area equal (10×3.14×(0.5)^2 = 7.85 cm^2, the formula as follows:
LA = 7.85 × dry weight of leaves per plant / dry weight of leaves disks

Harvesting took place 23/9/2014 and 20/9/2015 in the first and second seasons, respectively. At harvest time, five individual guarded plants were randomly taken from one row in each sub-plot to determine:

1- Plant height (cm)
2- Fruiting zone length (cm)
3- Number of capsules / plant
4- Capsules weight / plant (g)
5- 1000-seed weight (g)

Straw and seed yields (g/m^2) were obtained from one ridge (1 m^2) in each sub-plot.

Mature seeds were subjected to chemical analysis to determine oil and protein contents according to A.O.A.C. (1990).

Water relations:

1- Relative water content of leaves (RWC%):

At 70 days after sowing (DAS), leaf samples were immediately weighed (Fresh weight, FW) and transferred into sealed flasks, then rehydrated in water for 5h until fully turgid at 4^{o}C, surface swabbed and reweighed (turgid weight, TW). Leaf samples were oven dried at 70^{o}C for 48h and reweighed (dry weight, DW). RWC% was calculated according to Lazcano-Ferrat and Lovatt (1999)

RWC % = (FW – DW))

2- Water consumptive

Soil samples were taken, using a regular auger, at planting time, just before and 48 hours after each irrigation and at harvesting time for soil moisture determination. Duplicate of soil samples were taken from 0-150, 150-300, 300-450 and 450-600 mm depths and their moisture contents were determined gravimetrically.

Field capacity, permanent wilting point, bulk density and available moisture were determined for the experimental sit and presented in the following Table.

Depth (mm)	Wilting point %	Field capacity %	Available water %	Bulk density (g / cm^3)
0 – 150	19.34	40.82	21.48	1.05
150 – 300	15.01	31.68	16.67	1.14
300 – 450	12.02	25.38	13.36	1.20
450 - 600	8.56	18.07	9.51	1.26

The following equation was used to calculating water consumptive use according to (Israelsen and Hansen, 1962):

$Cu = D \times Bd \times (e_2 - e_1) / 100$ where,

Cu = Water consumptive use (ET) in mm

D = Soil depth (mm)

Bd = Bulk density in g/cm^3

e_1, e_2 = Soil moisture content before and after each irrigation

3- Water use efficiency (WUE):

Water use efficiency was calculated for each treatment according to the equation described by Vites (1965).

As follows:

WUE = seed yield (g/fad) / seasonal water consumption in m^3/fad.

Data were statistically analyzed according to Snedecor and Cochran (1980) and treatment means were compared by least significant difference test (LSD) at 0.05 level of probability. Bartlett test according to (Bartlett, 1937) was done to test the homogeneity of error variance. The test was not significant for all assessed traits, so, the two seasons data were combined. The discussions of the results were carried out on the basis of combined analysis for the two seasons.

RESULTS AND DISCUSSION

I- Growth

Results of Table (1) show the effect of water deficit stress and foliar spray of ascorbic acid on growth of sesame expressed as plant height, fruiting zone length, leaf area / plant and shoot dry weight. Results indicated that both factors under study had a significant effect on all growth characters.

The highest values of plant height, fruiting zone length and leaf area / plant were scored from irrigation plants by 2600 m^3/fad (wet) followed by 2300 m^3/fad (moist) with insignificant difference between such two treatments. While, the lowest values were recorded from irrigation by 1700 m^3/fad (dry) with a significant difference between this treatment and other. Whereas, the highest value of shoot dry weight/plant was obtained when plants irrigated by 2300 m^3/fad followed by 2600 m^3/fad, with insignificant difference between such two treatments was observed. While, the lowest value of such trait was obtained when plants irrigated by 1700 m^3/fad with a significant difference between this treatment and others. Whereas, the highest value of shoot dry weight/plant was obtained when plants irrigated by 2300 m^3/fad followed by 2600 m^3/fad, with insignificant difference between such two treatments was observed. While, the lowest value of such trait was obtained when plants irrigated by 1700m^3/fad with a significant difference between this treatment and others. In this connection, Abdo, Fatma and Anton (2009) found that the maximum value of plant height and fruiting zone length were obtained when sesame plants watered by wet treatment, 20-25% available soil moisture depletion (ASMD). El-Naim and Ahmed (2010) reported that irrigation sesame plant by water quantitey of 7500 m^3/h increased plant height, they added that such increment may be attributed to either an increase in node number or internode length or both. Moreover, they found the same treatment increased leaf area index (L.A.I.), because of better total leaf area / plant due to availability of moisture content for leaf growth.

Table (1): Plant height, fruiting zone length, leaf area and shoot dry weight as affected by water deficit stress and foliar application of Ascorbic acid in 2014 and 2015 summer seasons.

Irrigation level (I)	Foliar spray of Ascorbic acid (ppm)	Plant height (cm)			Fruiting zone length (cm)			Leaf area / plant (cm^2) (80 DAS)			Shoot dry weight / plant (g) (80 DAS)		
		2014	2015	Comb.	2014	2015	Comb.	2014	2015	Comb.	2014	2015	Comb.
I_1 (2600 m^3/fad) (Wet)	Control	166.7	170.3	168.5	87.7	89.3	88.3	2156	2200	2178	28.68	30.10	29.39
	200	175.0	178.0	176.5	93.3	95.3	94.3	2343	2390	2366	33.43	34.99	34.21
	400	180.3	184.0	182.2	98.0	100.0	99.0	2455	2505	2480	37.33	38.41	37.87
mean		174.0	177.5	175.8	93.0	94.9	93.9	2318	2365	2341	33.15	34.50	33.82
I_2 (2300 m^3/fad) (moist)	Control	162.3	165.7	164.0	85.3	86.7	86.0	2092	2135	2115	28.44	29.98	29.21
	200	171.0	174.3	172.6	90.7	92.3	91.5	2273	2320	2297	34.21	36.01	35.11
	400	177.3	180.7	179.0	95.0	96.7	95.8	2381	2430	2406	37.22	39.16	38.19
mean		170.2	173.6	171.9	90.3	91.9	91.1	2249	2295	2272	33.29	35.05	34.17
I_3 (2000 m^3/fad) (medium)	Control	153.0	155.0	154.0	74.7	76.7	75.7	1917	1955	1936	27.45	28.19	27.82
	200	161.0	163.3	162.2	80.0	82.0	81.0	2079	2120	2100	29.36	30.32	29.84
	400	165.7	168.0	166.8	83.7	86.0	84.9	2182	2225	2203	31.33	32.25	31.79
mean		159.9	162.1	161.0	79.5	81.6	80.5	2059	2100	2080	29.38	30.25	29.82
I_4 (1700 m^3/fad) (dry)	Control	143.0	146.0	144.5	68.0	69.3	68.7	1769	1805	1787	20.97	23.15	22.06
	200	150.3	153.3	151.8	72.7	74.3	73.5	1920	1960	1940	23.74	25.20	24.47
	400	154.7	157.7	156.2	76.3	77.7	77.0	2014	2055	2034	26.24	27.62	26.93
mean		149.3	152.3	150.8	72.3	73.8	73.1	1901	1940	1920	23.65	25.32	24.49
General mean of Ascorbic acid (A.A.)	Control	156.2	159.2	157.7	78.9	80.5	79.7	1683	2024	2003	26.39	27.86	27.12
	200	164.3	167.3	165.8	84.2	86.0	85.1	2154	2197	2176	30.19	31.63	30.91
	400	169.5	172.6	170.1	88.3	90.1	89.2	2258	2304	2281	33.03	34.36	33.70
L.S.D. 5%	I	7.1	7.3	4.7	5.6	5.8	3.7	147	151	97	3.06	3.20	2.03
	A.A.	4.7	4.8	3.1	3.6	3.7	2.4	112	115	74	1.93	2.02	1.28
	I × A.A.	N.S.	N.S	N.S	N.S.	N.S.	N.S	181	186	119	3.90	4.09	2.60

Concerning the effect of foliar spray of ascorbic acid, all growth traits under study significantly increased when plants sprayed by 400 ppm ascorbic acid. Such finding due to that ascorbic acid is a small, water-soluble anti-oxidant molecule which acts as a primary substrate in the cyclic pathway of enzymatic detoxification of hydrogen peroxide. Ascorbic acid is the first substance in detoxification and neutralizing of super oxide radicals (Noctor and Foyer, 1998). Also, latter has important role in vital process in plant growth such as cell division and cell wall expansion (Pignocchi and Foyer, 2003). Moreover, ascorbic acid plays important role in ascorbate-glutathione pathway and scavenges reactive oxygen species (ROS) in chloroplast (Foyer and Harbinson, 1994) and cytosol (Asada, 1999). In this respect, Dolatabadian *et al.* (2010) found that foliar application of ascorbic acid (150 mg/L) increased stem, leaf dry weight and leaf fresh weight of Grain corn.

The interaction between water deficit stress and foliar application of ascorbic acid was found to be significant on leaf area/plant and shoot dry weight/plant. The maximum value of leaf area/plant was obtained when plants watered by 2600 m^3/fad and sprayed by 400 ppm ascorbic acid. While, the highest value of shoot dry weight/plant was recorded when plant irrigated by 2300 m^3/fad and sprayed by 400 ppm ascorbic acid. It can be noticed that under dry condition (1700 m^3/fad, dry) spraying plants by 400 ppm ascorbic acid recorded the highest values of all growth traits under study compared to control and 200 ppm ascorbic acid treatments. Such finding indicated that ascorbic acid reduced the harmful effects of reative oxygen species (ROS) and improved plant resistance to water stress, similar results were gained by Dolatabadian *et al*., (2009).

II- Yield and yield components:

Data in Table (2) show that applied water levels had a significant effect on number of capsules/plant, capsules weight/plant, 1000-seed weight as well as straw and seed yields. The highest values of capsules number and weight/plant as well as 1000-seed weight were scored from wet treatment (2600 m^3/fad), followed by moist treatment (2300 m^3/fad) with insignificant difference between such two treatments. The maximum values of straw and seed yields, (645.7 and 230.2 g/m^2, respectively) were obtained from plants irrigated by 2300 m^3/fad followed by plants watered by 2600 m^3/fad, with insignificant difference between such two treatments. Such results may due to the good accumulation of dry matter in shoot/plant as shown in Table (1) when plants irrigated by 2300 m^3/fad (moist treatment). The lowest values of yield and all yield components traits under study were recorded from severe water deficit stress *i.e.* dry treatment (1700 m^3/fad) with significant difference between such treatment and others. In this respect, Rezvani *et al.* (2005) reported that yield of sesame is affected in severe drought stress and low irrigation. Haj *et al.* (2008) suggested that drought stress reduced seed yield of sunflower due to the reduction in leaf area.

As for the effect of foliar spray of ascorbic acid Table (2), showed that ascorbic acid had a significant effect on capsules number and weight / plant, 1000-seed weight as well as straw and seed yields. The highest values of such traits were scored from foliar application of 400 ppm ascorbic acid. Such findings explain the role of ascorbic acid as antioxidant compound. In this connection, Dolatabadian *et al.* (2009) showed that, application of ascorbic acid on ***Zey mays*** plants alleviates reactive oxygen species (ROS) and this will be beneficial for plants tolerance to oxidative stresses.

The interaction effect between water applied and foliar spray of ascorbic acid on yield and its components was found to be significant on yield and its components under study except 1000-seed weight. The highest values of capsules number and weight / plant were obtained when plants irrigated by 2600 m^3/fad and sprayed by 400 ppm ascorbic acid. Whereas, straw and seed yields had the maximum values when plants received irrigation by 2300 m^3/fad and sprayed by 400 ppm ascorbic acid. It is worthy to mention that under dry treatment (1700 m^3/fad), spraying 400 ppm ascorbic acid recorded the maximum value of straw and seed yields, 502.2 and 168.3 g/m^2, respectively. Such finding due to the role of ascorbic acid for alleviation of water stress effects, (Dolatabadian *et al.,* 2009).

Table (2): Number of capsules, capsules weight, 1000-seed weight as well as straw and seed yields as affected by water deficit stress and foliar application of Ascorbic acid in 2014 and 2015 summer seasons.

Irrigation level (I)	Foliar spray of Ascorbic acid (ppm)	Number of capsules /plant			Capsules weight/plant (g)			1000-seed weight (g)			Straw yield (g/m^2)			Seed yield (g/m^2)		
		2014	2015	Comb.	2014	2015	Comb.	2014	2015	Comb.	2014	2015	Comb.	2014	2015	Comb.
I_1 (2600 m^3/fad) (Wet)	Control	87.7	91.7	89.7	33.81	35.39	34.60	3.41	3.56	3.49	563.6	566.4	565.0	198.6	206.8	202.7
	200	99.0	103.3	101.1	38.16	39.16	39.01	3.50	3.66	3.58	643.8	647.6	645.7	223.2	232.0	227.6
	400	105.3	110.0	107.7	40.59	42.46	41.53	3.58	3.75	3.67	706.2	706.8	706.5	245.2	254.4	249.8
mean		97.3	101.7	99.5	37.52	39.24	38.38	3.50	3.66	3.58	637.9	640.3	639.1	222.3	231.1	226.7
I_2 (2300 m^3/fad) (moist)	Control	84.3	88.0	86.1	32.50	33.96	33.23	3.37	3.52	3.45	551.4	553.8	552.6	191.0	198.8	194.9
	200	94.0	98.3	96.2	36.24	37.94	37.09	3.46	3.62	3.54	658.4	663.0	660.7	231.6	241.0	236.3
	400	101.3	106.0	103.7	39.05	40.91	39.98	3.54	3.70	3.62	723.2	724.2	723.8	254.4	264.2	259.3
mean		93.2	97.4	95.3	35.93	37.60	36.77	3.46	3.61	3.54	644.3	647.0	645.7	225.7	234.7	230.2
I_3 (2000 m^3/fad) (medium)	Control	71.3	74.3	72.8	27.49	28.68	28.08	3.15	3.29	3.22	466.0	468.0	467.0	155.0	161.4	158.2
	200	80.0	83.7	81.9	30.84	32.30	31.57	3.24	3.39	3.32	548.4	552.4	550.4	183.8	191.2	187.5
	400	86.0	90.0	88.0	33.15	34.74	33.95	3.31	3.47	3.39	608.0	610.8	609.4	204.8	212.6	208.7
mean		79.1	82.7	80.9	30.49	31.91	31.20	3.23	3.38	3.31	540.8	543.7	542.3	181.2	188.4	184.8
I_4 (1700 m^3/fad) (dry)	Control	64.0	67.3	65.7	24.67	25.98	25.33	3.05	3.18	3.12	430.4	431.8	431.1	129.4	130.0	129.7
	200	70.3	73.0	71.6	27.10	28.18	27.64	3.13	3.28	3.21	477.0	481.0	479.0	156.0	162.4	159.2
	400	73.7	76.7	75.2	28.41	29.60	29.00	3.21	3.35	3.28	501.4	503.0	502.2	165.0	171.6	168.3
mean		69.2	72.3	70.8	26.73	27.92	27.32	3.13	3.27	3.20	469.6	471.9	470.8	150.1	154.7	152.4
General mean of Ascorbic acid (A.A.)	Control	76.8	80.3	78.6	29.62	31.00	30.31	3.25	3.39	3.32	502.9	505.0	503.9	168.5	174.3	171.4
	200	85.8	89.6	87.7	33.09	34.57	33.83	3.33	3.49	3.40	581.9	586.0	584.0	198.7	206.7	202.7
	400	91.6	95.7	93.6	35.30	36.93	36.11	3.41	3.57	3.49	634.7	636.3	635.5	217.4	225.7	221.5
L.S.D. 5%	I	9.0	9.4	6.0	3.35	3.50	2.23	0.21	0.22	0.14	69.2	71.2	47.6	23.6	25.3	16.6
	A.A.	5.7	5.9	3.8	2.11	2.21	1.40	0.16	0.17	0.11	44.6	46.4	31.0	15.3	16.4	10.8
	I × A.A.	11.4	12.1	7.6	4.27	4.47	2.84	N.S	N.S	N.S	79.6	82.6	55.2	27.2	29.2	19.2

Chemical composition of sesame seeds:

1- Protein and oil contents of seeds:

Results in Table (3) show that water deficit stress and foliar spray of ascorbic acid had a significant effects on protein and oil contents of seeds. Seed protein content increased when plants irrigated by 1700 m^3/fad (19.42%), while oil content was decreased (50.49%). In other words the maximum value of oil content was obtained when plants watered by 2600 m^3/fad (wet) (56.74%), however protein content was obtained the lowest one (15.55%).

Protein content of seeds showed a reverse trend to that observed with oil content under water deficit condition, such results reveal that the increase in protein content by water deficit condition is said to be on account of decrease in oil accumulation in sesame seed suffer from water stress condition. In this connection, Unger (1982), Hang and Evans (1985) on sunflower, reported that the increase in water quantities increased oil content, while protein content was reduced. This evidence was supported by Weiss (1983) who reported that oil content is negatively correlated with protein content. Alpaslan *et al.* (2001) reported that prolong irrigation interval (water stress condition) of sesame plants increase protein content and decreased oil content of seeds. El-Naim and Ahmed (2010) concluded that irrigated sesame plant by

7500 m^3/h (wet treatment) increased oil content and decreased protein content of seeds.

As for foliar application of ascorbic acid, spraying 400 ppm ascorbic acid significantly increased protein and oil contents of seed, 18.71 and 55.09%, respectively compared to control and spraying 200 ppm ascorbic acid. Such finding prove that ascorbic acid enhanced the accumulation of protein and oil in sesame seeds. Moreover, ascorbic acid plays important role in ascorbate-glutathione pathway and scavenges reactive oxygen species (ROS) in chloroplast (Foyer and Harbinson, 1994). Similar, results were obtained by Dolatabadian *et al.* (2010) who found that protein percentage of Grain corn increased due to foliar application of 150 mg/L ascorbic acid. El-Shafey, Amina (2016) reported that foliar application of 200 ppm ascorbic acid induced significant increase for protein and oil content of soybean seeds.

Table (3): Protein and oil contents of seeds as well as relative water content of leaves (RWC)%, seasonal water consumptive use (WCU) and water use efficiency (WUE) as affected by water deficit stress and foliar application of Ascorbic acid in 2014 and 2015 summer seasons.

Irrigation level (I)	Foliar spray of Ascorbic acid (ppm)	Protein content of seeds (%)			Oil content of seeds (%)			(RWC) %			(WCU) m^3/ fad			(WUE) g / m^3 / fad		
		2014	2015	Comb.	2014	2015	Comb.	2014	2015	Comb.	2014	2015	Mean	2014	2015	Comb.
I_1 (2600 m^3/fad) (Wet)	Control	13.73	14.88	14.31	54.71	55.49	55.10	72.69	74.11	73.40	1790	1800	1795	466.0	482.5	474.1
	200	14.94	16.10	15.52	55.80	57.82	56.81	75.16	77.60	76.38	1825	1835	1830	513.7	531.0	522.4
	400	16.52	17.10	16.81	57.79	58.85	58.32	77.39	79.14	78.27	1845	1855	1850	558.2	576.0	567.1
mean		15.06	16.03	15.55	56.10	57.39	56.74	75.08	76.95	76.02	1820	1830	1825	512.6	529.8	521.2
I_2 (2300 m^3/fad) (moist)	Control	14.81	15.99	15.40	54.20	54.69	54.45	69.90	72.38	71.14	1600	1610	1605	501.4	518.6	510.0
	200	16.19	17.51	16.85	55.66	57.76	56.71	73.78	75.22	74.50	1640	1650	1645	593.1	613.5	603.3
	400	17.18	18.42	17.80	56.92	58.52	57.72	75.65	77.95	76.80	1665	1675	1670	641.7	662.5	652.1
mean		16.06	17.31	16.68	55.59	56.99	56.29	73.11	75.18	74.15	1635	1645	1640	578.7	598.2	588.5
I_3 (2000 m^3/fad) (medium)	Control	16.48	17.50	16.99	50.42	52.24	51.33	64.75	66.13	65.44	1415	1425	1420	460.1	475.7	467.9
	200	17.49	18.91	18.20	51.39	53.01	52.20	65.86	68.34	67.10	1465	1475	1470	526.9	544.4	535.7
	400	19.53	19.87	19.70	54.31	56.27	55.29	68.57	71.51	70.04	1500	1510	1505	573.4	591.3	582.4
mean		17.83	18.76	18.30	52.04	53.84	52.94	66.39	68.66	67.53	1460	1470	1465	520.1	537.1	528.7
I_4 (1700 m^3/fad) (dry)	Control	17.90	18.74	18.32	47.21	50.03	48.62	53.70	56.70	55.20	1220	1230	1225	445.5	443.9	444.7
	200	19.07	19.81	19.44	49.17	51.39	50.28	57.71	60.91	59.31	1260	1270	1265	520.0	537.0	528.5
	400	20.12	20.90	20.51	51.33	53.81	52.57	63.81	66.77	65.29	1295	1305	1300	535.1	552.3	543.7
mean		19.03	19.82	19.42	49.24	51.74	50.49	53.41	61.46	59.93	1258	1268	1263	500.2	511.1	505.6
General mean of Ascorbic acid (A.A.)	Control	15.73	16.78	16.26	51.64	53.11	52.38	65.26	67.33	66.30	1506	1516	1511	468.3	480.2	474.2
	200	16.92	18.08	17.50	53.01	55.00	54.01	68.13	70.52	69.32	1548	1558	1553	538.4	556.5	547.5
	400	18.34	19.07	18.71	55.09	56.86	55.98	71.36	73.84	72.60	1576	1586	1581	557.1	595.5	586.3
L.S.D. 5%	I	1.74	1.84	1.16	5.43	5.61	3.59	6.97	7.23	4.62	-	-	-	63.9	68.1	42.9
	A.A.	1.10	1.16	0.73	2.95	3.04	1.88	4.39	4.57	2.91	-	-	-	41.4	44.2	27.8
	I × A.A.	2.22	2.35	1.49	6.93	7.17	4.58	8.89	9.24	5.89	-	-	-	73.6	78.6	49.5

The interaction between water applied and foliar application of ascorbic acid recorded a significant effect. The maximum value of protein content was obtained when plants irrigated by 1700 m^3/fad and sprayed with 400 ppm ascorbic acid, while the highest value of oil content was recorded from plants irrigated by 2600 m^3/fad and sprayed with 400 ppm ascorbic acid.

Water relations

1- Relative water content of leaves (RWC%)

RWC was proposed as a good indicator of plant water status (Sinclair and Ludlow, 1985) because RWC through its relation to cell volume, may be more closely reflects the balance between water supply to the leaf and transpiration rate.

Table (3) show that RWC at 70 DAS significantly affected by the two factors under study. Results indicated that decreasing water applied up to irrigation by 1700 m^3/fad decreased gradually RWC. Such finding showed that water status in plant cells was affected by water stress conditions. It can be observed that RWC recorded insignificant differences between wet (2600 m^3/fad) and moist (2300 m^3/fad) treatments. Similar results was obtained by Abdo, Fatma (2007) on maize plants. Ali *et al.,* (2011) explained such finding that, under severe drought stress, plants failed to maintain the turger, this might be due to the excessive water loss through transpiration required to reduce the leaf temperature.

Foliar application of ascorbic acid (A.A) significantly increased RWC. The maximum value was obtained by sprayed 400 ppm A.A. compared to other treatments. Dolatabadian *et al.* (2009) explained such results, that the application of ascorbic acid scavenged reactive oxygen species (ROS) and prevented biosynthesis of extra proline which might have contributed to osmotic adjustment and allowed the plant to maintain turgor pressure and adapt to limited water availability.

The interaction between water applied treatments and foliar application of ascorbic acid recorded a significant effect on RWC. The highest value was obtained when plants irrigated by wet treatment (2600 m^3/fad) and sprayed with 400 m^3/fad ascorbic acid. It can be noticed that, under dry treatment (1700 m^3/fad) the maximum value of RWC was obtained when plants sprayed by 400 ppm ascorbic acid. Such finding due to the roll of A.A. as mention before by (Dolatabadian *et al.,* 2009).

2- Water consumptive use (WCU):

Results of Table (3) indicate that the seasonal water consumptive use values was ranged from 1225 to 1850 m^3/fad as the mean of both seasons under study. The results revealed that (WCU) was increased with increasing water applied from 1700 to 2600 m^3/fad. it is worthy to mention that both moist and medium treatments had intermediate values. In other words, the rate of (WCU) was increased with increasing water applied level as the following ranking:

Wet > moist > medium > dry

Such results could be explained on the basis that, increasing water quantities up to 2600 m^3/fad provides chance for more luxuriant use of water. These finding could be ascribed to the availability of soil water to sesame plants in addition to higher evaporation rate from wet than from dry soil surface. In this connection, Ibrahim (1981) showed that the increase in evapotranspiration rate by maintaining soil moisture at high level can be attributed to excess available water in the root zone to be consumed by the plants. These results are in the line with those reported by Anton and El-Raies (2000).

Regarding the effect of ascorbic acid application, results indicated that the maximum value of WCU (1581 m^3/fad) was achieved when plants sprayed by 400 ppm ascorbic acid. Such finding due to the increase of leaf area/plant by application of 400 ppm ascorbic acid (Table, 1), similar results was obtained on Grain corn plants by Dolatabadian *et al.* (2010).

The interaction between water applied treatments and foliar application of ascorbic acid recorded the maximum value of WCU when plants watered by 2600 m^3/fad (wet treatment) and sprayed with 400 ppm ascorbic acid.

3- Water use efficiency (WUE):

Water use efficiency, expressed in grams seeds per m^3 water consumed in complete evapotranspiration, is presented in Table (3). WUE recorded the highest value (588.5 g/ m^3/fad) when sesame plants irrigated by 2300 m^3/fad (moist treatment), whereas it was lower under wet, medium and dry treatments due to the high seed yield which obtained from plants under moist treatment in proportion to their water consumed. It is worthy to mention that, the different between wet and moist treatments was significant in (WUE) traits. So, it could be concluded that moist treatment (2300 m^3/fad) seemed to be more efficient in consuming water compared with other irrigation treatments. In other words, from the stand point of water conservation, moist treatment (2300 m^3/fad) seemed to be more economic for saving water and gained a suitable seed yield. Similar results on sesame was obtained by Anton and El-Raies (2000).

Concerning the effect of foliar application of ascorbic acid on WUE. Results revealed that spraying 400 ppm ascorbic acid recorded the maximum value of WUE (586.3 g/ m^3/fad) compared to other treatments. These results are in line with those reported by Bakry *et al.* (2012) who stated that the application of ascorbic acid (AA) on wheat plants increased WUE. Farjam and Kzemi-Arbat (2015) reported that ascorbic acid application on chickpea plants significantly increased rate of biological water use efficiency (BWUE) compared to control.

The interaction between water applied and foliar application of ascorbic acid recorded the heighest value of WUE (652.1 g/ m^3/fad) when plants received 2300 m^3/fad (moist treatment) and sprayed by 400 ppm ascorbic acid. It can be observed that under dry treatment (1700 m^3/fad) the application of 400 ppm ascorbic acid recorded the maximum value of WUE (543.7 g/ m^3/fad) compared to 200 ppm A.A. or control treatments.

Such finding due to the role of ascorbic acid (A A) for reduced the damaging action of drought and decreased enzyme activity due to scavenging of reactive oxygen species (ROS) thereupon it may be effective for the improvement of stressed plants in arid and semi-arid regions (Dolatabadian *et al*., 2009).

CONCLUSION

In the light of present results, it clearly that the maximum seed yield and WUE were obtained by adding 2300 m^3/fad (moist treatment) and sprayed by 400 ppm ascorbic acid. Such treatment can be recommended from the stand point of water conservation. It can be noticed that, under dry treatment (1700 m^3/fad), the application of 400 ppm ascorbic acid gave the highest value of seed yield and WUE, which proved the role of ascorbic acid for alleviation of water deficit effects.

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استجابة السمسم للرش الورقى بحامض الاسكوربيك تحت ظروف الإجهاد المائى

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أجريت تجربة بالصوبة السلكية لقسم بحوث فسيولوجيا المحاصيل بمحطة بحوث الجيزة – مركز البحوث الزراعية خلال موسمى صيف ٢٠١٤، ٢٠١٥ لدراسة تقليل أثر الإجهاد المائى على السمسم (صنف شندويل – ٣) بواسطة الرش الورقى بحامض الاسكوربيك بتركيزات كنترول، ٢٠٠، ٤٠٠ جزء فى المليون وكانت معاملات الرى هى إضافة ٢٦٠٠ م٣/ فدان (معاملة مبتلة) و ٢٣٠٠ م٣/ فدان (معاملة رطبة) و ٢٠٠٠ م٣/ فدان (معاملة متوسطة) و ١٧٠٠ م٣/ فدان (معاملة جافة).

– سجلت أعلى قيم لطول النبات وطول المنطقة الثمرية ومساحة الأوراق / نبات وعدد ووزن الكبسولات / نبات ووزن الألف بذرة عند الرى بـــ ٢٦٠٠ م٣/ فدان متبوعاً بالرى بـــ ٢٣٠٠ م٣/ فدان بدون فرق معنوى بين المعاملتين.

– بينما كانت أعلى قيم للوزن الجاف للمجموع الخضرى / نبات ومحصولى القش والبذور عند الرى بـــ ٢٣٠٠ م٣/ فدان متبوعاً بالرى بـــ ٢٦٠٠ م٣/ فدان.

– وكانت أقل قيم لجميع صفات النمو والمحصول ومكوناته عند الرى بـــ ١٧٠٠ م٣/ فدان (المعاملة الجافة). ارتفع محتوى البذور من البروتين وإنخفض محتواها من الزيت عند رى النباتات بـــ ١٧٠٠ م٣/ فدان . انخفض تدريجيا المحتوى النسبى للماء بالأوراق (RWC) بتقليل كمية الماء المضافة حتى ١٧٠٠ م٣/ فدان. ارتفع الاستهلاك المائى الموسمى (WCU) بزيادة كميات الماء المضافة من ١٧٠٠ إلى ٢٦٠٠ م٣/ فدان . وكانت أعلى قيمة لكفاءة استخدام الماء (WUE) عند رى النباتات بـــ ٢٣٠٠ م٣/ فدان (المعاملة الرطبة).

– أدى الرش الورقى بـــ ٤٠٠ جزء فى المليون حامض الاسكوربيك إلى زيادة معنوية لطول النبات ومساحة الأوراق / نبات والوزن الجاف للمجموع الخضرى/نبات وعدد ووزن الكبسولات / نبات ووزن الألف بذرة ومحصولى القش والبذور ومحتوى البذور من البروتين والزيت و RWC و WCU و WUE مقارنة بالكنترول أو الرش بـــ ٢٠٠ جزء فى المليون حامض الاسكوربيك.

– سجل تأثير التفاعل أعلى قيم لمساحة الأوراق/نبات وعدد ووزن الكبسولات/ نبات ومحتوى البذور من الزيت و RWC , WUE عند الرى بـــ ٢٦٠٠ م٣/فدان والرش الورقى بـــ ٤٠٠ جزء فى المليون حامض الاسكوربيك. بينما كانت أعلى قيم للوزن الجاف للمجموع الخضرى / نبات ومحصولى القش والبذور و WUE عند الرى بـــ ٢٣٠٠ م٣/فدان والرش الورقى بـــ ٤٠٠ جزء فى المليون حامض الاسكوربيك ، وكانت أعلى قيمة لمحتوى البذور من البروتين عند الرى بـــ ١٧٠٠ م٣/فدان والرش الورقى بـــ ٤٠٠ جزء فى المليون حامض الاسكوربيك.